QPPS : Qos Provision Packet Scheduling Algorithm in High Speed Downlink Packet Access

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Abstract : -The 3rd Generation WCDMA standard has been enhanced to offer significantly increased performance for packet data. But coming application such as multimedia on desiring data rates will urge the UMTS support. To support such high data rates, High Speed Downlink Packet Access (HSDPA) labeled as 3.5G wireless system, has been published in UMTS Release 5. Under the HSDPA system, it will have to support high speed transmission and promises a peak data rate of up to 10Mb/s. To achieve such high speed rate, system provides the information of Channel Quality Indicator (CQI) information to detect the air interface condition. Then, there are many channel condition related scheduling schemes have been proposed to attend achievement of high system performance and guarantee the quality-of-service (QoS) requirements. However, there is no solution of packet scheduling algorithm can consider differences of data-types priority management under the hybrid automatic repeat (HARQ) scenario. In this paper, we propose the weight combination packet scheduling algorithm to target to enhance the system efficiency and balance QoS requirements. The proposed schemes is simulated with OPNET simulator and compared with the Max CIR and PF algorithms in fast fading channel. Simulation result shows that the proposed algorithm can both increase the cell throughput effectively and meet user's satisfaction base on QoS requirements.

Key-words **:** HSDPA; UMTS; Scheduling; QOS

1. Introduction

The wireless technology began in the early 1980s with the first mobile phone, until now, we are in the 3rd generation. The initial technology utilized analog interface and it only supported voice capacities. This technology is still used in somewhere in the world. High demand of cell phone, increased demand for enhanced quality and continuously desire of more features, the 2nd generation (2G) was introduced. 2G is voice service only at the beginning, but it does provide higher bandwidth, better voice quality and limited data service which use packet data technology. Extension of the 2G system is introduced in 2.5G system as General Packet Radio Service (GPRS).

The major improvement of 2.5G system is significant with the data packet service enhancement. Furthermore, the continuous success of mobile communication systems push the need for better quality of service (QoS), more efficiency systems and more services. It soon lead to the development of the 3rd generation (3G) telecommunication system: Universal Mobile Telecommunication System (UMTS) [1]. UMTS is the standard version of 3G mobile systems in European. It promises a transmission rate up to 2Mb/s, which makes it possible to provide a wide range of multimedia services such as video telephony, internet access and broadband data. However, it is expected that there will be a strong demand for multimedia applications. In order to offer broadband packet transmission service, High Speed Downlink Packet Access (HSDPA) [2] labeled a 3.5G wireless system, has been introduced in Release 5 of UMTS. HSDPA is expected to achieve higher performance with a peak data rate of 14Mb/s. In HSDPA, high-speed packet transmission between users is transmitted through the normal channel, called High-speed Downlink Shared Channel: HS-DSCH. It also relies on new technologies such as adaptive modulation and coding, hybrid automatic repeat request, fast cell selection and fast packet scheduling. Among these new technologies, packet scheduler is the major component to decide the system performance. It can track the instantaneous users' channel conditions and select the transmission for those who are experiencing good channel conditions in order to maximize the system throughput. However, this concept raises the fairness issue, as those who are in bad channel conditions user may not get served and then starvation.

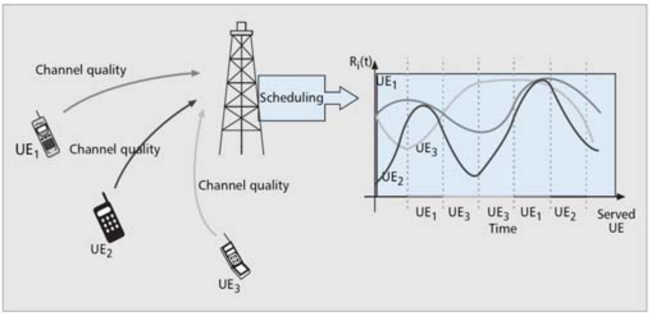
The rest of this paper is organized as follows. Section 2 describes the packet scheduling in HSDPA and some major scheduling method as MaxCIR and PF. The proposed Packet Scheduling Algorithm with QoS Provision in HSDPA is presented in section 3. And we present the simulation results in section 4. Finally, it contains our concluding remarks.

