International Journal of Scientific & Engineering Research Volume 8, Issue 5, May-2017
ISSN 2229-5518

Optimized Packet Scheduling Algorithm for Downlink LTE Networks

Preethi Pattabiraman, P.PrittoPaul

Abstract— The release 8 of 3rd Generation Partnership Project which marked the beginning of Long Term Evolution, implemented a lot of novel and efficient changes to the physical layer of the communication networks. By implementing Orthogonal Frequency Division Multiplexing for downlink channels, it brought an inherent efficiency in communication. But packet scheduling algorithms which are implemented at the eNodeB, actually allocates resources to the User Equipment based on different parameters like Channel Quality Index, Quality of Service, Quality of Experience, throughput are used in the packet scheduling algorithms. Analyzing the usage of buffers at both the ends of eNodeB and User Equipment will still improvise the performance of Packet Scheduling algorithms. This paper aims to propose a novel Packet Scheduling methodology that assigns priorities to the User Equipment based on the queue overflow probability and the residual energy of the user equipment. Modified Adaptive Resource Allocation algorithm proposes to improvise the system throughput, packet delivery ratio and reduce delay. This is then compared with existing algorithms.

Index Terms— LTE, Packet Scheduling, eNodeB, UE, access points, MARA, 3GPP, NGN

1 Introduction

After the grand release 8 of the Third Generation Partnership Project (3GPP), the field of telecommunications is rapidly evolving to meet the growing demands of the world, which has grown more data hungry and has a very high expectation on Quality of Service (QoS) and the end user experience. This has raised the bar on how communication should happen. Higher data rates, lesser delay, higher QoS, high fairness are some reasons to go for 4G. 3GPP marked the beginning of 4G, which is the starting point of Next Generation Networking (NGN). 3GPP clearly defines the basic requirement of NGNs which are tabulated in Table 1.

Table 1. Main characteristics of LTE as per 3GPP

Sl No	Characteristics	Requirements
1	Bandwidth	1.4, 3, 5, 10, 15, 20 MHz
2	Downlink	OFDMA (Orthogonal Frequency Division Multiple Access)
3	Uplink	SC-FDMA (Single Carrier Frequency Division Multiple Access)
4	Packet Data rates	Uplink: 50Mbps Downlink: 100Mbps (For 20MHz spectrum)
5	RAN Round Trip Time	<30ms
6	Cell Size (Coverage)	5-100 km (minor degradation after 30 km)
7	Modulation	Uplink: QPSK, 16QAM, 64QAM Downlink: QPSK, 16QAM, 64QAM
8	Range of mobility	500Km/h
9	End user latency	<10ms
10	Duplexing Schemes	Frequency Division Duplex (FDD), Time Division Duplex (TDD) and Half-duplex FDD
11	Hard QoS	GBR, non-GBR

Thus LTE is build upon strict requirements which require special physical devices and different network layer architecture to realize the characteristics put forth by 3GPP. 4G can be realized either by WiMAX or LTE, but the backward compatibility of LTE makes it an ideal candidate to realize LTE.

2 Literature Survey

The literature survey for this work is split into two different categories. Comparing the research works that compare the existing algorithms is the first category. Second category is that research work which has proposed new algorithms.

2.1 Comparing existing algorithms

In [1], the basic explanation of LTE is discussed and a simul tion environment is assumed as a single cell with varying users between 80-100, who are having different degrees of mobility (1-100 km/h). The traffic was considered to be video streaming and the comparison was done for Max-Rate, PF, M-LWDF and Exp-PF algorithms for the parameters throughput, PLR and fairness. In [2], the PF, M-LWDF and Exp-PF algorithms were compared for a single cell environment with ICI, for best effort, video and VoIP flow. The parameters were throughput, PLR, delay, fairness index and spectral efficiency.

