

Service Class-Aided Scheduling for LTE

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Abstract— LTE (Long Term Evolution) supports QoS (Quality of Service) with several service classes. For each class of traffic, a big difference exists on BER (Bit Error Rate) requirement. This leads to a considerable difference in transmission power for various classes of traffic. In this paper, a novel scheduler is designed and proposed for LTE which supports CoS (Class of Service) with the consideration of priority as well as target BER. By the CQI (Channel Quality Indicator) and QCI (QoS Class Identifier), a minimum transmission power is assigned from the target BER for each class of traffic per each user. Hence, with the other information such as user's used rate in the past and the priority of traffic, the probability of occupying channels is determined. The simulation results of Service Class scheduling are compared with that of Maximum Rate and Proportional Fair. The results show that the service class-aided scheduling can improve the throughput of whole system significantly.

Keywords— Class of Service, Power Control, Scheduling, QoS, LTE, OFDM

I. INTRODUCTION

The success of the Internet in the late of the previous century had a profound impact on the development of wireless network. From the demand of customers and the development of wireless technology that provides a very high bandwidth for wireless such as LTE. The IP-based services are more and more going wireless. In other words, the IP traffic will transmit over wireless transmission. It leads to wireless network must support almost the characteristics of this traffic.

The IP based network uses packet as a key element of all type of traffic. Because volume of Internet traffic is always huge, it is very likely congestion in network. Consequently, there is a high probability of drop for any packet. Furthermore, in packet network for the same connection the traffic can transmit via multi-paths or different conditions that have different delay parameter, resulting in a fluctuation in time of transmission (jitter). To overcome these problems, the service class is used to guarantee the quality of each type of service in packet networks. There are two standards of class of service: Type of service (ToS) and Differentiated Service that use n bits of packet header to support 2^n classes. Class of service determines the priority, the delay, and the probability of drop for packet. Nowadays, class of service is "mandatory" for employing IP based service, and becomes an important characteristic in packet network. Therefore, wireless network also should support class of service to guarantee QoS.

Although LTE has been designed as a completely packet-oriented multi-service system without the reliance on circuit-

switched connection-oriented protocols prevalent in its predecessors [5], it is complicated to deploy class of service due to the channel variation over time, frequency and space. A feasible method is using scheduling in wireless network as a cross layer that adapts both the channel variation in wireless network and class of service in packet network.

To the best of our knowledge, in published literatures on service class scheduling, the authors mainly focused on delay to meet the requirement of some applications that demand tightly on latency. However, different classes of traffic will require different BER and it leads to difference in Signal to Noise Ratio (SNR) at the receiver or transmission power at the transmitter. Also note that each class has different priority. Therefore, in this paper a novel service class-aided scheduling in combination with consideration of priority as well as BER is proposed and its performance is investigated in terms of throughput performances.

II. CURRENT SCHEDULING

A fundamental difficulty in wireless network is allocating scarce resources among different users while there is a constraint in total power. There are three main methods of scheduling proposed for LTE: maximum rate, proportional fair and delay-limited capacity [5]. The first concentrates on getting the maximum throughput for whole users, while the second tries to get the same rate for every user and the last concentrates on delay rather than throughput of system.

A. Maximum Rate [1]

The maximum rate is achieved when the power allocated for each resource is the smallest. It means only the user with the best channel gain is scheduled. The maximum total rate $\sum_{n=1}^N R_n$, where R_n is the total rate allocated to user n . The probability of user n to occupy the channel k is given by

$$P(n,k) = f(r_n * h_k(n,f)/p_{n,k})$$

Where r_n is the requirement rate of user n , $h_k(n,f)$ is the channel gain of user n in resource k of sub frame f , $p_{n,k}$ is the power to allocate user n on the resource k . This equation is water-filling formula; the user n is selected when the channel gain is high while the power is low. The decision to decide which user will occupy the channel k is based on the user that has $\max_{n=1,2,\dots,N} P(n,k)$. The total power for all users is limited by

$\sum_{n=1}^N P_n < P$. The advantage of this method is that the throughput is the highest; however there is unfairness among users

because only the users with best channel gain are scheduled. Therefore, it is unused in reality.

B. Proportional Fair [5], [1]

For the customer, the maximum rate is unacceptable because there are some users never receive any traffic. On other hand, proportional fair provides the same rate for every user. The probability of user n to occupy the channel k is given by

$$P(n,k)=f(h_k(n,f)/(r_n * p_{n,k}));$$

Where r_n is the used rate of user n , $h_k(n,f)$ is the channel gain of user n in resource k of sub frame f , $p_{n,k}$ is the power to allocate user n on the resource k . When the user already transmits a high traffic r_n , the probability to occupy the channel decreases. The decision to decide which user will occupy the channel k is based on the user that has $\max_{n=1,2,\dots,N} P(n,k)$.

