User Location Recommendation Combined with MLWDF Packet Scheduling in LTE Downlink Communication

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Abstract—**In wireless networks with multiple users, packet scheduling is widely used to provide Quality of Services (QoS) for real-time services. However, if radio resources are limited due to poor channel qualities, it is difficult to improve QoS by applying packet scheduling mechanisms solely. In this paper, we propose a user location recommendation scheme combined with the Modified Largest Weighted Delay First (MLWDF) packet scheduling scheme in the Long Term Evolution (LTE) downlink communication. We conduct simulation scenarios using *LTE-Sim* [9] which has been conceived as a comprehensive system-level simulator for fully implementing the protocol layers of LTE and providing a complete performance verification. The simulation results illustrate that, in comparison with other existing packet scheduling approaches, the proposed scheme effectively improves QoS including throughput, packet delay, and packet loss rate for video streaming services in LTE downlink communications.**

***Keywords-** Long Term Evolution (LTE); Location Recommendation; Packet Scheduling; QoS (Quality of Service)*

I. Introduction

As the demands of mobile applications such as social network services, real-time gaming, video streaming services and web TV grow, Long Term Evolution (LTE) access technologies [1] [2] [3] become a promising Broadband Wireless Access (BWA) solution. It is important to provide sufficient Quality of Service (QoS) for real-time multimedia applications in LTE wireless networks. Packet scheduling is a widely used mechanism to provide QoS for users and improve throughput of system in wireless networks with multiple users [4] [5] [6] [7]. There have been some recent works on packet scheduling in wireless networks. Proportional Fairness (PF) is a well-known algorithm that takes into account the current channel condition and average data rates in past time to improve both the system throughput and fairness among users. Modified Largest Weighted Delay First (MLWDF) supports different QoS requirements for real-time services. In addition to the current channel condition and average data rates in past time, it further considers different priorities and head-of-line packet delays of real-time traffic to provide QoS. In general, PF is suitable for non-real-time applications whereas MLWDF is suitable for real-time services. Exponential/Proportional Fair (EXP/PF) has been designed to deal with both the non-real-time and real-time services. It increases the priority of real-time flows with respect to non-real-time ones, where their head-of-line packet delay is very close to the predefined threshold [8].

However, if radio resources are limited due to poor channel qualities, it is difficult to improve QoS by applying packet scheduling mechanisms solely. Therefore, in this paper, we propose a novel approach from a different perspective, namely user location recommendation, which provides a certainly good channel quality for satisfying the QoS requirements in wireless networks. The proposed location recommendation algorithm is further combined with the MLWDF packet scheduling scheme to ensure QoS for real-time services. We conduct simulation scenarios using *LTE-Sim* [9] which has been conceived as a comprehensive system-level simulator for fully implementing the protocol layers of LTE and providing a complete performance verification. The simulation results illustrate that, in comparison with other existing packet scheduling approaches, the proposed scheme effectively improves QoS including throughput, packet delay, and packet loss rate for video streaming services in LTE downlink communications.

The rest of this paper is organized as follows. Section II illustrates the existing packet scheduling mechanisms. The problem description and proposed location recommendation scheme are presented in Section III. Section IV illustrates the simulation setup and results. Finally, the conclusion and future work are given in Section V.

II. Packet Scheduling Mechanisms

In this section, we briefly introduce several packet scheduling methods which will be compared with our approach.

1) Proportional Fairness (PF): it mainly takes into account the current channel condition and average data rates in past time to improve both the system throughput and fairness among users. For this scheduler, the weight of packet scheduling for flow i can be described as:

$$w_i^{PF} = \frac{R_i}{\overline{R_i}}, \tag{1}$$

where R_i is the data rate associated with the current channel conditions of flow i; $\overline{R_i}$ is the estimated average data rate of flow i.

2) Modified Largest Weighted Delay First (MLWDF): it supports different QoS requirements for real-time services. In addition to the current channel condition and average data rates in past time, it further considers different delay bounds and head-of-line packet delays of real-time traffic to provide QoS. For this scheduler, the weight of packet scheduling for flow i can be described as:

$$w_i^{MLWDF} = a_i \cdot D_{HOL,i} \cdot \frac{R_i}{\overline{R_i}}, \tag{2}$$

where $D_{HOL,i}$ is the delay of the head-of-line packet of flow i; a_i is given by

$$a_i = -\frac{p_i}{Th_i}, \tag{3}$$

where Th_i is the predefined packet delay threshold of flow i; p_i is the maximum probability that $D_{HOL,i}$ exceeds the delay threshold Th_i.