In [3], most of the basic algorithms were compared for a single cell scenario with 20-200 users who have a mobility of 60-120 km/h. This comparison was just for multimedia flows for the parameters PLR, fairness, E2E delay, throughput, and spectral efficiency. In [4], PF, M-LWDF and Exp-PF were compared for less mobile users with speeds 3 km/h. The parameters were delay, fairness, throughput, spectral efficiency. In [5], frequency reuse is discussed and interference within the cell is considered too. The algorithms compared are PF, Exp-PF and M-LWDF for video and CBR flows. This also classifies the algorithms based on the way RBs are allocated: channel unaware, channel aware/QoS unaware and channel aware/QoS aware. The parameters are delay, fairness; PLR, throughput and spectral efficiency.

2.2 Newly proposed Algorithms

Based on the key parameters required for the performance of LTE, new algorithms that are totally different from the basic algorithms are proposed. These algorithms are effective and show a higher performance than the basic algorithms.

In [6], every user is allocated priority based on the remaining lifetime of UE and the queue overflow probability. The service should be selected such that the queue length never exceeds the maximum length of the buffer. It has better throughput, QoS, lesser BLER and more fair. But power management is not clear. In [7], the algorithm is proposed on allocation of RBs based on CQI and prioritizing the traffic as RT or NRT. This algorithm (CABA) ensures fairness and assumes that the UE buffer is finite. It works by reporting the CQI values, BSR values, and then finding the traffic as RT or NRT. It has lesser packet dropping probability and more fairness and throughput. But it is complex to implement. In [8], an algorithm exclusively for multimedia applications is proposed. Current algorithms cant be used because, they are sensitive to packet loss. This algorithm (DPS) proceeds by finding the HOL delay and finding that user with corresponding higher instantaneous SNR, for whom the packet is then transmitted. Then the RBs are updated accordingly till all the UEs are allocated RBs. This algorithm has higher throughput and fairness and lesser delay and PLR. But the service degrades when the number of UEs is high. In [9], an algorithm is proposed for those users who move at very high speeds. If a user moves at various speeds, the variance of the CQI is very high. If this is above a specific threshold, then the next location of CQI is predicted or PF algorithm is implemented. The throughput is higher, if variance of CQI is stable and BLER is less. But if the speed is very high, the performance is worst and the prediction of new location is complex and time consuming. In [10], an algorithm is proposed to achieve inter class fairness. The algorithm called, Queue-HOL-M-LWDF, considers both RT and NRT (and thus queue length and delay). This algorithm has improved PLR, throughput, fairness and spectral efficiency . However, delay is considered only when packet delay is higher than HOL delay.

3 Architecture of Long Term Evolution (LTE)

The main reason for the backward compatibility of LTE is its flat architecture, which is termed System Architecture Evolution (SAE). A non hierarchical architecture which makes it can an ideal candidate for wireless communication and cellular services. Components in SAE are the User Equipment (UE), the Evolved UMTS Terrestrial Radio Access Network (E-UTRAN) and the Evolved Packet Core (EPC) and they are depicted as in Fig 1.

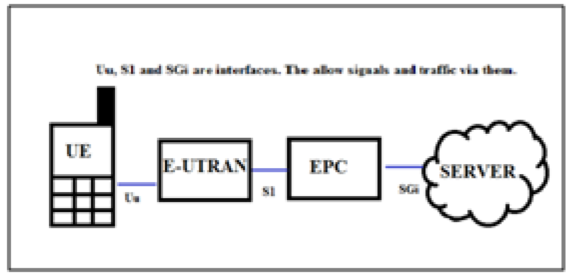

Fig 1 Architecture of LTE

3.1 User Equipment (UE)

The mobile termination point, which holds the UICC (Universal Integrated Circuit Card), is the actual equipment the user holds. This UICC runs the Universal Subscriber Identity Module (USIM), and this is required for availing the services and for accessing Internet. UE is comprised of Mobile Termination (MT), Termination Equipment (TE) and the UICC.

3.2 Evolved UMTS Terrestrial Radio Access Network (E-UTRAN)

E-UTRAN handles all radio communication between the UE and EPC. The base stations are called eNodeBs (eNBs) and they control the activities of the network. eNB controls the mobiles in cells and the eNB communicating with an UE is called its serving eNB. Structure of E-UTRAN is given in Fig 2.

