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Improving QoS Parameters using Dynamic Priority Scheduling (DPS) Protocol for Wireless Sensor Networks

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Abstract**:** ***Packet scheduling is an emerging topic in wireless data transmission since the migration towards the packet-based networks. The uncertainty factor of the channel brings another dimension and opportunity to the scheduling schemes. Packets are defined with dead-line values depending on the type of the traffic they belong to. This value essentially describes the life time of the packet, which can wait in queue before it is no longer useful, in this case it should be dropped. The second possibility of dropping a packet arises due to the fact that each item of user equipment has a finite-sized queue and packets are constantly arriving to be sent. The incoming number of packets/time slot depends on traffic load. If traffic load is on average higher than the rate at the packets are scheduled, the queues gradually fill until they are full. This paper focuses on Dynamic Priority Scheduling (DPS) protocol approach to meet QoS requirements for packets such as throughput, delay and packet loss.***

Index Terms**:** ***DPS, Dynamic priority scheduling, Wireless sensor networks, QoS, WSN***

I. INTRODUCTION

Scheduling schemes for packet transmission using various algorithms in wireless sensor networks are promising and wide area for research. Capabilities of differentiation between different classified data-ows are of great interest in the growing jungle of services offered over both wireless and wired platforms. There is a rising interest in providing solutions to public safety and emergency groups utilizing commercially deployed structures in recent years. Currently, the majority of such bodies employ their own dedicated systems and spectrum [16]. There are numerous reasons why these groups should be using commercially available systems. Several of them would be greater bandwidth availability, access to latest Smartphone hardware and capabilities, lower equipment, maintenance, operating cost and wider coverage. However, interoperability between different agencies is a very significant problem in today's public safety and emergency groups and the issues regarding this problem are faced quite often [1]. The multimedia capable devices for such groups will definitely enrich the communication compared to the ones capable of only voice. In addition, various types of technological deployments and further evolution of such technologies will provide an everlasting advantage to the public safety and emergency groups [3].

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II. WIRELESS SENSOR NETWORK

Wireless sensor network(WSN) consists of collections of random or planned deployment of sensor nodes, used to sense the parameters like pressure, temperature, soil moisture, sound vibration etc., in ad-hoc structure or infrastructure network. (Li-jun et al (2007)). The captured data is being transmitted to sink node through the neighbour nodes [2]. The sink node relays it to base station, the Base station (BS) forwards it to the remote server through the internet for remote monitoring. Figure.1 shows the setup of WSN.

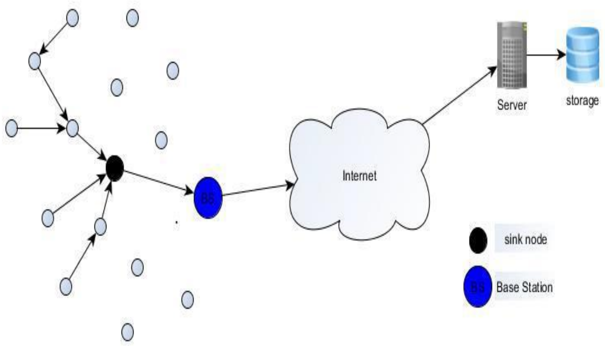

Figure.1 Structure of the Wireless Sensor Network

By way of collection for sensor nodes in application field, the structure is defined I. F. Akyildiz et al (2002), Mohammad Ilyas & Imad Mahgoub (2004). Based on the deployment and function of nodes, WSN is classified into following types

- Flat architecture
- Hierarchical structure

A. Flat Architecture

In flat architecture nodes are placed in one hop w.r.t the sink node (SN) in star topology or peer to peer network. All the nodes perform an identical function. Example of flat architecture in star topology is shown in Figure.2.

