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Packet Scheduling Algorithm with QoS Provision in HSDPA

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Abstract

The 3rd Generation WCDMA standard has been enhanced to offer significantly increased performance for packet data. But coming application like multimedia on desiring data rates will spur the UMTS can support. To support for such high data rates, High Speed Downlink Access (HSDPA), labeled as a 3.5G wireless system , has been published in UMTS Release05. Under the HSDPA system, 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 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 (H-ARQ) scenario. In this paper, we propose the weight combination packet scheduling algorithm to target to enhance the system efficiency and balanced 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 effectively increase the cell throughput and meet user's satisfaction base on QoS requirements.

1. Introduction

The wireless technology began in the early 1980s with the first mobile phone introduction, until today has get in the 3rd generation. The began technology utilized analog interface and only supported voice capacities. This technology is still used in somewhere of the world. Continuously high demand of cell phone, and increased need for enhanced quality and more features desire, the 2nd generation (2G) was introduced. 2G is voice only at beginning, but it does provide higher bandwidth, better voice quality and limited data service which use packet data technology. Extension of the 2Gsystem is introduced in 2.5G system as General Packet Radio Service (GPRS). The major improvement of 2.5G system is significant the data packet service enhancement. Further, the continuous success of mobile communication systems push the need for better quality of service (QoS), more efficiency systems and more services have 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 of up to

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2Mb/s, which makes it possible to provide a wide range of multimedia services likes, 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, bas 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 is possible by time-sharing amount access users. It also relies on new technologies like adaptive modulation and coding, hybrid automatic repeat request, fast cell selection and fast packet scheduling. Among these new technologies, packet scheduler is major component to decide the system performance, can track the instantaneous users' channel conditions and select for transmission those who are experiencing good channel conditions in order to maximize the system throughput. However, in this concept raises the fairness issue, as those who are in bad channel conditions user may not get served then starvation.

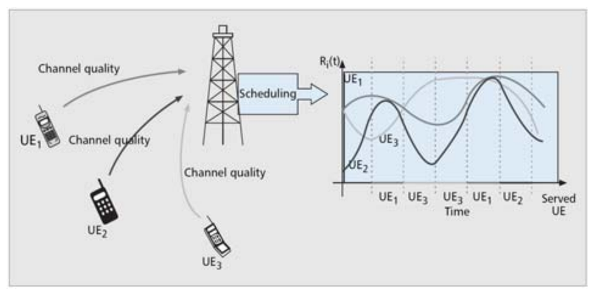
The paper consists of five sections. Section 2 explains packet scheduling in HSDPA and introduce some major scheduling method as MaxCIR and PF. Section 3 we propose Packet Scheduling Algorithm with QoS Provision in HSDPA. In section 4, we present thesimulation results. Finally section 5 is the conclusion and future work.

2. Related Works

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

2.1. Packet Scheduling

In HSDPA system, packet scheduler is one of central radio resource management (RRM) functions since it determine overall behavior and performance. 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 transmission 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 for higher modulation and coding to increase the system throughput.



■ Figure 1. Channel Quality Indicator monitor

In order to quickly get 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 reducedfrom 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 notice 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 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 discussion above, the HSDPA packet scheduler is implemented at the MAC-hs of Node B. Base station can serve N users in the same time, N≧1, and selects one transmission user in a slot of fixed time duration. Without loss in generality, it is assumed that each user has one connection request. Node B mains N queue buffer for matching N users, shown in Figure 2. Upon call arrival, the radio link controller (RLC) layer receives traffic in the from of high layer IP packet, which are divide 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 works every TTI, each user regularly notice the Node B of its channel quality conditions by sending a report via a channel quality indicator (CQI) in the uplink channel back the Node B. The CQI contains information about the moment 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 that Node B selects the appropriate UE according to adopted scheduling order and sends data to the scheduled user at 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 rates . Then users with good channel conditions will appreciate higher supportable transfer rates by using higher modulation and coding rates, where as users with band channel conditions will experience lower data rates replace of adjusting their transmission power.