2. Related Works

In this section, basic concepts of HSDPA for packet scheduling algorithm and the famous scheduling method are introduced as follow.

2.1. Packet Scheduling

In HSDPA system, packet scheduler is one of central radio resource management (RRM) functions since it determines overall behavior and performance of the system. The main goal of packet scheduling is to maximize system throughput while satisfying the QoS requirement. In each time interval (TTI), Packet scheduler determines which user shared channel transmission should be assigns at a given time. User equipment (UE) should use high-speed physical downlink shared channel (HS-PDSCH) to transmit the data. In HSDPA, the packet scheduler can exploit short term variations in the different users' radio conditions by selecting good instantaneous channel condition for transmission, which is illustrated in figure 1. This concept is based on the fact that good channel conditions allow higher modulation and coding to increases the system throughput.



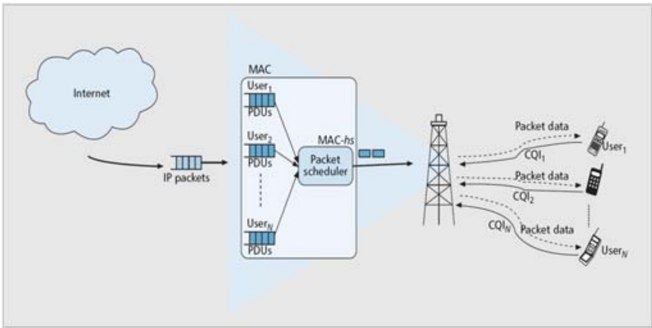
■ Fig. 1. Channel Quality Indicator monitor

In order to get quickly up-to-date information on the channel conditions of different users, the packet scheduler functionality has been moved from the radio network controller (RNC) in UMTS to the medium access control high-speed (MAC-hs) sublayer at the Node B. It is a new sublayer added to the MAC layer in order to execute the packet scheduling algorithm. In addition, the minimum TTI has been reduced from 10ms to 2ms in UMTS Release 5, which includes HSDPA. This is because it allows the packet scheduler to efficiently exploit the varying different users' channel conditions. It should be notify favoring users with good channel conditions to prevent the bad channel conditions from being served, but may cause the starvation. A good algorithm should take into consider not only maximization the system throughput but also balance the fairness of users by their QoS requirement. That is packet scheduling algorithms should trade-off between system performance and fairness.

2.2. Packet Scheduler Model and Process

In this section, we simply introduce the packet scheduler model and how it works in HSDPA. As discussed above, the HSDPA packet scheduler is implemented at the MAC-hs of Node B. Base station can serve N users in the same time and each user was served in a slot of fixed time duration. Without loss in generality, it is assumed that each user has just one connection request. Node B maintains N queue buffers for matching N users, shown in figure 2. Upon call arrival, the radio link controller (RLC) layer receives traffic in the form of high layer IP packet, which is divided into fixed size protocol data units (PDUs). These PDUs are stayed in the transmission queues of the corresponding user in a first-in first-out priority. Subsequently, the PDUs are transmitted to the dedicated user according the adopted scheduling order.

The packet scheduler will work in every TTI. Each user regularly notice the Node B of its channel quality conditions by sending a report via channel quality indicator (CQI) in the uplink channel back the Node B. The CQI contains information about the current user channel conditions. This information includes transport block size, the number of simultaneous channel code, and the type of modulation and coding schemes that UE can support. After the Node B selects the appropriate UE according to scheduled order, it sends data to the scheduled user with the specified data rate. The UE is able to calculate its current channel conditions by measuring the received signal power from Node B and then using a set of models described in [3] to determine its current supportable data rate. Then users with good channel conditions will appreciate higher supportable transfer rates by using higher modulation and coding rates where users with bad channel conditions will experience lower data rates replace of adjusting their transmission power.