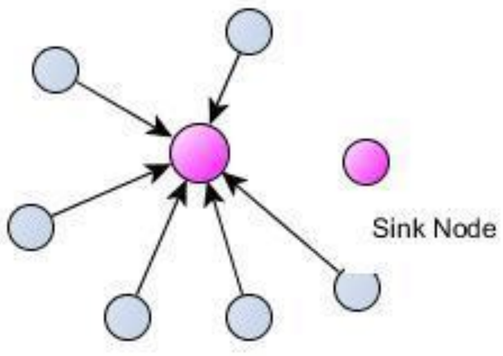

Figure.2 Flat structure –Star Topology

B. Hierarchical Structure

As shown in Figure.3, in the hierarchical structure, also called tiered architecture, all the nodes will not perform the same function. If we refer to the diagram some sensor nodes are capable of sensing the data and forwarding it to a higher level, the receiving node will compute in terms of aggregating and removing the data redundancy which is then collected from similar nodes and sent to next hierarchy to deliver that information to server through network [5].

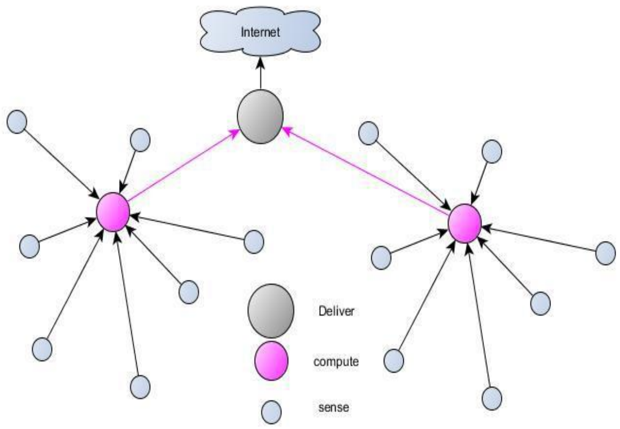

Figure.3 Hierarchical *Structure*

III. Routing Approaches

Another important stage in the process is the way the captured data is reaches to the sink node (SN) by efficient routing protocols. This is classified into following categories.

- Flooding
- Unicasting
- Multicasting

Flooding:

The collected data is being forwarded to all the nodes, which are connected to the network and data will reach the destination through intermediate nodes. The copy of the message is handled by all the nodes, which increases the traffic and energy consumption in the network.

Unicast:

The captured data is forwarded to one of the nearest neighbour nodes from the source node, that node again forwards to one of its neighbouring nodes, continuing this process is continued until the destination is reached.

Multicast:

The obtained data is forwarded to a group of nearest neighbour nodes from the source node, which again forward to their own set of neighbour nodes. This process is continued until the destination is reached.

IV. Challenges in Achieving Quality of Service (QoS)

To provide a QoS in WSNs is a tough task because of the following reasons.

A. Unbalanced traffic: The sensed data moves from the outer region to the inner region of the networks that is data flows towards one or two set of sink nodes. Traffic mainly flows through a huge number of sensor nodes to a small group of sink nodes. This leads to unbalanced traffic where some nodes face heavy traffic and other don't.

B. Data redundancy: If any event occurs in one particular region, the sensor nodes sense and send similar data to the sink node (SN). Every intermediate node, handles the redundant data. But the redundancy of data helps to transmit reliable data to the sink node ((SN). The solution for redundancy is data fusion or aggregation in the intermediate nodes. Extra energy is consumed for fusion.

C. Network dynamics: Node failure or the Mobility of intermediate nodes or neighbour nodes leads to link failure leading to a dynamic topology.

D. Energy balance: The Energy load should be equally allocated to sensor nodes. But in some applications one node has more energy, i.e., sink node has more power than the ordinary nodes.

E. Multiple traffic types: Heterogeneous Sensor Networks with different sensing parameters, (for e.g., one sensor node sensing temperature, other pressure and vibration, some other sound and speed)face different traffic conditions in the network, which has to be effectively handled.

F. Data Funnelling: Data Funnelling is a major challenge task in WSN, where the event generated data are routed from sensor to sink node. If the entire sensor data is transmitted simultaneously towards the sink node, it is many to one transmission [4]. Figure.4 shows that the set of nodes close to sink node is defined as intensity region at choke point, where the packets have a chance of getting dropped due to buffer overflow. The sensor nodes at intensity region consume more power due to more data processing, leading to more dead nodes, creating energy hole in that region, causing link failure.