Table 1. The proposed user location recommendation algorithm

***Algorithm*：** User Location Recommendation

Offline stage：

1. Construct and initialize the geographical QoS map $\{(l_1,\varphi_1),(l_2,\varphi_2),...,(l_m,\varphi_m)\}$;

Online stage：

2. User j, UE_j informs the serving BS of (l_j,δ_j,φ_j)

// l_j : Current location of UE_j

// δ_j : Desired QoS for application service

// φ_j : QoS level of UE_j at current location

3. ***If*** $\varphi_j < \delta_j$

4. ***For*** k = 1 to m

5. Export (l_k,φ_k)

6. Set Λ as the set of $\{(l_k^*,\varphi_k^*)\}$ in which $\varphi_k^* \geq \delta_j$

// φ_k^* is adequate to the desired QoS of application

7. ***If*** $\Lambda \neq \varnothing$

8. Calculate the moving distance from the current location l_j to each location l_k^* in Λ

9. Feedback the location $\hat{l}$ with the minimum moving distance

10. Return $\hat{l}$

// Go to the new location $\hat{l}$

11. ***End if***

12. ***End for***

13. ***End if***

3) Exponential/Proportional Fair (EXP/PF): it has been designed to deal with both the non-real-time and real-time services. It increases the priority of real-time flows with respect to non-real-time ones, where their head-of-line packet delay is very close to the predefined threshold [8]. For real-time flow i, the weight of packet scheduling is derived as:

$$w_i^{EXP/PF} = \exp\left[\frac{a_i \cdot D_{HOL,i} - \mathrm{H}}{1+\sqrt{\mathrm{H}}}\right] \cdot \frac{R_i}{\overline{R_i}}, \tag{4}$$

where

$$\mathrm{H} = \frac{1}{N_{\text{real\_time}}} \sum_{i=1}^{N_{\text{real\_time}}} a_i \cdot D_{HOL,i}, \tag{5}$$

and $N_{\text{real\_time}}$ is the number of active downlink real-time flows.

III. Proposed Location Recommendation Scheme

In order to provide adequate service qualities for users, the user location possibly could be adjusted according to the channel condition and QoS demand. In this paper, we propose a user location recommendation scheme which provides a certainly good channel quality for satisfying the QoS requirement in wireless networks. The proposed location recommendation algorithm will be further combined with the MLWDF packet scheduling mechanism to ensure QoS for real-time services.

A. Problem Description

The fundamental objective in a location recommendation system is to output the suggested user location and moving path from the correlation between QoS and geographical map. This problem is formulated as

$$\hat{l} = LR(l,\ \delta,\ \varphi), \tag{6}$$

where $\hat{l}$ is the suggested new location by the proposed location recommendation mechanism, l is the current user location, δ indicates the service QoS requirement of users, and φ represents a geographical QoS map.

B. Proposed Location Recommendation Scheme

To solve the problem of user location recommendation, the proposed method can thus be divided into two phases: *offline* and *online*. In the offline phase, a geographical QoS map φ will be established. Consider a space which is divided into m locations. The QoS map of the m locations is defined as $\{(l_1,\varphi_1),(l_2,\varphi_2),...,(l_m,\varphi_m)\}$. Essentially, the QoS map can be constructed empirically by experiments. We can set up an experimental test-bed to measure QoS φ_i in a given location l_i point by point to construct the total QoS map.