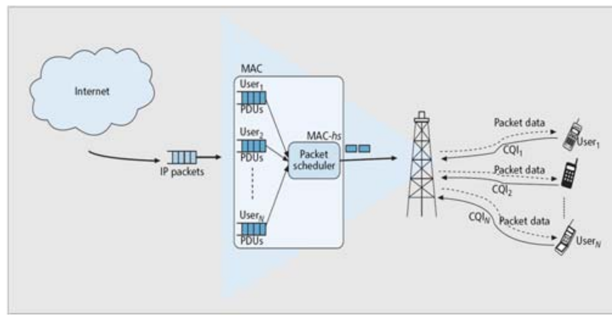


Figure 2. The HSDPA Packet Scheduler Model

2.3. Packet Scheduling Algorithm in HSDPA

The following introduction are 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. Starvation is not possible with an RR scheduler. This approach does not make use CQI information and therefore may offer lower system throughput than MaxCIR and PF.

- Maximum Carrier-Interference Ratio (CIR)

  This algorithm tends to maximize the system throughput by choosing the user who 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 get service. The priority of user i, $P_i(t)$, is simply determined by following equation:

$$P_i(t) = S_i(t) \tag{1}$$

Where $S_i(t)$ is instantaneous CIR of user i. However, there is problem that users with bad channel conditions cannot be scheduled ever than starvation

- Proportional Fairness (PF)

  PF schedulers solve the starvation problem by fairness thinking. 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:

$$P_i(t) = R_i(t) / \overline{R}_i(t) \tag{2}$$

  Where $R_i(t)$ is current supportable data rate of useri 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. Packet scheduling algorithm in QoS Provision in HSDPA

In this section, we proposed a method which considers satisfying both the QoS requirements and maximum the system throughput. We simply separate communication users to different traffic class and map to relevant QoS boundary. Meanwhile, the algorithm also check the CQI information to make sure the HS-PDSCH resource be assigned to appropriate users to improve the system throughput. When resource is limited by HS-PDSCH, the algorithm will suspend HQAR user operation according to the traffic classes and channel status without scarifying the QoS. With our new strategy, high priority is given prior to other processing users with bad channel status. In other words, transmission opportunities are give to UEs with high priority traffic and good channel conditions rather than bad channel condition users.

3.1. Scheduling architecture and relevant factors

Under HSDPA, we consider these factors to make adjudgement the resource assignment process, following input parameters are decide the user's priority:

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

3.1.1. Traffic class definition

HSDP is designed to support both non-real-time (NRT) and some extent real-time (RT) applications. The multimedia mobile communication process, system will base on the traffic type difference to assign the different QoS, the design for RT application should be different from that for NRT applications. 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). The 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 suer 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 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:

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

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:

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

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 [8]:

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

Meanwhile, we will check the HS-PDSCH resource is available or not. When resource status is OK, the HS-PDSHC are assigned by the MaxCIR algorithm. If channel condition become worse during short interval, retransmission of the packet may also result in an error. Therefore, in each TTI the scheduler checks user's CQI information and decides whether the HARQ process will be suspended or not. The threshold can be set by following equation:

$$CQI_{RT\_min}(User\_ID)= \min\{RT\_user(CQI)\} \tag{6}$$

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

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:

3.1.3. Timer value

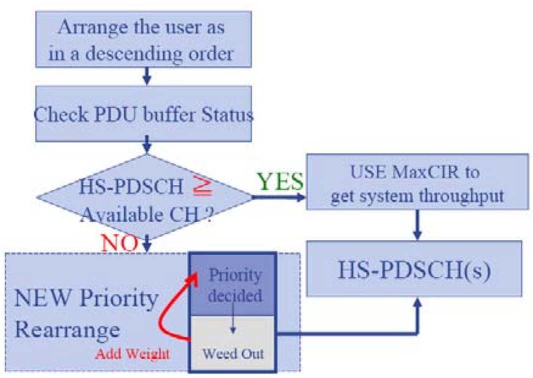
For suspending user in HARQ to release resource to extend the system throughput is part of algorithm purpose. But mainly idea should also guarantee the QoS requirement. When the chosen user get in the HARQ status, we also start the timer to recode the suspended time of user to prevent the user out of the QoS delay bound to starvation. We directly against two different NRT traffic maximum suspend time to define as:

- Streaming service: QoS bound*(1-85%)

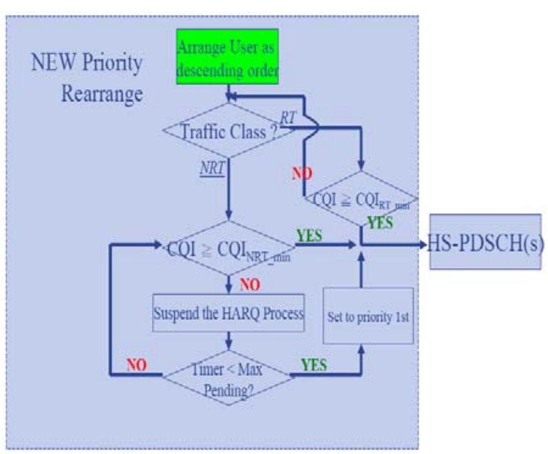
◆ Web browser service: QoS bound*(1-90%)