■ Fig 2. The HSDPA Packet Scheduler Model

2.3. Packet Scheduling Algorithm in HSDPA

The following introductions are some conventional scheduling algorithms: round robin (RR)[4], Maximum carrier to interference (MaxCIR)[5] and Proportional Fairness (PF)[6]

◆ Round Robin

It is the simplest scheduling algorithm which served in a cyclic orderly fashion. This method is the fairest in the sense that the average delay and throughput would be the same for all users. Starvation is not possible with a round robin scheduler. However, there are two drawbacks associated with round robin method. The first is that it neglects the conditions of the radio channel for each user. The second drawback is that there is no differentiation in the quality of services for different classes of users.

◆ Maximum Carrier-Interference Ratio (CIR)

This algorithm tends to maximize the system throughput by choosing the user who are with the best channel quality condition in every TTI. It can be seen that algorithm provides high system performance since only those with high current supportable data rates will get the service. The priority of user *i*, $P_i(t)$, is simply determined by following equation (1):

$$P_i(t) = S_i(t) \quad (1)$$

Where $S_i(t)$ is instantaneous CIR of user *i*. However, there is a problem that users with bad channel conditions cannot be served even cause starvation.

◆ Proportional Fairness (PF)

PF schedulers solve the starvation problem by fairness thinking. This method takes into account both the short-term variation of the radio channel conditions and the long-term throughput of each user. It tries to increase the degree of fairness among users by selecting those with the largest relative channel quality. PF scheduler will pick up the users with following equation (2):

$$P_i(t) = R_i(t) \Big/ \overline{R_i}(t) \quad (2)$$

Where $R_i(t)$ is current supportable data rate of user i at time t and $\overline{R_i}(t)$is average throughput of user i up to time t. During periods when a user is not scheduled, $\overline{R_i}(t)$ will decrease and a lower $\overline{R_i}(t)$ makes the user move likely to selected.

3. QoS Provision packet scheduling algorithm in HSDPA (QPPS)

The traditional scheduling mechanism will bring the situations such as: disregard the minimum QoS, occupy the channel or cause the starvation. As a result of the ability, negotiate between the user and the base station, of the high speed packet access system. The base station could get the corresponding parameters of the users. The proposed scheduling method will detect the communication types, measure the actual channel condition and consider the minimum threshold of the QoS to fit in with the tendency of the mobile network.

3.1. Scheduling architecture and relevant factors

There are three parameters will be concerned for the priority of the user:

- Traffic class definition
- Channel Quality Indicator (CQI) information
- Timer value

3.1.1. Traffic class definition

As above, the system should guarantee the minimal QoS of the different communication types. We will assign the corresponding QoS, the maximal tolerable delay time, for each service in order to maintain the guarantee of the minimal QoS. There are two main types of the communication service: real-time traffic (RT) and non real-time traffic (NRT). Among the communication, the RT traffic needs rapidly real-time response. It is the tightest bound of minimum delay time and stability of continuously support data rate. (i.e., video telephony and real-time online game). In opposition, NRT traffic can be minced to streaming application (i.e., video streaming and mobile TV streaming), others are generality multimedia applications (i.e., interactive program, web surfing and pushing mail). Table 1 show the mapping of QoS parameters [7]. In order to satisfy the QoS value, user data should be transmitted within its delay bound for each service.

▪ Table 1. Traffic class and delay bound

QoS parameter	Video Telephony	Video Streaming	Web Browsing
Delay bound	< 150 ms	< 1s	< 2s

3.1.2. CQI information

The channel characteristics change rapidly in fast fading environment. It implies that although a user was scheduled due to its high CQI value, the CQI value might change lower in the next transmission interval. CQI's definition will change according to the different channel model. Therefore, appropriate channel modeling is required for system architecture. The channel model consists of five major parts: path loss, shadowing, multi-path fading, intra-cell and inter-cell interference. Each part is considered to be independent and expressed in power dB. The path loss is calculated as follows:

$$L(d) = 137.4 + 10\beta \log_{10}(d) \quad (3)$$

Where d is the distance form the UE to Node B in Km, β is the path loss exponent and is equal to 3.8. The signal to noise ratio (SNR) is determined by following equation (4):

$$\begin{aligned} SNR &= P_{Tx} - L_{Total} - 10\log_{10}\left(10^{\frac{I_{Inter}-L_{Total}}{10}} + 10^{\frac{I_{Inter}}{10}}\right) \\ &= P_{Tx} - 10\log_{10}\left(10^{\frac{I_{Intra}}{10}} + 10^{\frac{I_{Inter}+I_{Total}}{10}}\right) \end{aligned} \quad (4)$$