When the QoS map $\{(l_1,\varphi_1),(l_2,\varphi_2),...,(l_m,\varphi_m)\}$ is built in the offline phase, the proposed location recommendation system can suggest users, in the online phase, the nearest optimal location based on their service requirements. Any user may periodically

Table 2. Simulation parameters

Parameters	Values
Simulation duration	120s
Minimum number of user	1
Maximum number of users	25
Speed	3 km / hr
Frame structure	FDD
Number of Resource Blocks	100 RBs
Cell radius	1 km
Transmission power of BS	46 dBm
Path loss model	$L = 128.1 + 37.6 \log_{10}R$
Bandwidth	20MHz

inform the Base Station (BS) of δ_i which refers to its QoS requirement. The BS can derive the user current location l_i by employing the positioning techniques [10]. When the estimated QoS level of the current location φ_i is smaller than the desired QoS requirement δ_i, the BS suggests a new suitable location index by $\hat{l}$ to the user by checking the geographical QoS map. In summary, the pseudo code of proposed location recommendation algorithm is shown in Table 1. Finally, the proposed location recommendation algorithm will be further combined with MLWDF packet scheduling method to improve QoS for real-time services.

IV. Performance Evaluation and Discussion

In this section, we conduct simulation scenarios of LTE downlink communications to demonstrate the effectiveness of the proposed location recommendation scheme combined with the MLWDF packet scheduling mechanism. The simulation is programmed using *LTE-Sim* [9], which has been conceived as a comprehensive system-level simulator for fully implementing the protocol layers of LTE and providing a complete performance verification. The simulation setup considers a single BS with transmission power of 46 dBm and cell radius of 1 km. The wireless channel of simulations is based on the path loss model without fading described as $L = 128.1 + 37.6 \log_{10}R$ [11], where

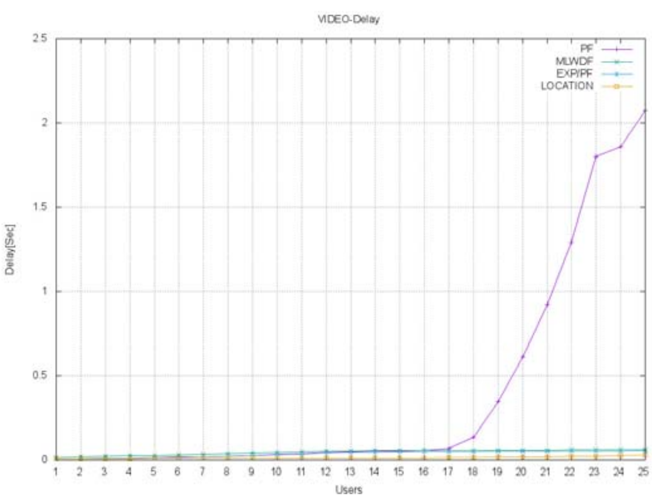

Fig. 1. Packet delay of video streaming services

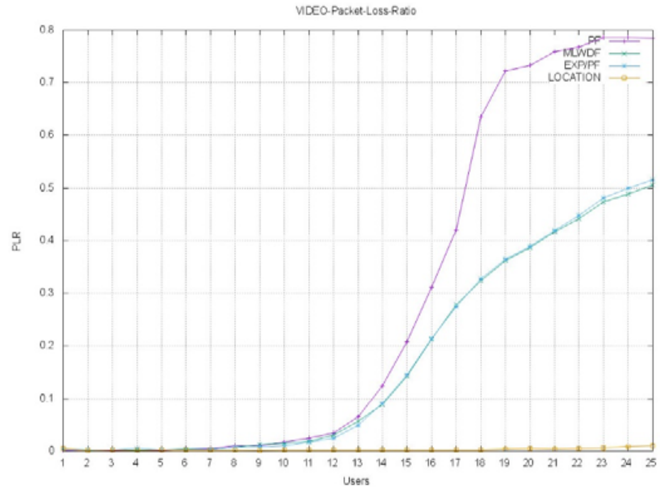

Fig. 2. Packet loss rate of video streaming services

L is the path loss and R is the distance between BS and user equipment. The users are randomly deployed in the cell coverage, and are equally divided into two kinds of service classes, video streaming and File Transfer Protocol (FTP) application. We compare the performance of the proposed location recommendation scheme with that of existing packet scheduling schemes including PF, MLWDF and EXP/PF. The performance metrics are indexed as the throughput, packet delay, and packet loss rates of video streaming services. The system parameters and their values are listed in Table 2.