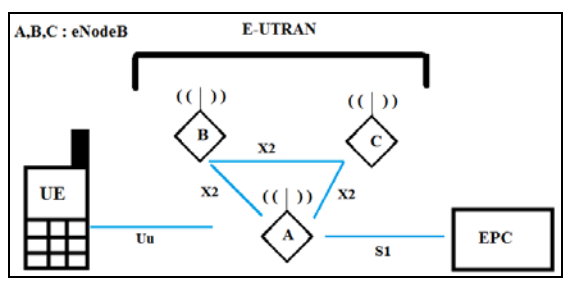

Fig 2 Architecture of E-UTRAN

Each eNB connects with the EPC via the S1 interface, and it can also connect to nearby eNBs by X2 interface. This is used to signal and forward packets during HO.

3.3 Evolved Packet Core (EPC)

EPC is the heart of the LTE system. EPC holds:

1. Home Subscriber Server (HSS): a central database that

contains information about all the network operator's subscribers.

2. Packet Data Network (PDN) Gateway (P-GW): communicates with the external world (PDN). It communicates via the SG interface. Each PDN is identified with an APN.
3. Serving Gateway (S-GW): acts as router, and forwards data between eNB and P-GW.
4. Mobility Management Entity (MME): controls the high level operation of UE by signaling the messages and HSS.

Architecture of EPC is given in Fig 3.

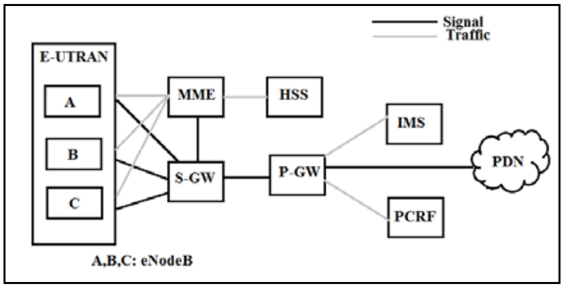

Fig 3 Architecture of EPC

4 Packet Scheduling

The process of dynamic allocation of resources in LTE such that the UEs can access Internet and other services is called packet scheduling. This scheduling is done by the eNB, and this eNB executes an algorithm that allocates the available resources to the individual UEs in the given cell. Generally, every UE has a dedicated buffer (virtual) at the eNB. These buffers store the packets before they are sent to the required UEs. At every Transmission Time Interval (TTI), based on the instantaneous values of Sound-to-Noise Ratio (SNR) and Channel Quality Index (CQI). (this is done inherently by the physical layer of the LTE), the eNBs allocates the resources and sends the packets to the UEs. This is depicted in Fig 4. Since the design of a downlink algorithm is an open research topic, there are numerous algorithms proposed by researchers. The most important are summarized in Table 2.

Table 2. Common downlink PS algorithms

Sl No	Algorithm	Explanation	Parameter on which algorithm was developed
1	Best CQI (B-CQI)	Choose the users with the highest SINR and allocate the resources among those users effectively	SINR, CQI
2	Max-Rate	Same as B-CQI; uses only SNR for choosing users	SNR
3	Round Robin (RR)	Allocate equal packet transmission time to each user	Transmission time
4	Proportional Fair (PF)	Choose a user with highest priority ki $ki = argmax \frac{ri(t)}{Ri(t)}$ Where Ri(t) is the average throughput of the user i in a window of time.	Priority based on throughput of the user
5	Maximum Largest Weighted Delay First (M-LWDF)	Combine PF property with Head of Line packet delay	PF, HOL packet delay
6	Frame Level Scheduler (FLS)	1. First level as to find the amount of data to be transmitted 2. Second level to use PF	Amount of data in RT to be transmitted