3.2. HSPDSCH Assignment

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



■ Figure 3. Flow Chart of normal condition scheduling



■ Figure 4. Flow Chart of normal condition scheduling

Let us assume that 4 user can share the HS-PDSCHs in at TTI among 6 user as shown in Figure5. With MaxCIR algorithm only can seen the scheduling windows will be available 4 and new scheduling algorithm can check user who is in the TTI windows and process algorithm, shown in figure6.

4. Simulation

4.1. Simulation Environment

In our analysis, we use OPNET simulator to build the UMTS system. In network environment, components include UE, Node B, RNC, SGSN, GGSN and FTP server.

MaxCIR Algorithm / HS-PDSCHs Assignment

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

■ Figure 5. MaxCIR Scheduling result

QoS provision Algorithm / HS-PDSCHs Assignment

Priority	UE	Traffic class	CQI	HARQ	Timer	Weed out | Weight
6	[illegible]	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	[illegible]	Video Phoning	22	Transmission	150ms	N

■ Figure 6. QoS provision scheduling result

Node B is located in the center of a cell and serves N users. It has omin-directional antenna. We consider two traffic classes, RT and NRT. Assumed the uplink channel for CQI report is error free. The traffic models [7]: Near Real Time Video Model for RT traffic and Modified Gaming Model for NRT traffic. The overall system parameters are shown in Table 2.

4.2. Simulation Result

There are two scenarios in our simulation, one is test algorithm efficiency, the other is testing the user's satisfaction. We compare the performance of our algorithm with the MaxCIR and PF algorithm on cell throughput performance. The definition is as follows (8).

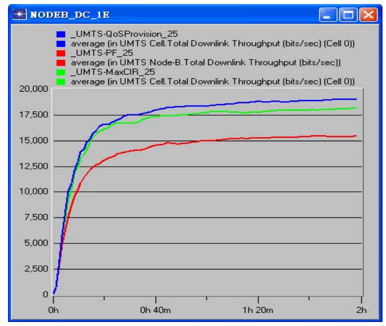
Figure 7 shows the cell throughput with 25users in one cell system. From the comparison result for long term scheduling, QoS provision effetely management the resource both good channel condition user and minor channel condition user to increase the throughput. From the comparison in figure 8 it can be seen that the method we proposed has the better performance on data stability to provide the UE to match 128 byte/s data requirement. According the user increase from 10 to 50, the MaxCIR and PF is hardly to handle the cell heave loading condition. The QoS provision is efficiency to manger the resource to achieve outstanding average performance.

▪ Table 2. Simulation parameters

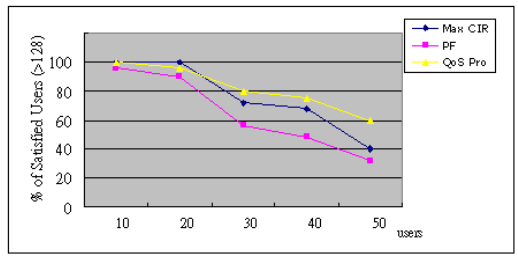
Parameter	Value
Simulation time	100s
Frame period	2ms
Cell diameter	1 km
Power delay profile	Pedestrian A
Mobile Ped A speed	3 km/hr
Base Station Transmission power	38 dBm
Intra-cell interference	30 dBm
Inter-cell interference	-70 dBm
Standard deviation of shadowing (σ)	10 dB
Pass loss exponent (β)	3.8

$$Cell\_throughput = \frac{Successfully\_transmitted\_data}{Simulation\_time}$$

(8)



▪ Figure 7. Cell throughput comparison



▪ Figure 8. UE be service matching result

5. Conclusions and Future Works

In this paper we propose the QoS provision scheduling algorithm is effectively when HSDPA resource limited. Meanwhile, the new method not only guarantee the QoS requirements but also maximum the system throughput performance with stable and efficiency.

In early future, HSUPA will be structured, it more complete the UMTS as HSxPA, achieve the bi-direction wireless communication and support the multimedia application. Under the high speed process requirement, the resource arrangement and QoS guarantee will be obviously important

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