The packet delays of video streaming with different schemes are shown in Fig. 1. It is shown that PF provides a much large packet delay than other schemes especially when the number of users exceeds 18 since it only considers channel conditions and average data rates for packet scheduling. MLWDF and EXP/PF have similar performances, and both of them can provide sufficient QoS in terms of low packet delays because they further consider delay bounds and head-of-line packet delays of real-time

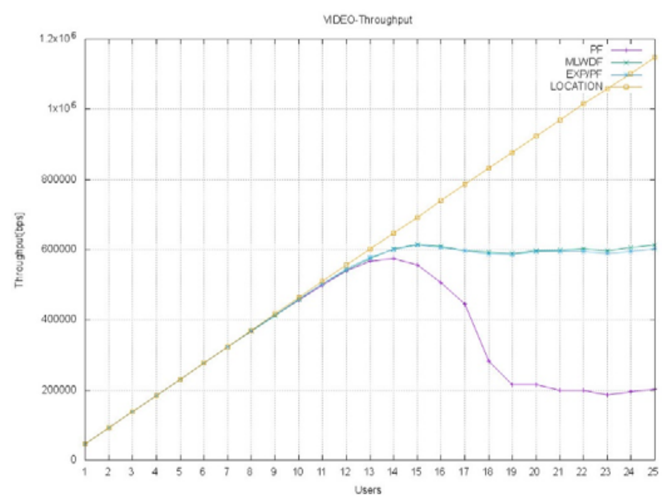

Fig. 3. Throughput of video streaming services.

traffic for packet scheduling. The proposed location recommendation scheme combined with the MLWDF packet scheduling mechanism is superior to all the other ones because it further adjusts the user location according to its QoS demand. In comparison with MLWDF, our scheme can decrease packet delays of video streaming by 52% in average.

Fig. 2 shows the packet loss rates of video streaming with different schemes. It is shown that PF provides a much large packet loss rates than other schemes especially when the number of users exceeds 16. MLWDF and EXP/PF have almost the same performances, but, both of them can no more provide sufficient QoS in terms of low packet loss rates (less than 10%) when the number of users exceeds 15. The reason is that the video packets are generally with a long length, resulting in a higher probability of packet loss when the radio resources are insufficient due to lots of users. The proposed scheme performs best among all while it always provides an adequately low packet loss rate by guiding users to the position where the channel conditions provide sufficient QoS. In comparison with MLWDF, our scheme can decrease the packet loss rates of video streaming by as large as 94% in average.

Finally, the throughput of video streaming with different schemes are shown in Fig. 3. It is shown when the number of users is less than 12, all the schemes have similar performance while the throughput rises with the increase of user numbers. With PF, throughput decreases dramatically as the number of users exceeds 15. This is consistent with the results of packet loss rates shown in Fig. 2. MLWDF and EXP/PF have nearly the same performances, in which throughput stay almost constant when the number of users exceeds 15. The proposed location recommendation scheme combined with the MLWDF packet scheduling mechanism is superior to all the other ones while it provides a linearly growing throughput with the increase of user numbers. In comparison with MLWDF, our scheme can increase throughput of video streaming by as large as 45% at most (as the number of users is 25). From the simulation results shown in Figs. 1 to 3, it is demonstrated that by comparison with existing packet scheduling schemes PF, MLWDF and EXP/PF, the proposed location recommendation scheme combined with the MLWDF packet scheduling method can effectively improves QoS including throughput, packet delay, and packet loss rate for video streaming services in LTE downlink communications.

V. Conclusion and Future Work

In this paper, we propose a novel approach from a different perspective, namely user location recommendation, which provides a certainly good channel quality for satisfying the QoS requirement in wireless networks. The proposed location recommendation scheme is further combined with the MLWDF packet scheduling mechanism to ensure QoS for real-time services. We conduct simulation scenarios in LTE downlink communications using *LTE-Sim* [9] which has been conceived as a comprehensive system-level simulator for fully implementing the protocol layers of LTE and providing a complete performance verification. The simulation results illustrate that, in comparison with other existing packet scheduling approaches, the proposed scheme effectively improves QoS including throughput, packet delay, and packet loss rate for video streaming services in LTE downlink communications. In the future, the proposed scheme will be implemented on realistic LTE networks for thorough performance field testing.

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