J. Vis. Commun. Image R. 31 (2015) 335–346

Contents lists available at ScienceDirect

J. Vis. Commun. Image R.

journal homepage: www.elsevier.com/locate/jvci

An effective cross-layer designed packet scheduling, call admission control, and handover system for video streaming services over LTE network ☆

Wan Kim [a], Gi Seok Park [b,1], Hwangjun Song [c,*]

[a] Cloud Technology Lab, Software R&D Center, Samsung Electronics Co., Ltd., Republic of Korea
[b] Dept. of IT Convergence Engineering, POSTECH (Pohang University of Science and Technology), Republic of Korea
[c] Computer Science and Engineering, POSTECH (Pohang University of Science and Technology), Pohang 790-784, Republic of Korea

ARTICLE INFO

Article history:
Received 12 December 2014
Accepted 9 July 2015
Available online 18 July 2015

Keywords:
Video streaming service
Quality-of-Experience
LTE network
Packet scheduling
Call admission control
Handover
Cross-layer designed system
Cell availability

ABSTRACT

This paper presents an effective cross-layer designed packet scheduling, call admission control, and handover system to provide a seamless video streaming services over LTE network. The proposed packet scheduling algorithm allocates wireless network resources to admitted UEs while considering QoE states and wireless link states of UEs simultaneously. The proposed call admission control algorithm estimates the cell availability at the next call arriving time based on the current QoE states of UEs to determine the admission of a new UE. The proposed handover algorithm determines the appropriate handover trigger timing to keep a balance of the QoE states among immediately adjacent cells based on both the cell availability and wireless link states. Finally, simulations are conducted to evaluate the performance of the proposed system. Results indicate that the proposed cross-layer designed system improves the QoE states of all admitted UEs and overall network utilization better than other existing methods.

1. Introduction

Wireless network access technologies have been quickly developed to support various mobile data service requirements. The cellular link speed has increased to approximately 2 Mbps for 3G network, and 200 Mbps for 4G (LTE, Long Term Evolution) network by taking advantage of wideband dynamic spectrum allocation [1], now B4G (beyond 4G) and 5G networks are currently under development. Mobile data services are already widely deployed over internet and currently increasing growth due to popularity of application on smart device OS (Operating System) including iOS, Android, and Window Phone OS. According to a forecast of the authoritative industry report [2], mobile video streaming services will account for approximately 66.5% of network traffic by 2017. Although the state-of-the-art technologies are capable of supporting high data rates, it is still a challenging problem to provide diverse mobile data service of high quality over wireless network. In particular, it is difficult to support seamless high-quality mobile video streaming services through wireless network because a large amount of data is required compared to data required by other mobile data services including text and images. Video streaming services are also strictly time-constrained whereas wireless channels are inherently time-varying. Furthermore, bit rates of video data are generally more variable due to generic characteristics of the entropy coder, scene changes, and inconsistent motion changes of the underlying video. These facts make the problem extremely challenging.

To make effective use of limited wireless network resources with supporting seamless high-quality video streaming services, resource management algorithms such as packet scheduling, call admission control, and handover algorithms play an essential role in wireless network. In the packet scheduling algorithm, the scheduler determines which packets will be transmitted to the next scheduling interval. The call admission control algorithm decides whether to accept or not the new service requests by considering a wireless network capacity in a cell. Finally, the handover algorithm ensures the UE (User Equipment) is freely transferred among adjacent cells while remaining connected. Nowadays, the cross-layer design has been widely studied to enhance video quality with minimal redundancy over time-varying wireless network. By sharing information among layers and/or jointly determining

☆ This paper has been recommended for acceptance by Prof. M.T. Sun.

* Corresponding author. Fax: +82 54 279 2299.
E-mail addresses: wan318.kim@samsung.com (W. Kim), kiseok@postech.ac.kr (G.S. Park), hwangjun@postech.ac.kr (H. Song).
[1] Fax: +82 54 279 2299.

http://dx.doi.org/10.1016/j.jvcir.2015.07.008
1047-3203/

control parameters at multiple layers, cross-layer technologies can efficiently deal with the inherent uncertainty in wireless network.

In this paper, we propose an effective cross-layer designed packet scheduling, call admission control, and handover system for seamless video streaming service over LTE network. One of the unique features of the proposed cross-layer designed system is that the proposed packet scheduling, call admission control, and handover algorithms are tightly coupled on the QoE (Quality of Experience) state information to effectively improve QoE of all admitted UEs and utilize the limited and time-varying wireless network resources in multiple cells over LTE network. This paper is organized as follows. Related works are discussed in Section 2, the proposed cross-layer designed packet scheduling, call admission control, and handover system is described in Section 3, simulation results are detailed in Section 4, and finally concluding remarks are given in Section 5.