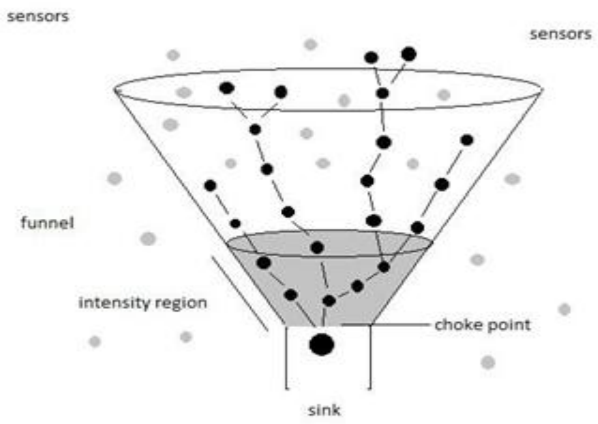

Figure.4 Data Funnelling

V. THE PRIORITY BASED PACKET SCHEDULING

The packet switching networks are emerged to serve data services, consequently the main goal of IP based networks are to provide data traffic [8]. These networks did not designed to guarantee QoS to BE traffic or provide prioritization to any service; therefore, the throughput depends on channel situation and quality, and on the network traffic load. As a result there will be unsatisfied users [7]. But LTE is intended to support all services in packet switching scheme. So both data and voice services can be provided by LTE technology. Consequently, it is hard to provide QoS for VoIP traffic in LTE, because the packets delay or packets loss has bad impact on VoIP service.

Thus, an algorithm will be provided, that has the capability to provide the desired QoS and achieves users satisfaction with high probability. If we give a strict prioritization of VoIP packets over other BE packets, we will get satisfied QoS of VoIP users, but the overall system performance will be degraded. This can simply be concluded, because when the VoIP packets have a strict prioritization, the BE packets may have not any Physical Resource Block (PRB) to use [9]. In this work; the BE throughput will be emphasized while the QoS of VoIP traffic is supported. Also negative impact of having a mixed traffic on the general system performance will be minimized.

To achieve this, we have to differentiate the traffic and prioritize the services in a good manner, using a well-designed packet scheduler. The Priority scheduling algorithms are the most crucial functions in the LTE communication network systems [10]. A scheduler assigns the available resource blocks (time and frequency) among users terminals. The packet scheduling can be defined as the process of assigning user packets to suitable shared resource to accomplish some performance guarantees [15].

VI. PROPOSED DYNAMIC PRIORITY SCHEDULING (DPS) ALGORITHM

The architecture of Dynamic priority scheduling algorithm consists of three steps: Classifier, time domain scheduler and frequency domain scheduler. The classifier has two functions; the first one is to differentiate the mixed traffic into two groups, one for RT traffic such as VoIP users and the other group for NRT traffic such as FTP users, depending on the information taken from the application layer.

The second function is to priorities the users at each group and sorts them in queues depending on reports of QoS and CQI taken from the physical layer, according to a certain equations in order to achieve the main algorithm goals. The users inside the queues are prioritized from the top to the bottom.

The proposed dynamic priority scheduling architecture is depicted in Figure.5

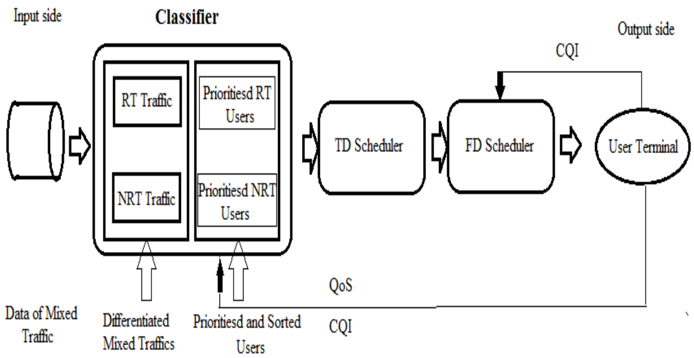

Figure.5 Dynamic priority scheduling (DPS) algorithm

A. Queues Prioritizing and Sorting:

Realtime traffic "VoIP users"

First the users will be checked, the users have data packets to be sent are measured to be scheduled. The prioritizing metrics of the RT traffic depends on both QoS required for RT users and the CQI. The RT user waiting time is the time that the active RT user has not been allocated or delayed, and this should not exceed the upper pound of delay for RT traffic, the standard value in LTE networks is 40ms. The waiting time and CQI are updated every TTI, as a result both the user delay and PDR will be reduced, the fairness and system overall throughput will be improved. The priority of an RT user k can be calculated by:

$$\boldsymbol{Priorityvoip} = T\text{k delay\_time} * CQI \qquad (1)$$

Where, Tk delay_time and it is the waiting time of VoIP user and CQI is the instantaneous channel quality indicator.
In each TTI, the user with the highest priority value is sorted at the front of the queue followed by users with priority value in descending order.