The total power for all users is limited by $\sum_{n=1}^N P_n < P$. The

advantage of this method is that every user has the same rate and it is used in real systems such as HSDPA and EVDO [9], but the throughput is smaller than the maximum rate.

C. Delay-limited Capacity [7], [5], [2]

Although proportional fair introduces some fairness to the systems, this form of fairness may not guarantee the delay for applications that have a very tight latency constraint [5]. Therefore, another metric is needed, and one such example is "delay-limited capacity" that tries to control the delay time for traffic. This is done by applying service class scheduling [2]. 3GPP/3GPP2 has defined nine traffic classes mainly according to their resource type, priority, delay, and packet error loss rate [5]. The Table 1 shows the main QoS requirements and example services. Obviously, service class scheduling made a considerable improvement in terms of delay-control for traffic. However, there are still many advantages if a service class scheduling is applied more efficiently. The aspect of packet error rate control will be considered in the next section in this paper to improve the throughput of system.

TABLE 1. STANDARDIZED QoS CLASS IDENTIFIERS (QCIs) FOR LTE

QCI	Resource Type	Priority	Delay Budget (ms)	Packet Error Rate	Example Services
1	GBR	2	100	10^{-2}	Conversational voice
2	GBR	4	150	10^{-3}	Conversational video
3	GBR	5	300	10^{-6}	Non-conversational video
4	GBR	3	50	10^{-3}	Real-time gaming
5	Non-GBR	1	100	10^{-6}	IMS signaling
6	Non-GBR	7	100	10^{-3}	Voice, video (live streaming), Interactive

					gaming
7	Non-GBR	6	300	10^{-6}	Video (buffered streaming)
8	Non-GBR	8	300	10^{-6}	TCP-based (e.g. WWW, e-mail) chat, FTP, p2p file sharing, progressive video, etc.
9	Non-GBR	9	300	10^{-6}	

III. PROPOSED SERVICE CLASS-AIDED SCHEDULING

We propose a service class scheduling that concerns both BER parameter and priority of data in combination with power control. The Figure 1 shows the flow chart of scheduling scheme.

From QoS Class Identifiers (QCI) and Channel Quality Indicators (CQI), the BER target of each class to guarantee the packet error rate can be defined by a vendor or a service provider. In theory, for example with BPSK modulation and under Rayleigh fading channel, the error probability with high SNR [10]:

$$Ber = \frac{1}{2} (1 - \sqrt{\frac{SNR}{1 + SNR}})$$

With the Taylor expansion for $x = \frac{1}{SNR}$, $x_0 = 0$:

$$\begin{aligned} f(x) &= \sqrt{\frac{SNR}{1 + SNR}} = (1 + x)^{-1/2} \\ &= f(x_0) + f'(x_0)(x - x_0) + f''(x_0) \frac{(x - x_0)^2}{2} + \dots \\ &= 1 - \frac{x}{2} + g(x^2) \approx 1 - \frac{x}{2}. \end{aligned}$$

When SNR is high, we have: $g(x^2) \approx 0$

$$So, Ber \approx \frac{x}{4} = \frac{1}{4SNR}$$

So, the minimum SNR(n,k,c) of user n with class c on channel k at the receiver that is depending on BER target is also determined. Because the path loss is frequency and distance dependent, so these factors are almost constant for each user. Moreover, the noise power is also assumed to be constant. Therefore, with the minimum SNR at the receiver, the minimum transmission power $pt(n,k,c)$ is also determined.

The logical channels from 1 to No.Channel are sorted in the decrease of quality. The purpose of scheduling is to build up a matrix Allocation(n,k,c) in which if allocation(n,k,c) equals one it means the class c of user n will occupy the channel k and otherwise allocation(n,k,c) will be zero. In order to decide the matrix allocation(n,k,c), the probability $p(n,k,c)$ for the class c of user n to occupy the channel k is needed to be calculate. From the priority parameter of QCI, the priority of class c

is expressed in the formula $priority(c)=10^{No.Class-c}$. This formula is used to make the decision impact of priority on the probability $p(n,k,c)$ comparing with other factors. In other words, it will guarantee that the higher priority traffics always be transmitted before the lower priority ones. The probability $p(n,k,c)$ will be calculated from the best quality channel to the worst quality one. For each channel k , all the unallocated class of users are considered providing that the total remain power $P1$ is enough for the required transmission power $pt(n,k,c)$ and the used rate of the user is smaller than the required rate $r1(n,k,t)$.

