UNIVERSITI PUTRA MALAYSIA

QUALITY OF EXPERIENCE-ORIENTED CROSS-LAYER DOWNLINK SCHEDULING FOR HETEROGENEOUS TRAFFIC IN LONG TERM EVOLUTION NETWORKS

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By

MEYSAM NASIMI

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Master of Science

July 2014

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DEDICATIONS

In the name of Allah, Most Gracious, Most Merciful

To my ever-loving parents
To my beloved wife

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

QUALITY OF EXPERIENCE-ORIENTED CROSS-LAYER DOWNLINK SCHEDULING FOR HETEROGENEOUS TRAFFIC IN LONG TERM EVOLUTION NETWORK

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July 2014

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Long Term Evolution (LTE) is a recently evolving technology proposed by Third Generation Partnership Project (3GPP) to provide a smooth migration towards Fourth Generation (4G) of cellular networks. Due to the ever-increasing demands for high speed data communication along with transmission of various types of services over cellular networks, it is of vital importance for the LTE system to has an efficient radio resource management. In particular, satisfying the Quality of Service (QoS) requirements of different applications is one of the key challenges of radio resource management that needs to be dealt by the LTE system. In this thesis, a cross-layer scheduler that interact between three different layers of wireless protocol stack, namely application, the Medium Access Control (MAC) and physical layer is proposed. The cross-layer scheduler provides efficient allocation of the wireless resources across different types of application (i.e., real-time and non real-time) run by different users to maximize network resource utilization and user-perceived quality of service, or also known as Quality of Experience (QoE). Here, Mean Opinion Score (MOS) is used as a unified QoE metric that indicates the user-perceived quality for real-time or multimedia services, notably video applications. Along with multimedia services, the proposed framework also takes care of non-real-time traffic by ensuring a certain level of fairness.

In the proposed framework, different modules were employed to handle cross-layer scheduling, including video application, Cross Layer Resource Allocator (CLRA), scheduler and transmitter. Video application module at the application layer buffers the incoming video from backbone and reports video distortion to CLRA module. Next, CLRA exploits the video distortion along with channel distortion from physical layer to estimate MOS value. Finally, based on the obtained MOS

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value, frame priority weight, QoS delay constraints and channel quality status, in every TTI, the user with the highest weight metric will obtain scheduling opportunity. To appreciate the effectiveness of the proposed framework, two different scenarios of single-cell and multi-cell were taken into considerations. The simulation, applied to scenarios where users simultaneously run different types of applications, confirms that the proposed QoE-oriented cross-layer framework leads to 14.2% and 18% of improvement in terms of user-perceived quality and spectral efficiency respectively.

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Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains

PENJADUALAN PAUTAN TURUN MERENTAS LAPISAN BERORIENTASI-MUTU PENGALAMAN UNTUK TRAFIK HETEROGEN DI DALAM RANGKAIAN EVOLUSI JANGKA PANJANG

Oleh

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Evolusi Jangka Panjang (LTE) merupakan teknologi yang baru sahaja berkembang baru-baru ini sepertimana dicadangkan oleh Projek Perkongsian Generasi Ketiga (3GPP) bagi memberikan perpindahan yang lancar ke arah Generasi Keempat (4G) bagi rangkaian selular. Disebabkan oleh permintaan yang semakin meningkat untuk komunikasi data berkelajuan tinggi serta penghantaran pelbagai jenis perkhidmatan melalui rangkaian selular, ianya adalah penting bagi sistem LTE untuk mempunyai pengurusan sumber radio yang baik. Memuaskan keperluan kualiti servis (QoS) bagi aplikasi yang berbeza khususnya, merupakan salah satu cabaran utama dalam pengurusan sumber radio yang perlu dihadapi oleh sistem LTE. Dalam tesis ini, penjadual lapisan bersilang yang bersama-sama mengoptimumkan tiga lapisan protokol tanpa wayar yang berbeza iaitu aplikasi, kawalan capaian media (MAC) dan lapisan fizikal telah dicadangkan. Penjadual lapisan bersilang memberikan peruntukan yang berkesan untuk sumber-sumber tanpa wayar bagi jenis-jenis aplikasi yang berbeza (iaitu masa nyata dan bukan masa nyata) yang digunakan oleh pengguna yang berbeza untuk memaksimumkan penggunaan sumber rangkaian dan kualiti tanggapan pengguna terhadap kualiti servis, atau turut dikenali sebagai kualiti pengalaman (QoE). Dalam kajian ini, purata skor pendapat (MOS) telah digunakan untuk menyatukan metrik QoE yang menunjukkan kualiti tanggapan pengguna bagi masa nyata atau perkhidmatan-perkhidmatan multimedia, terutamanya aplikasi-aplikasi video. Bersama-sama dengan perkhidmatan multimedia, rangka kerja yang dicadangkan juga menguruskan trafik bukan masa nyata dengan memastikan suatu tahap kesaksamaan. Simulasi kami yang diaplikasikan kepada senario di mana pengguna menjalankan pelbagai jenis aplikasi secara serentak, mengesahkan bahawa rangka kerja lapisan bersilang yang berorientasikan QoE yang telah dicadangkan membawa kepada peningkatan yang ketara dari segi memaksimumkan

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kualiti tanggapan pengguna serta mengekalkan kesaksamaan di kalangan pengguna.

Dalam rangka kerja yang dicadangkan, modul yang berbeza telah digunakan untuk mengendalikan penjadualan silang lapisan, termasuk aplikasi video, Pemuliharaan Sumber Lapisan Silang (CLRA), penjadual dan pemancar. Modul aplikasi video di lapisan aplikasi menampan video yang masuk dari tulang belakang dan melaporkan gangguan video kepada modul CLRA. Seterusnya, CLRA mengeksploitasi gangguan video bersama-sama dengan gangguan saluran daripada lapisan fizikal untuk menganggarkan nilai MOS. Akhir sekali, berdasarkan nilai MOS yang diperolehi, pemberat keutamaan bingkai, kekangan kelewatan QoS dan status kualiti saluran, pada setiap TTI, pengguna dengan metrik pemberat tertinggi akan mendapat peluang penjadualan. Untuk menghargai keberkesanan rangka kerja yang dicadangkan, dua senario yang berbeza iaitu sel tunggal dan sel berbilang telah diambil pertimbangan. Simulasi tersebut, diaplikasikan untuk senario di mana pengguna menjalankan pelbagai jenis aplikasi pada masa yang sama, mengesahkan bahawa rangka kerja lapisan silang berorientasikan QoE yang dicadangkan membawa kepada 14.2% dan 18% peningkatan daripada segi kualiti anggapan pengguna dan kecekapan spektrum masing-masing.

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I certify that a Thesis Examination Committee has met on 3 July 2014 to conduct the final examination of Meysam Nasimi on his thesis entitled "Quality of Experience-Oriented Cross-Layer Downlink Scheduling for Heterogeneous Traffic in Long Term Evolution Networks" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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