Non Realtime traffic "FTP users"

The average throughput and CQI are used to resolve the priority metrics. The average throughput is used to maintain the fairness between the system users and the CQI to develop the system overall throughput. The priority order can be calculated by

$$\boldsymbol{Priority}\text{FTP} = CQI\,/\,R\text{k}(t) \qquad (2)$$

where, $Rk(t)$ is regular throughput of user k.
The average achieved throughput of the user k is updated using the moving average formula, as used in and many others papers, and can be calculated by:

$$Rk(t + 1) = (1 - 1/tc)Rk(t) + (1/tc)\Sigma\ r\ M\ k\ ,m\ k,m(t) \quad (3)$$

where tc is the extent of time window to calculate the average throughput, $1/tc$ is called the attenuation coefficient with the widely used value 0.001, $\boldsymbol{r}k,m(t)$ is the acquired data rate of user k at PRB m, if m is allocated to k else it is zero.

Time domain scheduler (TDS)
The main function of the TDS is to pick a set of users with the highest priorities equal to available PRB to be allocated at Frequency domain scheduler. The decision of user selection must guarantee the QoS necessities of RT users first, then the NRT traffic. If there is any RT user in a deep fading and have bad CQI, this user will not be allocated and will be dropped and replaced with other user. The CQI will be updated and check every TTI.

Frequency domain scheduler (FDS)
The selected set of users at TDS will be passed to the FDS, and the actual resources allocation to these users is done by the FDS. For each user the FDS check the available PRBs and allocates the best PRB; which has the highest CQI value. And depending on the value of the reported CQI, the MCS will be determined and assigned to the scheduled user.

Algorithm:
At a given time t, PRBs are allocated to users by the following steps:
Step 1: Differentiate the mixed traffic into two groups and initialize the number of PRBs.
Step 2: Priorities the users at each group and sorts them in queues depending on (2) and (3).
Step 3: Sort PRBs and determine PRBs group to each queue.
Step 4: Pick a set of prioritized users from the queues based on the resources reserved for VoIP and FTP traffic.
Step 5: Allocate the best PRB to highly prioritized user.
Step 6: Remove the assigned PRB from the PRBs list and the allocated user from the users list.
Step 7: Go to step 5 if the PRBs set are not vacant else go to next TTI.
Resource allocation is completed when all PRBs are allocated. Users with no data packets are not considered in FD scheduling.

VII. PERFORMANCE METRICS AND SIMULATION MODEL

Performance Metrics:
The Dynamic priority scheduling algorithm is evaluated under performance metrics of QoS of both traffic types; RT and NRT, overall system throughput and user fairness. We used PDR and delay viability of RT such as VoIP and average achieved throughput of NRT such as FTP. The PDR can be calculated by