Where P_{Tx} is the transmitted code power in dBm, L_{Total} is the sum of distance loss, shadowing and multi-path fading in dBm. I_{Inter} is the inter-cell interference I_{Intra} is the intra-cell interference in dBm. Then, SNR is mapped to the CQI table according to the following equation (5) [8]:

$$CQI = \begin{cases} 0 & SNR \le -16 \\ \left\lfloor \dfrac{SNR}{1.02} + 16.62 \right\rfloor & -16 < SNR < 14 \\ 30 & 14 \le SNR \end{cases} \quad (5)$$

Meanwhile, we will check the HS-PDSCH resource is available or not. There are two categories will be considered: normal condition and deficient condition.

- Normal condition:

The HS-PDSHC will be assigned by MaxCIR algorithm if the resource status is fine. The scheduler will check the CQI to decide the orders of the users.

- Deficient condition:

The scheduler checks the user's CQI in each TTI to decide whether the H-ARQ process will be suspended or not. The threshold could be determined by the following equations:

$$CQI_{RT\_\min}(User\_ID) = \min\{RT\_user(CQI)\} \quad (6)$$

$$CQI_{NRT\_\min}(User\_ID) = \min\{NRT\_user(CQI) - (SCH\_no - RT\_user) - 1\} \quad (7)$$

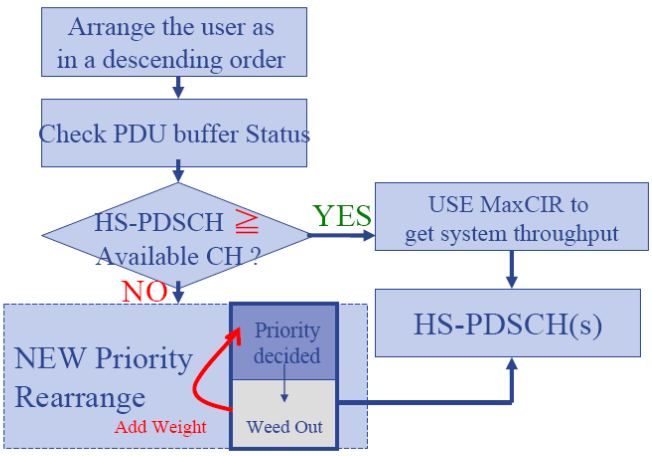
Where the $CQI_{RT\_min}(User\_ID)$ means the threshold of the real-time users, $CQI_{NRT\_min}(User\_ID)$ means threshold of the non real-time users, the *RT_user(CQI)* means the CQI values of the real-time users, the *NRT_user(CQI)* means the CQI values of the non real-time users, *SCH_no* means the amount of the all shared channels, and the *RT_user* means the amount of the all real-time users. We can see that the minimal threshold of the CQI is selected dynamically. And all of the suspended users are the non real-time services which are more tolerant of the delay.

3.1.3. Timer value

When the resource was deficient in the communication system, the users with worse CQI will be suspended to release the using resource. It may cause the starvation due to the suspended users exceed the QoS bound. Here, we will use the parameter, timer value, to guarantee the QoS requirement. When the users get into the H-ARQ status, we also start the timer to record the suspended time of the user.