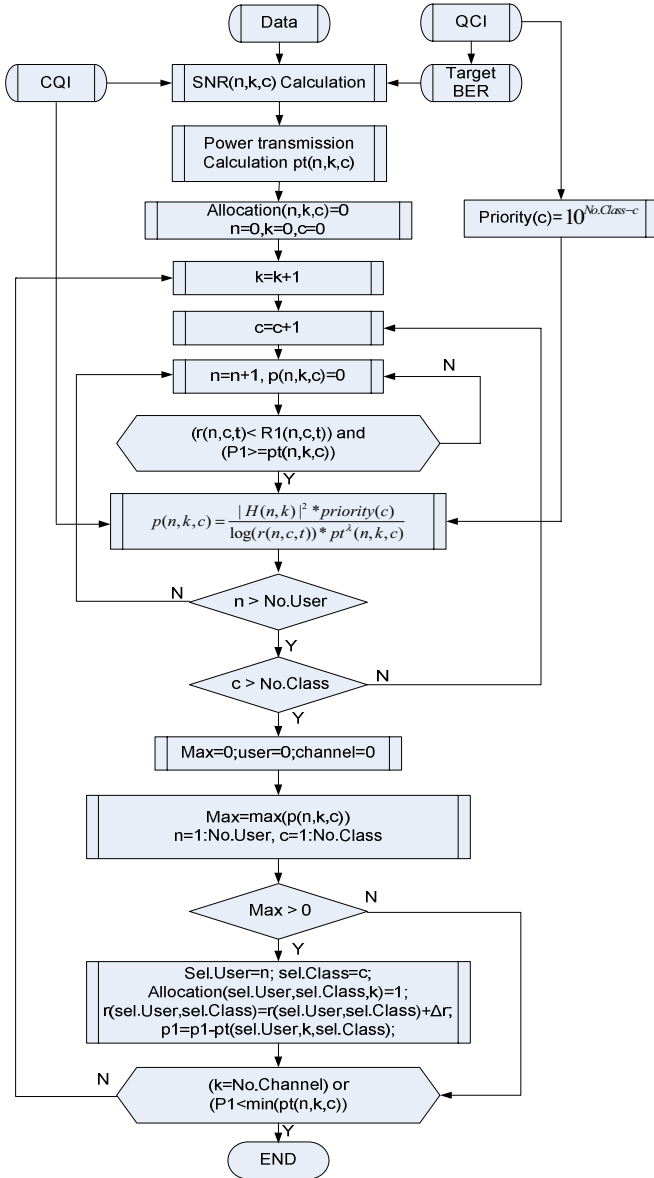


Figure 1. Flow chart for service class scheduling

Now the probability of each user to occupy each channel $p(n,k,c)$ can be calculated. Because the factors calculating the metric are measured in different units such as decibels for power, bit per second for data rate and the channel gain. They

are normalized and modified to indicate the impact on the metric and the correlation on each other:

$$P(n,k,c) = \frac{|H(n,k)|^2 * priority(c)}{\log(r(n,c,t)) * pt^\lambda(n,k,c)} \text{ and the power constraint}$$

$$\sum_{n=1}^N P_n < P.$$

Where $P(n,k,c)$ is the probability of class c of user n to occupy channel k . And λ is a constant which can be adjusted to express the importance of power constraint. For example, the issue of power constraint for uplink is more important than for downlink. Selecting the highest probabilities of all classes of all users for each channel $\max = \max(p(n,k,c))$ is the way to decide the class $sel.Class$ of user $sel.User$ will be mapped on each channel k : $Allocation(n,k,c)=1$. After this decision, the user's used rate $r(sel.User,k,sel.class)$ has increased Δr and the total power $p1$ is reduced by $pt(sel.User,k,sel.class)$. These procedure will be looped until the remain total power is smaller than the minimum of $pt(n,k,c)$ or the all the channels are occupied. Since the minimum power transmission is utilized for each class of traffic, there will be a considerably saving power. This saving power is used to transmit more data comparing to the case of scheduling without power control in combination with class of service. In other word, the throughput of the whole system will increase.

IV. SIMULATION RESULTS

To measure the effect of proposal scheduling, two case studies have been done based on OFDM wireless system to compare following scheduling policies:

- Maximum rate scheduler
- Proportional Fair scheduler
- Service class scheduler

The main simulation parameters are listed on the following Table 2.