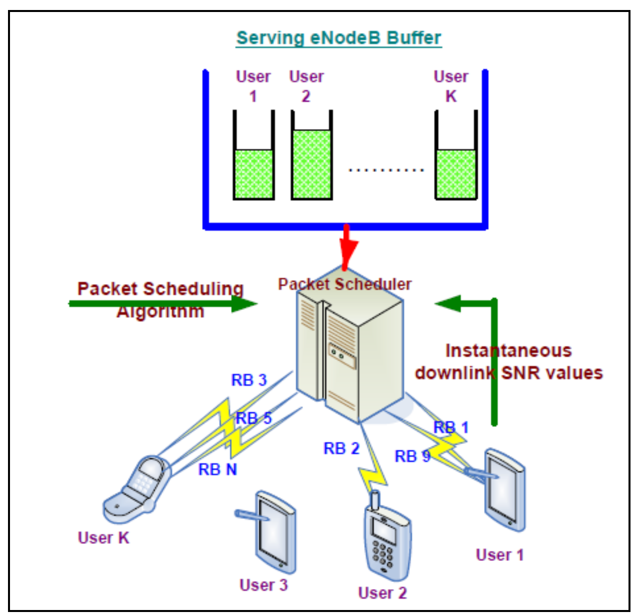

Fig 4 Packet Scheduling

4.1 Merits and Demerits of the Existing Algorithms

Based on the key parameters on which the different PS algorithms proposed, they can be analyzed to find which have better performance than others. Best-CQI chooses the users with higher SINR, thus, it has higher throughput and better performance. But B-CQI fails to provide fairness. Similarly, Max-Rate algorithm, tries to optimize the performance of the entire cell, but does not provide enough fairness. Round Robin (RR) algorithm, on the other hand, allocates an equal packet transmission time to each device in the network, thus optimizing fairness. But it falls short in providing good throughput for the system.

Proportional Fair (PF) algorithm allocates resources based on priority as per the ratio of the instantaneous throughput of the user to the average throughput of the user in a given window. Thus, priority is allocated based on the throughput of the users, it tries to balance between fairness and throughput. But it fails to provide the expected performance when Real Time (RT) traffic is considered. Also, packet delay and packet loss are higher. A slight modification of the PF algorithm, called the Exp-PF algorithm, allocates the priorities to the users based on the exponential value of the ratio taken in the PF algorithm. Though it provides comparatively lesser packet loss and delay, it can't be used for RT traffic. Maximum Largest Weighted Delay First (M-LWDF) algorithm allocates priorities based on the Head Of Line delay and executes the PF algorithm. This algorithm provides good throughput, fairness and lesser packet loss. But it does not consider the power saving mechanisms. Frame Level Scheduler (FLS) allocates the resources in two levels: in the first level, the amount of data to be transmitted is found and in the second level, PF is used to transmit data. Fairness is ensured, but it is more complex to implement.

5 Proposed Algorithm – Modified Adaptive Resource Allocation (MARA)

To achieve fairness and good throughput, a new algorithm Modified Adaptive Resource Algorithm (MARA) is proposed. This algorithm considers the buffer queue length at the eNB and the residual energy of the individual nodes.

5.1 Algorithm - MARA

The algorithm proposed considers the queue overflow probability, which is calculated as the ratio of the instantaneous queue length to the maximum queue length. Based on various other researches, the threshold value for the queue overflow is found and if the instantaneous ratio is lesser than the threshold value, lesser priority is allocated. Else, higher priority is allocated. Similarly, residual energy is calculated, and a threshold value is assumed. If the instantaneous energy value is lesser than the threshold value for energy, higher priority is allocated. Else, a lower priority is allocated. The algorithm is depicted in Fig 5. Based on the priorities set, the resources are allocated to the devices and services are done.