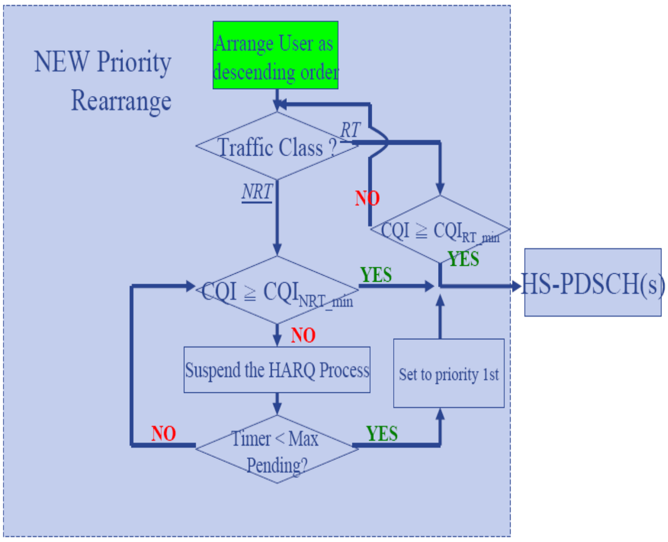
3.2. HS-PDSCH Assignment

In HSDPA, assume that the spreading factor is 16 in each TTI. The scheduler will check all users' buffer status whether the number of codes requested by UEs exceeds 15 or not. If the request of the HS-PDSCHs in a TTI is equal or small than 15, it will use MaxCIR algorithm as shown in figure 3. Otherwise, the new QoS Provision Algorithm will be carried out, as shown in figure 4.



■ Fig 3. Flow Char of normal condition scheduling

First, the scheduler will arrange the users in a descending order. After that, the scheduler checks the buffer of the users to determine that whether the available resource is less than the requested resource or not. If the available resource is enough, we will use the MaxCIR algorithm. If the resource is deficient, the new QoS Provision Algorithm will be carried out.



■ Fig 4. Flow Char of deficient condition scheduling

In the proposed algorithm, there are three steps to determine the scheduling orders.

1. The users will be categorized in two types which are real-time services and non real-time services. The real-time services have the higher priority than the non real-time services.
2. For the real-time services, the user with the worst CQI will be seen as the threshold. In order to serve the users which demand of the better channel condition as soon as possible, the users will be arranged in a descending order according to the CQI.
3. For the non real-time services, the equation 7 will be used to determine the threshold. If the CQI of the user is smaller than the threshold, the user will get into the HARQ process to suspend the communications. On the other hand, if the CQI is bigger than the threshold, the scheduler will assign the channel for transmitting. Here, the threshold of the non real-time services not only determines the orders of the communications but also determines whether the users get into the HARQ process and releases the resource to serve the other users or not.

Here is a example to describe the scheduling process. Let us assume that 4 users can share the HS-PDSCHs in a TTI among 6 users as shown in figure5. The user F is the only one real-time service, so it will be scheduled first. After that, the user B will be selected as the threshold of the non real-time services according to the equation 7 as shown in figure 5. Obviously, the user A and C will be suspended and the timer will record the suspended time. The scheduled result is shown as figure 6.

Priority	UE	Traffic class	CQI	HARQ	Timer	Weed out | Weight
6	F	Video phoning	22	Transmission	150ms	N
5	E	Interactive	21	Transmission	2s * 90%	N
4	D	Interactive	30	Transmission	2s * 90%	N
3	C	Interactive	10	Re-transmission	2s * 90%	Y
2	B	Streaming	18	Re-transmission	1s * 90%	N
1	A	Interactive	9	Re-transmission	2s*50%	Y

■ Fig 5. QoS provision algorithm / HS-PDSCHs assignment – initial state

Priority	UE	Traffic class	CQI	HARQ	Timer	Weed out | Weight
6	F	Video phoning	22	Transmission	150ms	N
5	E	Interactive	21	Transmission	2s * 90%	N
4	D	Interactive	30	Transmission	2s * 90%	N
3	C	Interactive	10	Re-transmission	2s * 90%	Y
2	B	Streaming	18	Re-transmission	1s * 90%	N
1	A	Interactive	9	Re-transmission	2s*50%	Y

■ Fig 6. QoS provision algorithm / HS-PDSCHs assignment –scheduling state

In fact, the scheduler will check the CQIs and update the scheduling order in each TTI. The threshold of the users is determined dynamically in this way. The scheduled result by the algorithm is shown in figure 7.