TABLE 2. SIMULATION PARAMETERS

No. of Users	5
No. of class	$2^n, n = 1 \rightarrow 3$
Bandwidth	20 MHz
No. of sub-channels	80
No. of sub-carriers per sub-channels	12
Sub-frame duration	1ms
Channel model	4 path fading
Path loss model	$L=128.1+37.6\log_{10}R$
Total BTS transmission power	43 dBm
Modulation	QPSK
Coding rate	1/2 Convolution coding
Channel Estimation	Perfect
Interference between neighbor cells	Avoidance

To compare the effect of schedulers, all users will be requested to receive the same data rate. It is assumed that all users are located at the order of distance from the base station. User 1 is 600m away from BTS, and the distance between two neighbor users is 100m. The interference between neighbor

cells is avoided by frequency planning. The number of class of service increases from 1, 2, 4 and to 8.

In the case study one of four classes, the class 1 with target BER=0.00001, class 2 with target BER=0.0001, class 3 with target BER=0.002, and class 4 with target BER=0.02. In Figure 2, for every user the important class (class 1) has the higher data rate. Therefore, we can confirm that the scheduler prefers traffic with higher priority. In Figure 3, the lowest BER is always the most important class (class 1) and vice versa. That is, the important classes will have better quality of transmission. Comparing the throughput for each user among three method schedulers, it is can be seen that service class got the “fairness” better than maximum rate and got “high rate” better than proportional fair method in Figure 4. The target BER=0.0001 is used for maximum rate and proportional fair schedulers. The user 5 throughput is improved significantly with service class scheduler. Thus we can say that the fairness among users and the fairness among different services improve. Figure 5 shows that the total throughput of the system for service class scheduler is higher than both maximum rate and proportional fair.

In the case study two, the number of classes increases from 1, 2, 4 and to 8, it can be seen that the fairness and throughput of system also increase. Figure 6 shows that the throughput of system increases when the number of class increases. In Figure 7, when the number of class increases, the fairness of sharing channel also increases among users. It means the user 1 and user 2 have to reduce the number of good quality channel for the rest of users 3, 4 and 5. So the probably of error for user 1 and user 2 increases while the one for other users decreases. Therefore, the throughput of user 1 and user2 increases slowly or even decreases whereas the throughput of user 3, 4 and 5 increases. So the fairness of throughput between users increases when the number of classes increases. The throughput for some users can decrease slightly but the total throughput of all users increases when the number of class increases.

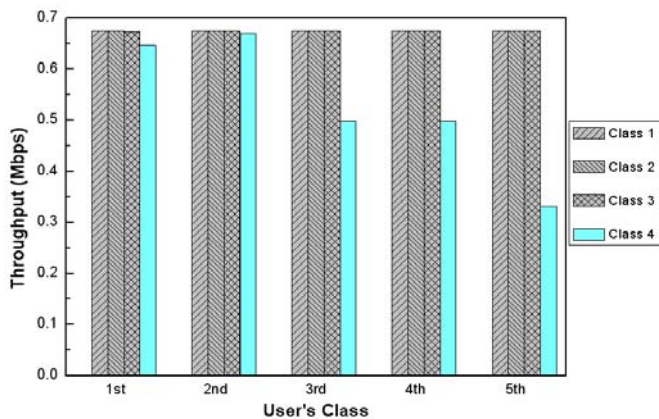


Figure 2. Throughput for each class (Mbps)

