UNIVERSITI PUTRA MALAYSIA

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2014

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ALI MOHAMMED MANSOOR ALSAHAG

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

October 2014

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DEDICATIONS

To my parents, my wife, and my wonderful Kids, my brothers.
To my supervisor and entire committee.
Finally, To All whom I love.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

ADAPTIVE RESOURCE ALLOCATION ALGORITHMS WITH QOS SUPPORT IN OFDMA-BASED WIMAX NETWORKS

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ALI MOHAMMED MANSOOR ALSAHAG

October 2014

Chairman: Professor Borhanuddin Mohd Ali, PhD
Faculty: Engineering

In Worldwide Interoperability for Microwave Access (WiMAX) the primary concern is Quality of Service (QoS) support which aims to satisfy the diverse service requirements and to guarantee higher data rates allocation for different service classes. However, IEEE 802.16 standard does not specify a bandwidth allocation algorithm to guarantee QoS, this is purposely done in order to allow service providers and vendors to innovate in this area and distinguish their products.

The performance benefits of existing solutions in PHY and MAC layers often fall short of providing the QoS support, particularly, it is still experiencing additional access latency and bandwidth allocation disorder where errors occur, that leads flows backlogged. At the same time, mapping the prioritized resources in PHY is become vital to design adaptive resource allocation algorithms that support QoS by way of maximize spectral efficiency, reduce outage probability and efficiently utilize the system resources. The aim of this thesis is to develop a fair and efficient packet scheduling and adaptive multiuser frequency-time domain resources allocation algorithms to support QoS for a diverse service class in OFDMA based IEEE 802.16 network.

This thesis presents four main contributions for QoS provisioning which are robust, scalable, and can be successfully executed in WiMAX system. The

first and second contributions are two slot resource allocation algorithms for OFDMA downlink (DL) scheduling, namely Weighted-rate Adaptive Slot Allocation (WASA) and Feedback Delay-based Slot Allocation (FDSA). The aim is to satisfy QoS requirements for diverse traffic type demands by exploiting available resources in time and frequency domain, and maximize spectral efficiency. These algorithms have been devised with two different approaches. WASA classifies the users based on their weighted-rate factor, which is greater than the minimum requirements, to determine the achievable data rate for each connection in each time-frequency slot. This weighted-rate factor takes into account the achievable data rate along with the QoS requirement to ensure improvements to the system capacity and to guarantee the service type priority for real time over non real-time connections.

On the other hand, FDSA allocates the resources based on feedback information delay, which adjusts its traffic in agreement with the feedback to explore the number of slots that must be allocated to the corresponding service type. The purpose of the delay feedback information in real-time service is to utilize available bandwidth efficiently and assign it evenly among the active connections. The

Third contribution is an efficient bandwidth allocation algorithm for the uplink transmission called Fuzzy Adaptive Deficit Round Robin (FADRR). FADRR is fully dynamic with fuzzy logic based approach and adaptive deadline-based scheme for various service class traffics in the base station (BS). The algorithm employs fuzzy logic control which is embedded in the scheduler, whereby the function is to control and dynamically update the bandwidth required by the various service classes according to their respective priorities, maximum latency and throughput. FADRR also presents a new adaptive deadline-based approach in order to guarantee a specific maximum latency for real-time connections.

The final contribution is Two-Tier hierarchical scheduling algorithm with Enhanced Deficit Round Robin (Two-Tier EDRR) to update and offer new scheduling information to DL and uplink (UL) sub-frame. The main objective is to dynamically allocate the overall bandwidth to DL and UL service classes in such a way that the overall system throughput is optimized without sacrificing their QoS requirements. This is done by assigning the bandwidth fairly among different service classes in a hierarchical structure. The key feature of Two-Tier EDRR is its low-latency queue, in which it allows strict priority queue with delay-sensitive data such as voice to be dequeued and start allocation first before packets in other queues are dequeued.

Simulation results indicate that the proposed WASA and FDSA achieve significant performance improvements in terms of spectral efficiency, outage probability, and fairness against the conventional OFDMA-TDMA and MAX-SNR algorithms. WASA obtains higher spectral efficiency in comparison with the

OFDMA-TDMA by about 46% and WASA experiences lowest outage probability by about 21%. FDSA attains lower outage probability than OFDMA-TDMA reached by about 51%. In terms of fairness, FDSA outperform MAX-SNR by about 51% and OFDM-TDMA about 71%, respectively.