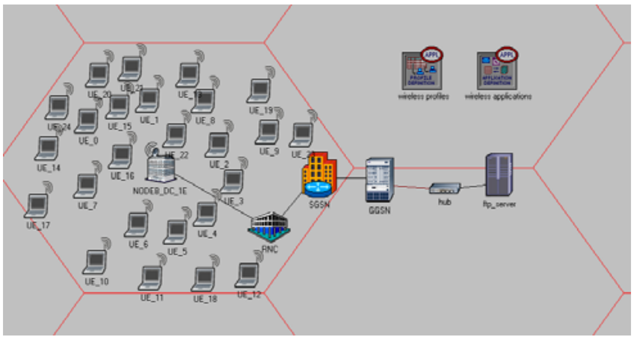
Priority	UE	Traffic class	CQI	HARQ	Timer	Weed out | Weight
6	C	Interactive	9	Re-transmission	2s * 50%	Y
5	A	Interactive	10	Re-transmission	2s * 90%	Y
4	B	Steaming	18	Re-transmission	1s * 90%	N
3	E	Interactive	21	Transmission	2s * 90%	N
2	D	Interactive	30	Transmission	2s * 90%	N
1	F	Video Phoning	22	Transmission	150ms	N

■ Fig 7. QoS provision algorithm / HS-PDSCHs assignment – result

4. Simulation

4.1. Simulation Environment

We use OPNET simulator to build the UMTS system as shown in figure 8. Node B is located in the central of a cell and equipped with an omni-directional antenna. There are two types of the communications which are the real-time services and the non-real-time services. We compare our approaches with other scheduling scheme, as seen in PF and MaxCIR. The parameters used in the simulation are shown in table 2.



■ Fig 8. Simulation environment

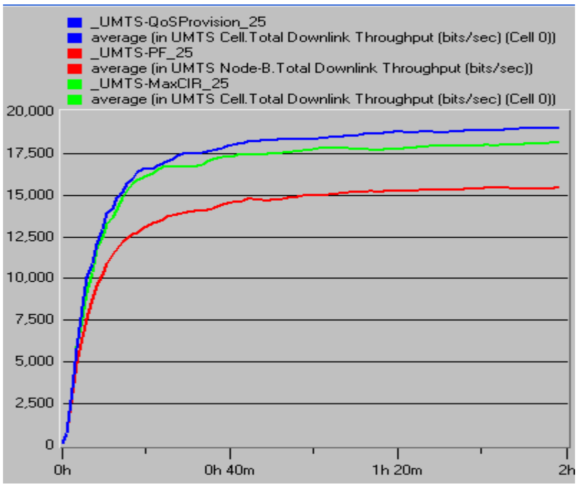
■ Table 2. Simulation parameters

Parameter	Value
Simulation time	100s
Frame period	2ms
Cell diameter	1 km
Power delay profile	Pedestrian A
Mobile Ped A speed	3 km/hr
Base Station Transmission power	38 dBm
Intra-cell interference	30 dBm
Inter-cell interference	-70 dBm
Standard deviation of shadowing (σ)	10 dB
Pass loss exponent (β)	3.8

4.2. Analysis

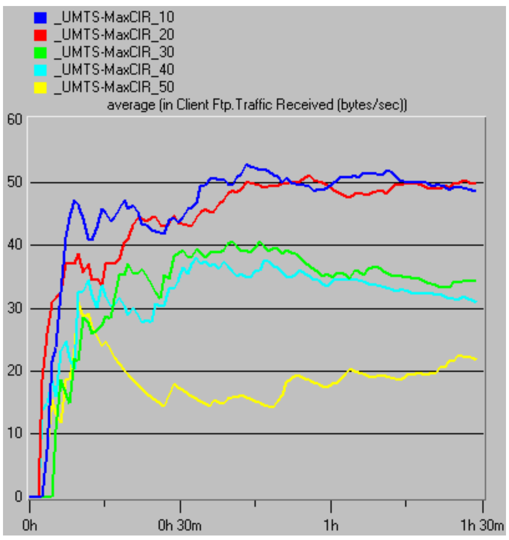
We will analyze the system performance and the extensibility of the approach with the other algorithms. Figure 9 shows the cell throughput performance with 25 users in one cell. The throughput is defined as equation 8.