$$\boldsymbol{PDR}k = Pkdropped / Pktotal \quad (4)$$

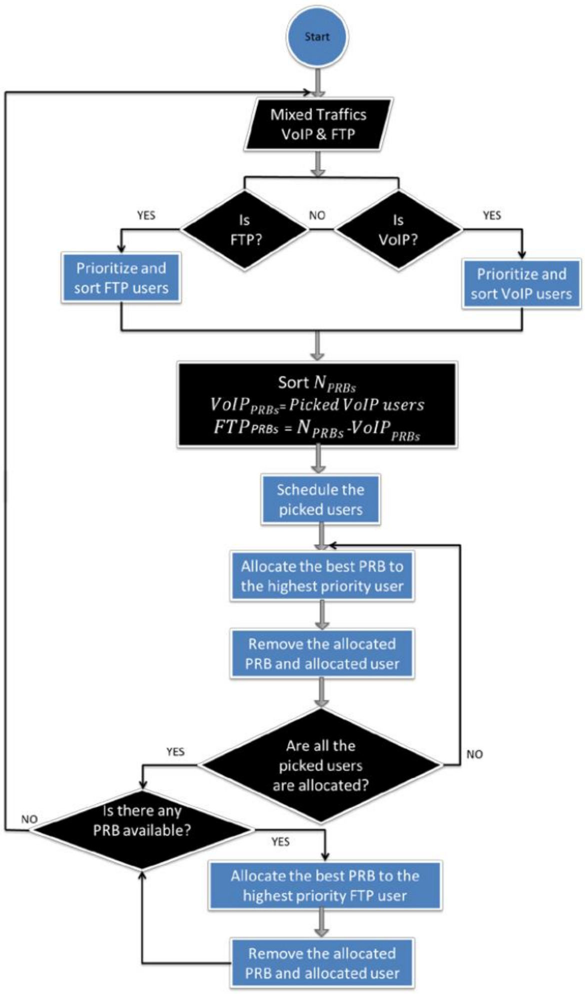

Figure.6 Flowchart of the Dynamic scheduling algorithm

where, PDRk is the packet drop ratio and it is the ratio of dropped packets to the total number of packets of a user k, Pk dropped is number of dropped packets of user k and Pk total is the total number of packets generated by user k, and it used to measure the QoS for RT (VoIP) users. And the delay violation probability is given by

$$\boldsymbol{Delay\ viability} = \boldsymbol{max}k\epsilon \mathbf{RT}\ (\mathbf{k}) \quad (5)$$

where, PDRk is the PDR of RT user.
The minimal average throughput across all the NRT (FTP) traffic users is taken as the minimum throughput to measure the QoS for NRT users, and it can calculated by

$$\boldsymbol{r}\mathbf{min} = \boldsymbol{min}k\epsilon\mathbf{NRT}\ \boldsymbol{rk} \quad (6)$$

where, $\boldsymbol{r}$k is the achieved throughput by NRT traffic user k.

The overall system average throughput is the amount of average throughput achieved by all the system users. The Raj Jain fairness index is used to measure the fairness between the system users, and it can be calculated by

Fairness = [Σ R k k =1 k]2 / ***K*** ℘ (R k k=1 k)**2**
(7)

Where, *R*k is the time regular throughput of user *k* and ***K*** is the total number of the system users. The highest fairness among the users is 1, and this occurs when all the NRT users have the same data rate

B. Simulation Model:

The evaluation of the priority packet scheduling algorithm is w.r.t the 3GPP UTRAN LTE downlink specifications and recommendations, so the simulation parameters and assumptions used for system level simulation are as described. In this work, the values and the parameters are considered as one omni-directional eNodeB in a single cell with 10 MHz total system bandwidth, the total system bandwidth is apportioned into 50 PRBs.

Each PRB consist of 180 kHz in frequency domain and 2 slots each of 0.5ms in time domain. The total eNodeB transmission power is 40w (46dBm), the carrier frequency is 2 GHz, a typical Urban Non Line of Sight (NLOS) wireless environment is considered, the path loss model is TS36942 is used, the quantity of users in the cell is constant and have random distribution and the number of VoIP users is assumed to be equal to the number of FTP users as in [6]. The aforementioned specifications and parameters are listed in Table.1. Link adaptation selects the coding and modulation Scheme for each user based on CQI measurements.

Parameter	Value
Number of cell(s)	1
Cell radius	1000m
Total system bandwidth	10 MHz
Number of PRB	50 (12 sub-carriers/PRB)
PRB Bandwidth	180KHz
TTI duration	1ms 14OFDM (symbols)
Carrier frequency	2 GHz
eNodeB total transmission power	40 W 46 dBm)
Users distribution	Random
User velocity	3 kmph
Shadow fading standard deviation	8dB
Smallest distance from UE to eNodeB	35 m
Path loss model	TS36942

Table.1 Simulation parameters values

VIII. Simulation Results and Analysis

The performance of the dynamic priority scheduling (DPS) algorithm is evaluated by compared with RR, SSSA and PF. The general system throughput versus total number of users is shown in Figure-7.