Queue overflow probability is considered because, if the virtual queue of the given UE is about to overflow, the packet loss/drop will be higher. This will reduce the integrity and the throughput of the system. So if the probability is higher, there is a higher change that packets are dropped. So UEs having such higher probabilities are given higher priorities. Residual energy indicates the remaining life time of the UEs. If an UE has very less energy/life, it will be given higher priority and the packets are transmitted. This improves the throughput of the system and ensures fairness.

```
Declare the eNodeB
Declare UEs
Use a random function to allocate positions for the UEs
neighbour selection:
for all the UEs
        for UEi, UEj
                find possible routes between UEi and UEj
                find the distance between UEi and UEj for all possible routes
using the Pythagorean theorm
                construct the route between UEi and UEj based on the
ascending order of the distances
                write them to a file
calculate remaining lifetime and overflow:
for all node k in routes
        send testPackets to all the packets in the route
        Qk = rand()
        ak = (Qmax-Qk)/T
        bk = (bit service rate)-(bit arrival rate)
        poverflowk = Qk/Qmax
        sum = sum(energies of all nodes)
        res = sum/(number of nodes)
        Rk = (Qmax-Qk)/res
        if(Rk < Rthreshold && poverflowk > overflowThreshold)
                set priorityk as 1
        if((Rk > Rthreshold && poverflowk < overflowThreshold)
                set priorityk as 3
        else
                set priorityk 2
transmit data:
for all nodes k
        if(priorityk == 1)
                allocate 60% of RBs
        else if (priorityk == 2)
                allocate 25% of RBs
        else
                allocate 15% of RBs
```

Fig 5 Proposed Modified Adaptive Resource Allocation (MARA) Algorithm

5.2 Simulation

The proposed MARA algorithm is simulated in an RT environment with a single eNB and 29 APs of the UEs. The simulation TTI is set to 1ms, with the system bandwidth is set to 10 KHz. A single cell environment is considered, in an urban scenario. The simulation is done for 45s.

The simulation occurs in different stages:

1. Probing for identifying neighbors
2. Calculation of queue overflow probability and finding residual energy
3. Assigning the priorities accordingly
4. Allocation of resources
5. Packet transmission

Thus at every TTI, the priorities change accordingly and the allocation varies. The routing algorithm used is Ad-hoc On demand Distance Vector (AODV) algorithm.

5.3 Simulation Parameters

There are a multitude of parameters to choose for comparing the performance of different algorithms in LTE. Of course, the most important of them are listed below as:

1. Packet Delivery Ratio (PDR): the ratio of the number of packets delivered to the total number of packets. This is a direct metric to identify throughput. This is calculated as (number_of_packets – number_of_lost_packets)/number_of_packets.
2. Packet Loss Ratio (PLR): an inverse measure of PDR. This is a direct measure to identify the load on the system. This is calculated as number_of_lost_packets/number_of_packets
3. Delay: the time taken to deliver a packet since the time of sending the packet. This is a direct measure of the throughput of the system.
4. Fairness: this indicates how equally the resources are allocated to the individual UEs in the system. This is calculated as the variance of the priorities allocated to the UEs.

5.4 Simulation Results

The simulation results are summarized as follows:

1. Packet Delivery Ratio: MARA provides higher PDR, consistent with the behavior of M-LWDF. PF shows higher PDR when there are fewer number of high priority users.

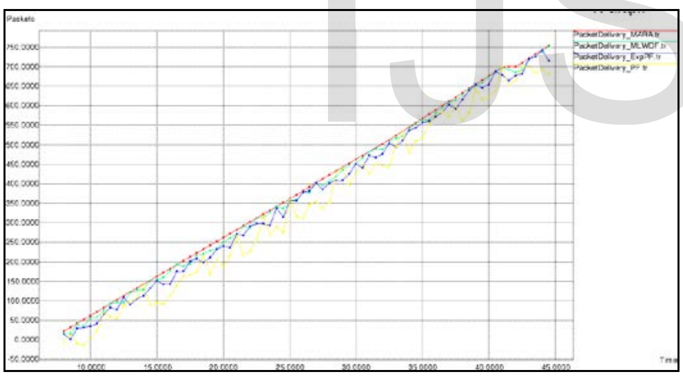

Fig 6 Comparison of Packet Delivery Ratio

2. Packet Loss Ratio: MARA here is consistent with the behavior of M-LWDF algorithm and packet loss is higher if there are higher numbers of users with higher priorities.