$$Cell\_throughput = \frac{Successfully\_transmitted\_data}{Simulation\_time} \quad (8)$$

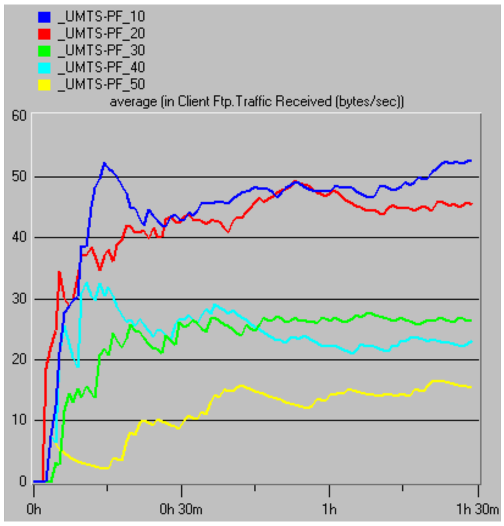


▪ Fig 9. system performance

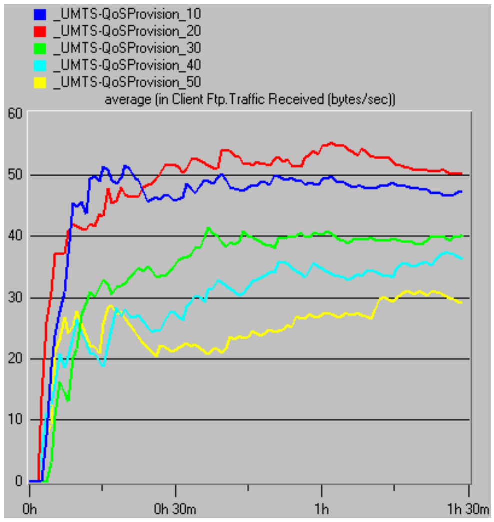
As shown in figure 9, we can see that PF will share the bandwidth between 25 users. The redundant bandwidth will be held as a result of fairness request of the PF. For this reason, the system performance will be restricted. On the other hand, the performance of the proposed QPPS will be better than the MaxCIR for the reason of the communication type provision. For the QPPS, we will serve the real-time users which usually request higher data transmitting rate. The redundant bandwidth in MaxCIR will be released by this way to improve the system performance.



▪ Fig 10. (a) MaxCIR algorithm



▪ Fig 10. (b) PF algorithm



▪ Fig 10. (c) QPPS algorithm

As shown in figure 10, the performance is almost the same when the amount of the users is between 10 to 20 users. When the amount of the users is arised, the performance of the PF algorithm will degrade the bandwidth. And it will uniformly share with the all users in fairness considering. When the amount of the users is between 30 to 50 users, the performance of the QPPS is better than the MaxCIR due to the QPPS will serve the real-time services firstly. We can find that the QPPS will not only provide the bandwidth for the users efficiently but also improve the system performance in deficient condition.

5. Conclusions

In this paper we proposed the QPPS, QoS provision packet scheduling algorithm, which will not only provide the bandwidth for the users efficiently but also improve the system performance in deficient condition. There are several advantage in this algorithm such as :

- Assign the scheduling order and improve system performance by the different type of communication in the deficient condition.
- Guarantee the QoS by avoiding the occupied resource by higher priority users and starvation of the lower priority users.
- Assign the resource according to the communication types of the users to maximize the throughput and satisfy the threshold of the QoS.

By the results of the simulations, we can find that the efficiency of the QPPS will more obvious when the resource is more deficient. In our future work, we will implement the scheduling scheme for the High Speed Uplink Packet Access (HSUPA) to construct the bi-directional high speed packet access system.

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