The proposed dynamic priority scheduling (DPS) algorithm shows higher system throughput as compared with RR and SSSA. These good results are obtained because multiuser diversity is oppressed by the projected algorithm through updating priority metrics during each scheduling decision, by calculating the CQI during each TTI, and makes better resource utilization. Note that the presentation of the PF is nearly, the same as the projected scheduling algorithm because they use the same priority metrics. Additionally at higher system load the general system throughput is slightly decreased because of the increase of number of the RT, "VoIP" users. Therefore they utilize more radio resources.

For the SSSA scheduling algorithm in the lower system load it shows extremely degradation in the system performance, because this algorithm does not use the whole available free radio resources and it just assigns only one PRB to each user. In the lower system load the quantity of PRBs is greater than quantity of users who have data to be sent. However, the general system throughput of the RR scheduling is reasonable because it doesn't develop the multiuser diversity and does not use any priority metrics; it just assigns the radio resources by turn, i.e. user by user.

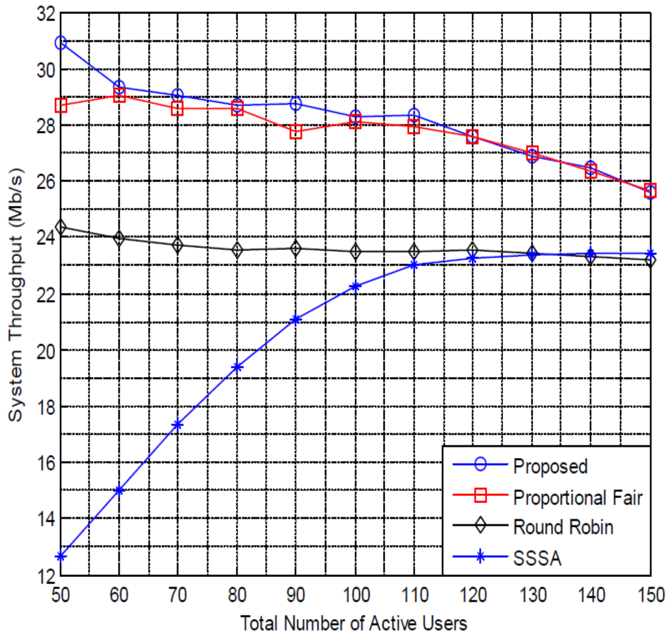

Figure.7 System throughput

Figure.8 shows average achieved throughput by SSSA, RR, PF and the proposed scheduling algorithms for BE traffic "FTP traffic " which does not have any QoS requirements. The planned scheduling algorithm shows higher throughput because it allocates the best carriers among the total BW to the users at every TTI. It means that each TTI the planned scheduling algorithm checks the total BW and sorts all the RBs and assigns the best RB to the user that has it. At lower system load, it is obviously, that the planned scheduling algorithm is the superior to all the other scheduling algorithms, and that is because in addition to the above explanation, the algorithm assigns more RBs to the FTP users because not all the VoIP users have data to be sent.

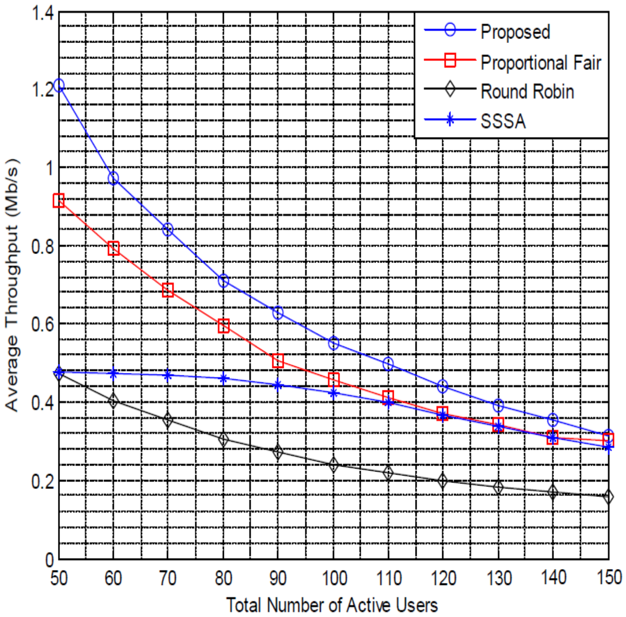

Figure.8 Average achieved throughput of BE users.