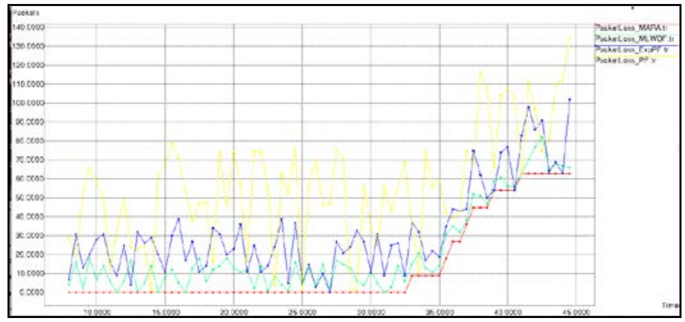

Fig 7 Comparison of Packet Loss Ratio

3. Delay: MARA has lesser delay, but again, M-LWDF gives optimal behavior too.

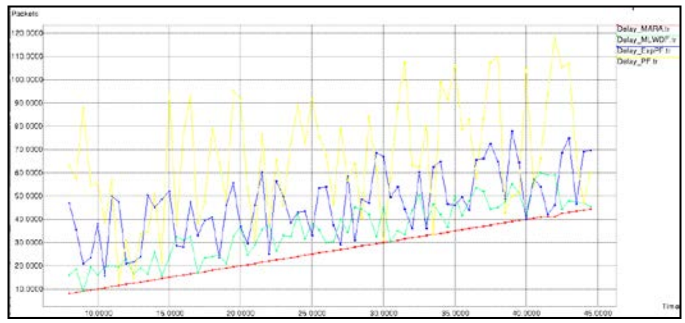

Fig 8 Comparison of Delay

4. Fairness: the fairness is fluctuating but on a scale of 5, for 30 UEs there is always fairness, indicating that there is a minimal flow of packets to all the packets.

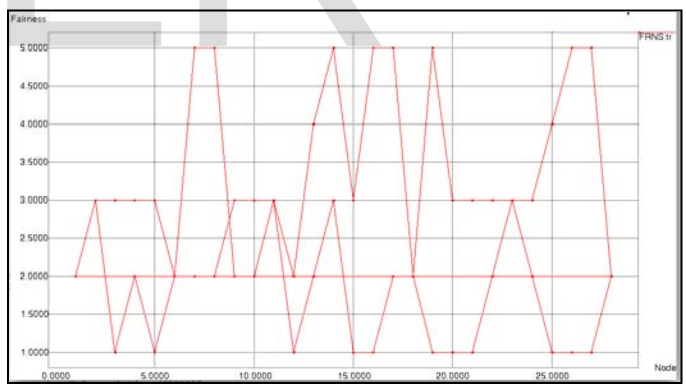

Fig 9 Fairness

6 Conclusion

In this paper the various algorithms available for downlink PS algorithms are analyzed. Of those M-LWDF algorithm is the best till date. But M-LWDF algorithm, does not consider the residual energy of individual nodes nor the queue overflow probability before the resources are allocated. MARA considers these two parameters more importantly and allocates based on them. Based on the simulation results, it is concluded that MARA performs on par with M-LWDF and provides better trade off in terms of PDR, PLR and delay. Also, it ensures fairness for all the UEs by providing optimum

————————————————

Preethi Pattabiraman is currently pursuing masters degree program in computer science and engineering in Velammal Engineering College, India, PH-9884333992. E-mail:preetiauguststar@gmail.com
P.PrittoPaul is working as Assitant Professor in department of computer science and engineering in Velammal Engineering College, India. E-mail:p.prittopaul@gmail.com

throughput to the system.

REFERENCES

[1] Antti Toskala, Harri Holma, Kari Pajukoski, Esa Tiirola, "UTRAN LONG TERM EVOLUTION IN 3GPP", The 17th Annual IEEE symposium on Personal, Indoor and Mpbile Radio Communications, 2006

[2] Huda Adibah Mohd Ramli, Riyaj Basukala, Kumbesan Sandrasegaran, Rachod Patachaianand, "PERFORMANCE OF WELL KNOWN PACKET SCHEDULING ALGORITHMS IN DOWNLINK 3GPP LTE SYSTEM", Proceedings of the 2009 IEEE 9th Malaysia International Conference on Communications, 2009