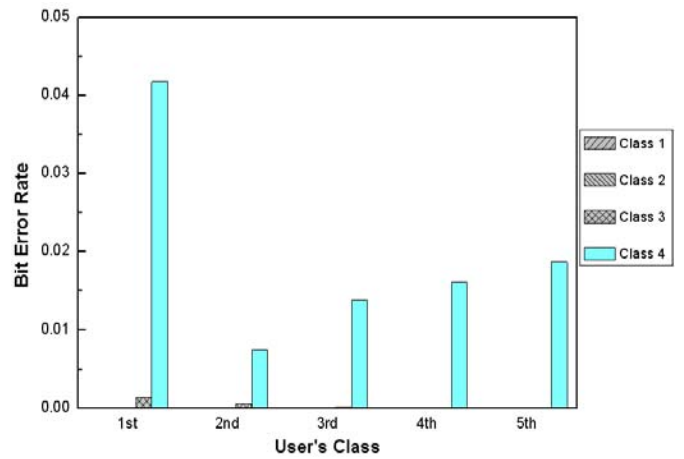


Figure 3. Bit error rate for each class

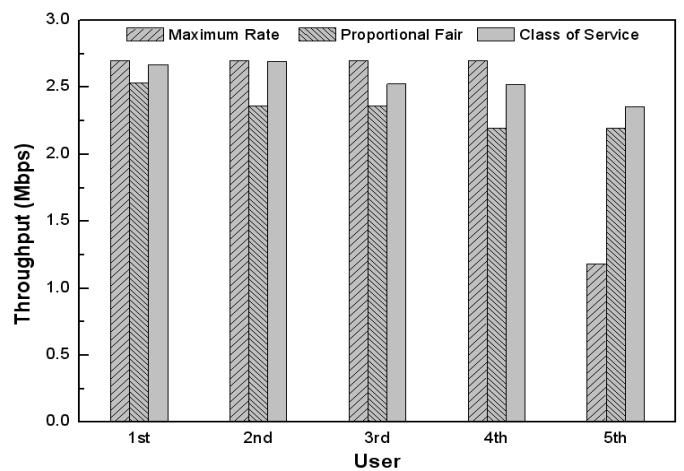


Figure 4. Throughput for each user (Mbps)

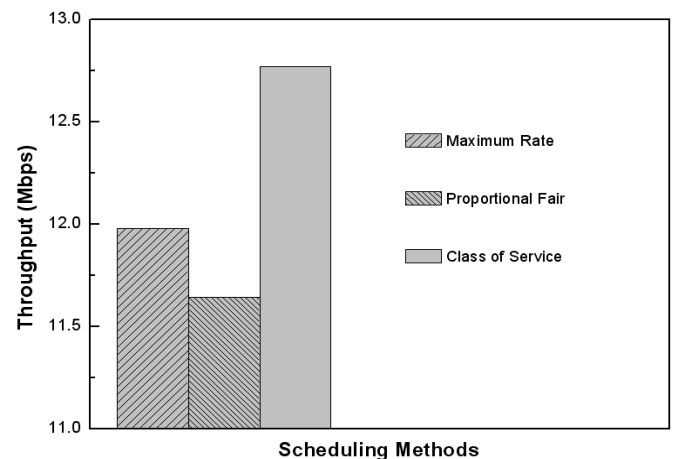


Figure 5. Throughput of the whole system (Mbps)

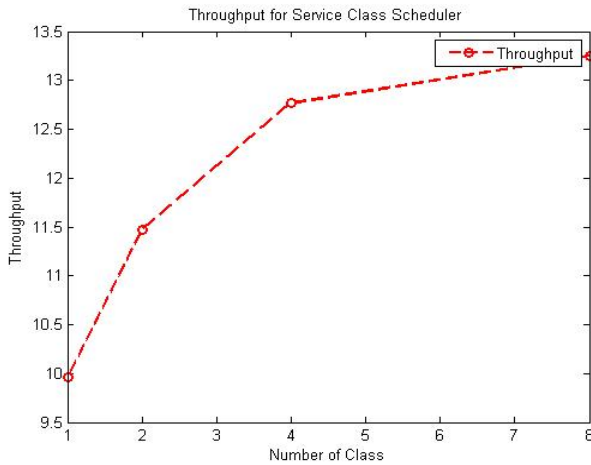


Figure 6. Throughput of system when increasing the number of classes

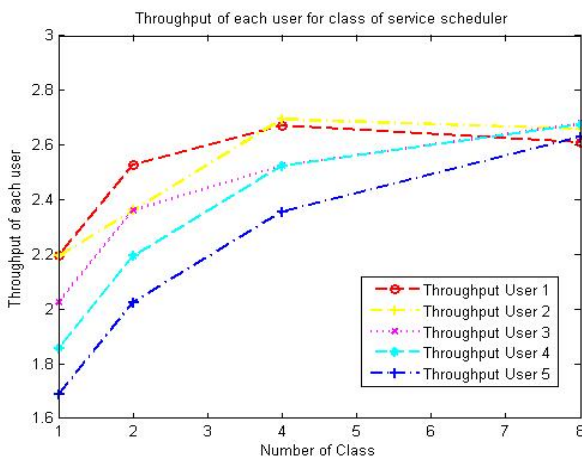


Figure 7. Throughput of users when increasing the number of classes

V. CONCLUSIONS

Proposed service class-aided scheduler guarantees Quality of service (QoS) and also improves the fairness among users and the throughput of the system. It is really promising to deploy multi-media services efficiently on 4G wireless network.

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