Fairness amongst users is calculated and has been shown in Figure.9. Fairness achieved by the planned scheduling algorithm is improved significantly as compared to RR and SSSA. Because the planned scheduling algorithm takes into account a fair share of resources among users. However, the proposed scheduling algorithm is updating the average achieved throughput and CQI of all users during each scheduling decision, allocates a fair share of radio resources among all users and improves overall system throughput at the same time. Also we can make a note of that the projected scheduling algorithm and the PF algorithm achieve nearly the same performance because both of them take into account a reasonable share of resources among users.

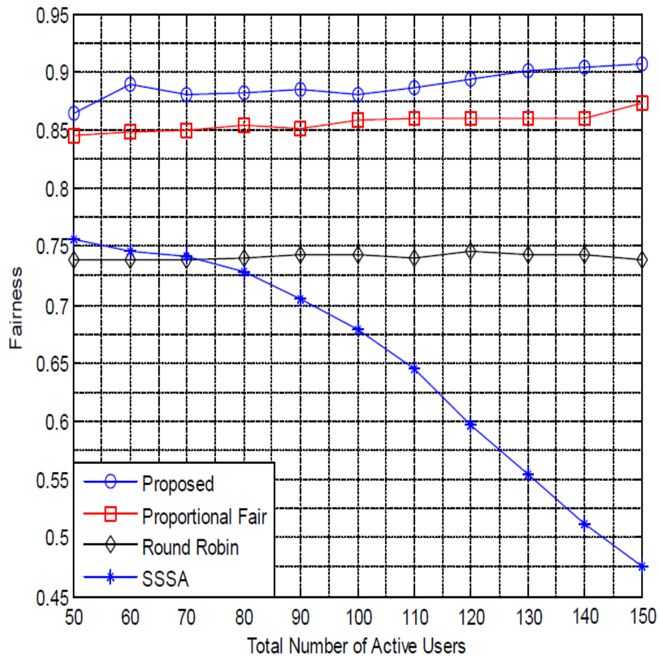

Figure.9 Fairness among users.

The averaged PDR of RT traffic versus total number of active users is shown in Figure.10. Both the proposed and the SSSA scheduling algorithms have the same PDR. This is because the proposed scheduling algorithm takes into account each user's updated waiting time during each TTI to take scheduling decisions, in the same manner the SSSA scheduling algorithm takes into account each user's updated queue length and the waiting time during each TTI to take scheduling decisions. This results in bringing packets with the longest delay at the face of queue thus reducing PDR due to time out. The projected scheduling algorithm calculates the waiting time each TTI and uses the waiting time in calculating the priorities of the users inside the queues. So the user by the top waiting time will be put in the top of the queue and will be allocated the radio resource firstly. In the other side both RR and PF take neither waiting time nor the queue length in the consideration when calculating the users' priorities. Therefore, the PDR is very large.

Figure.11 shows that the delay viability of RT users increases with total number of users for both the proposed, RR and SSSA scheduling algorithms. However the proposed algorithm gives the best performance at higher system load. This is because it prioritizes packets with longer delays reducing PDR of RT users due to time out. It is done by updating each user's waiting time during queue sorting at each TTI. Note that the delay viability is completely depends on the PDR.