2. Related works

Various packet scheduling algorithms have been proposed to effectively handle time-varying wireless channel/network conditions. The MAX SNR selects the UE with the best wireless link state so that it can maximize the instant network throughput. The PF (Proportional Fair) [3,4] approach not only takes the instantaneous wireless link states into account, but also looks at the long-term average wireless link states to maximize long-term throughput. However, neither the MAX SNR nor PF guarantees QoS (Quality of Service). On the other hand, some packet scheduling algorithms have been presented that focus on QoS problems. In the MLWDF (Modified Largest Weighted Delay First) [5,6] and EXP (Exponential rule) [7,8], they consider the wireless link states of UEs, and in addition they analyze the tolerable maximum queueing delay at the eNodeB to support a QoS. The EXP provides a stricter QoS than the MLWDF by using an exponential function to keep the queueing delay below a pre-determined maximum delay. However, MLWDF and EXP cannot provide QoS differentiation for various applications. In A-DTPQ (Adaptive Delay Threshold-based Priority Queueing) [9], it adaptively controls the tolerable maximum delay; wireless network resources are not allocated to real-time services when their delay is even less than the maximum delay. The A-DTPQ scheme does not consider the network utilization.

To simultaneously account for QoS and network utilization in a cell, a call admission control algorithm needs to consider not only the traffic characteristics, but also the time-varying wireless network capacity [10,11]. However, it is very difficult to estimate a wireless network capacity due to time-varying wireless link characteristics. In [12,13], Niyato et al. proposed a queue-aware call admission control algorithm that determines the connection acceptance probability based on a queueing model. The new connection is accepted when the total number of ongoing connections including incoming ones is less than a certain number of connections; otherwise, it is rejected. In [14], Jeong et al. presented a call admission control algorithm considering the network capacity in a cell and the current network load simultaneously, where the admission decision of a connection is taken by controlling the ratio between real-time and non-real-time traffic. In [15], Sohn et al. proposed an adaptive admission control algorithm that estimates the number of supporting UEs per OFDM (Orthogonal Frequency Division Multiplexing) frame on the basis of the bit error rate, average channel gain, and data rate requirements of every UE. However, this connection admission in [12–15] does not improve both the QoS of all connections and the network utilization since the QoS states of UEs (i.e., the number of buffered video frames) are not examined. In [16], the admission control algorithm is proposed based on the traffic priority to support adaptive multimedia service. When a cell is heavily loaded, the bandwidth of the service flow with the lowest priority is reduced first. In [17], Lee and Kim proposed a statistical connection admission control for mobile WiMAX (Worldwide interoperability for Microwave Access) systems that works based on the SNR (Signal-to-Noise Ratio) values of UEs and traffic parameters, where the class of traffic is categorized as UGS (unsolicited grant service), RT-VR (real time variable rate), NRT-VR (non-real time variable rate), or BE (best effort). In [18], Qian et al. proposed a novel radio admission control to optimize system capacity with supporting QoS of each service class by combining complete sharing and virtual partitioning resource allocation model. The admission control in [16–18] is based on traffic priority. However, when most of the traffic has a real-time variable rate, the priority-based admission decision is unfair and not useful.

Efficient handover algorithms have also been researched. In [19,20], Aziz et al. proposed a simple ICIC (Inter Cell Interference Coordination) scheme for determining an optimized handover parameter to avoid the radio link failure while maintaining low handover rates. However, the proposed ICIC scheme considers that the target cell always has resources available for the incoming UE, making a simple ICIC scheme not applicable in a real-world LTE system. In [21], Jansen et al. proposed the handover optimization algorithm to automatically control the values of the handover parameters such as hysteresis and TTT (Time-To-Trigger) for improving overall network utilization. The hysteresis and TTT value is selected to minimize the weighted sum of the handover failure ratio, Ping-Pong handover ratio, and call dropping ratio. In [22], Legg et al. proposed an intra-frequency handover by analyzing the influence of handover parameters according to different user mobility. In general, there exists a tradeoff between a low handover failure rate and a low handover frequency. In [22], offset and TTT are used for adjusting the balance between the handover failure rate and the handover frequency. In [23], Kitagawa et al. proposed a self-optimization algorithm for handover parameters to support robustness against the change in UE mobility by adjusting handover margin according to UE speeds. The adjustment direction of the handover margin is decided to maintain the balance of handover failure events. However, the handover algorithms in [21–23] do not consider load balancing among immediately adjacent cells. Thus, there is a gap in service quality among adjacent cells. In [24], Lobinger et al. proposed the coordination system for self-optimization between handover parameter optimization and load balancing to improve system performance, where the cell load is measured by the number of users served by the cell. It is difficult to improve cell utilization in a real system since the number of users in a cell is not proportional to the amount of consumed resources. In [25], Munoz et al. proposed the optimization system of the handover procedure which pursues an effective tradeoff between QoS of UEs in the cell and the amount of signaling load as a result of handovers, where the handover margin and TTT are control parameters used for adjusting a tradeoff between the handover signaling load and user experience. The call dropping ratio and the handover ratio are measured to quantify user experience degradation and to estimate the handover signaling load, respectively. However, it is difficult to support a fair service quality among UEs located in a neighboring cell since the load status of adjacent cells is not considered simultaneously.

A large number of cross-layer optimization techniques have been studied in the research literature to provide a seamless video streaming service over wireless network. In [26], Jeon and Jeong proposed a combined packet scheduling algorithm and call admission control algorithm based on a statistical approach to handle both real-time and non-real-time services. The packet scheduling algorithm and the call admission control algorithm perform their