[3] Samia Dardouri, Ridha Bouallegue," COMPARATIVE STUDY FOR SCHEDULING ALGORITHMS FOR LTE NETWORKS", International Journal of Computer, Electrical, Automation, Control and Information Engineering, Vol:8, No:3, 2014

[4] B.P.S.Sahoo, Deepak Puthal, Satyabrata Swain, Sambit Mishra, "A COMPARATIVE ANALYSIS OF PACKET SCHEDULING SCHEMES FOR MULTIMEDIA SERVICES IN LTE NEWORKS", International Conference on Computational Intelligence and Networks, 2015

[5] Farhana Afroz, Roshanak Heidery, Maruf Shehab, Kumbesan Sandrasegaran, Sharmin Sultana Shompa, "COMPARATIVE ANALYSIS OF DOWNLINK PACKET SCHEDULING ALGORITHMS IN 3GPP LTE NETWORKS", International Journal of Wireless & Mobile Networks (IJWMN) Vol:7, No:5, 2015

[6] Samia Dardouri, Ridha Bouallegue, "COMPARATIVE STUDY OF DOWNLINK PACKET SCHEDULING FOR LTE NETWORKS", Springer, DOI:10.1007/s11277-015-2289-2, 2015

[7] Patteti Krishna, Tipparti Anil Kumar, Kalithkar Kishan Rao, "EVALUATE THE PERFORMACE OF LONG TERM EVOLUTION - LTE DOWNLINK SCHEDULING SYSTEMS", Wireless Communications, Networking and Applications, Lecture Notes in Electrical Engineering, Pg:571, 2016

[8] Pardeep Kumar, Sanjeev Kumar, "PERFORMANCE ANALYSIS OF DOWNLINK PACKET SCHEDULING ALGORITHMS IN LTE NETWORKS", Advanced Computing and Communication Technologies, Advances in Intelligent Systems and Computing, Pg:453, 2016

[9] Ruiyi Zhu, Jian Yang, and Peng Si," Adaptive Resource Allocation in LTE Downlink Transmission Systems", Lecture Notes in Electrical Engineering, Springer, 2016

[10] Dardouri Samia, Bouallegue Ridha, "A New Scheduling Algorithm for Real-Time Communication in LTE Networks", IEEE 29th International Conference on Advanced Information Networking and Applications Workshops (WAINA), 2015

[11] Moustafa M. Nasralla and Maria G. Martini, "A Downlink Scheduling Approach for Balancing QoS in LTE Wireless Networks", IEEE 24th International Symposium on Personal Indoor and Mobile Radio Communications (PIMRC), 2013

[12] Pardeep Kumar, Sanjeev Kumar, Chetna Dabas, "COMPARATIVE ANALYSIS OF DOWNLINK SCHEDLUING ALGORITHMS FOR A CELL AFFECTED BY INTERFERENCE IN LTE NETWORK", Springer, DOI:10.1007/s40745-016-0076-x, 2016

[13] Preethi Pattabiraman, Dhaya R, Shaik Shahrukh, Aravindh J, "Survey On Various Algorithms For Packet Scheduling In LTE Downlink Transmission", Proceedings of International Conference on Innovative Trends in Engineering, Life Science and Business (ICITESB2016)

[14] Qurat-ul-Ain, Syed Riaz ul Hassnain, Mudassir Shah and Sahibzada Ali Mahmud, "An Evaluation of Scheduling Algorithms in LTE based 4G Networks", IEEE International Conference on Emerging Technologies (ICET), 2015

[15] Preethi Pattabiraman, R.Dhaya, "Survey on Packet Scheduling Algorithms for Downlink LTE Networks", *Proceedings of International* Conference on Emerging Techniques in Engineering,Science & Management (ICETESM2016) on 25 & 26 November 2016, VOL. 7, 2016, Pg. 162-167

[16] Mohammed Mahfoudi, Moulhime El Bekkali, Abdellah Najid, M. El Ghazi and Said Mazer, "A New Downlink Scheduling Algorithm Proposed for Real Time Traffic in LTE System", International Journal of Electronics and Telecommunications, Vol 61, No 4, 2015