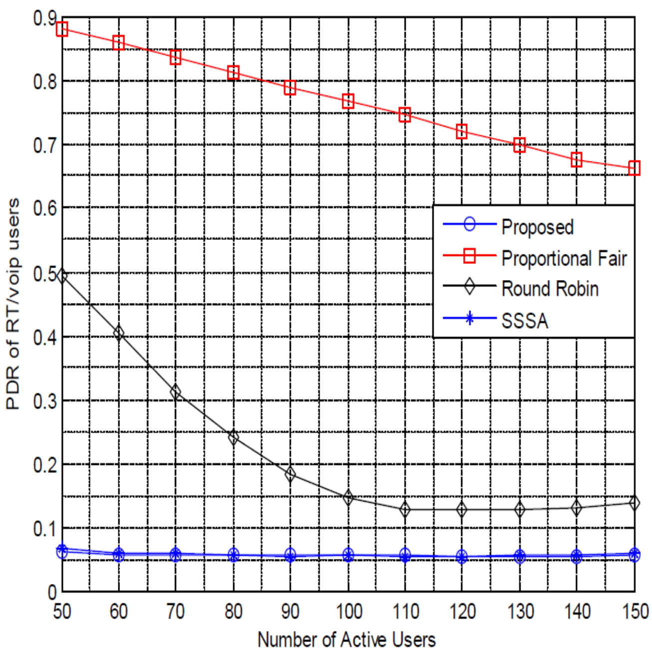

Figure.10 Packer drop rate of RT traffic.

We can summarize that, the obtained results show that the projected packet scheduling algorithm is a well-designed packet scheduler. It proves that it is capable to improve the overall system performance. Since it enhances the throughput of NRT traffic such as FTP service, and it achieves a good QoS of RT traffic such as VoIP service. It maintains the fairness amongst the users and maximizes the general system throughput. The projected packet scheduling algorithm deals with mixed traffic that is supported by the LTE networks.

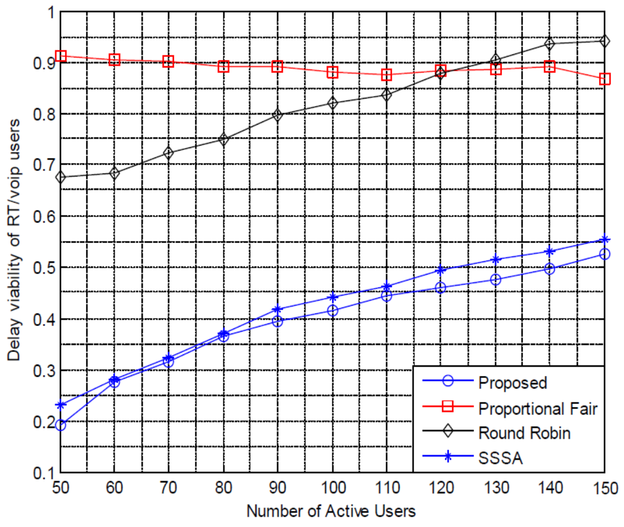

Figure.11 Delay viability of RT users.

The design of the projected algorithm consists of three stages. Classifier is the first stage, where the different types of the mixed traffic are differentiated firstly, and then sorted in a good manner depending on a special metrics. In order to advance the QoS of VoIP users we take keen on account both the waiting time of the users and CQI during the prioritizing the users inside the queue.

To enhance the performance of FTP users, we take keen on account both the average achieved throughput of the user and the CQI during the prioritizing the users inside the queue. By using these strategies we achieved a good degree of the fairness between the users and the throughput of the FTP traffic is maximized in addition to the general system throughput. A set of users that have the highest priorities are picked by the TDS, where the TDS is the second stage of the proposed scheduler. The TDS selects the set of users in order to meet the QoS requirements and then these users are passed to the last stage, where the last stage in the planned algorithm is the FDS. The FDS has the responsibility to assign the available radio resources to the selected users.

The resources allocation process is occurred in a way that guarantees and achieves the best utilization of the radio resources, in order to obtain the best performance of the system; this happen when the best PRB with the maximum CQI value is allocated to the user with the highest priority, and so on.

IX. CONCLUSION

In the comparison, the achieved outcome by the Dynamic priority scheduling algorithm is better than those of the SSSA algorithm, because of the good mechanism of the FDS, where all the PRBs are sorted with respect to each user first, and then the highest priority user is allocated the best PRB. Also in the proposed algorithm is superior to the PF in QoS of RT users in terms of PDR and delay viability, because the PF lacks to the traffic differentiation function and does not take the waiting time of the VoIP packets in consideration when prioritizing the RT traffic. Finally, in performance of the proposed algorithm is better than the RR algorithm, because the RR uses neither traffic differentiation nor services prioritization. Also, Dynamic priority scheduling algorithm is simpler than SSSA algorithm, because the proposed algorithm uses only the waiting time of VoIP packets and CQI when prioritizing the RT users, while the SSSA algorithm uses the product of normalized waiting time of every user and its channel conditions and the product is added into the queue length of the user.

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