Simulations results show the performance of the proposed FADRR outperforms the conventional MDRR and CDRR schemes. Specifically, it reduces the packet queue delay by 72% and 58% on average in comparison to MDRR and CDRR, respectively. Further, FADRR exhibits better fairness by up to 86% and 61% as compared to MDRR and CDRR, respectively. The throughput for Best Effort (BE) service is maintained at a certain minimum reserved rate, which is still higher by about 27% and 13% in comparison to CDRR and MDRR, respectively. FADRR achieves superior throughput performance for real time Polling Service (rtPS) flows compared to the MDRR and CDRR algorithms by about 18% and 11%, respectively.

Two-Tier EDRR provides better performance than the conventional algorithms in terms of end-to-end delay, throughput, and delay jitter for Unsolicited Grant Service (UGS), enhanced real time Polling Service (ertPS), rtPS, non-real time Polling Service (nrtPS) and BE services. It is observed that decreasing delay of real-time packets lead to increase packet delivery ratio, thus enabling the system to show higher throughput.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

ALGORITMA PENGAGIHAN SUMBER ADAPTIF DENGAN SOKONGAN QOS DALAM RANGKAIAN WIMAX BERASASKAN OFDMA

Oleh

ALI MOHAMMED MANSOOR ALSAHAG

Oktober 2014

Pengerusi: Profesor Borhanuddin Mohd Ali, PhD
Fakulti: Kejuruteraan

Dalam Kebolehoperasian Seluruh Dunia bagi Akses Gelombang Mikro (WiMAX) kebimbangan utama adalah Kualiti Perkhidmatan (QoS) sokongan yang bertujuan untuk memenuhi keperluan pelbagai perkhidmatan dan untuk menjamin peruntukan data pada kadar yang lebih tinggi bagi kelas perkhidmatan yang berbeza. Walau bagaimanapun, IEEE 802.16 standard tidak menyarankan algoritma peruntukan jalur lebar untuk menjamin QoS, ini sengaja dilakukan untuk membolehkan pembekal perkhidmatan dan vendor untuk membuat inovasi dalam bidang ini dan membezakan produk mereka.

Manfaat prestasi penyelesaian yang sedia ada di lapisan PHY dan MAC masih gagal untuk menyediakan sokongan QoS, terutamanya, ia masih mengalami kependaman akses tambahan dan gangguan peruntukan jalur lebar di mana kesilapan yang berlaku akan menyebabkan aliran tertunggak. Pada masa yang sama, pemetaan sumber keutamaan dalam PHY adalah penting untuk mereka bentuk penyesuaian algoritma peruntukan sumber yang menyokong QoS dengan cara memaksimumkan kecekapan spektrum, mengurangkan kebarangkalian gangguan dan menggunakan sumber sistem dengan cekap. Matlamat projek ini adalah untuk membangunkan penjadualan paket yang adil dan cekap serta penyesuaian pelbagai pengguna dalam domain masa dan frekuensi dengan algoritma perun-

tukan sumber untuk menyokong QoS bagi pelbagai kelas perkhidmatan dalam OFDMA berasaskan rangkaian IEEE 802.16.

Tesis ini mempersembahkan empat sumbangan utama untuk menyokong QoS yang teguh, berskala, dan boleh berjaya dilaksanakan dalam sistem WiMAX. Sumbangan pertama dan kedua adalah algoritma peruntukan sumber slot untuk penjadualan OFDMA muat turun (DL) yang dikenali sebagai Peruntukan Slot Kadar-Wajaran Penyesuaian (WASA), dan Peruntukan Slot Berasaskan Kelewatan Maklum Balas (FDSA). Tujuannya adalah untuk memenuhi keperluan QoS daripada pelbagai jenis trafik permintaan dengan mengeksploitasi sumber yang ada dalam domain masa dan frekuensi serta memaksimumkan kecekapan spektrum. Walau bagaimanapun, kedua-dua algoritma ini telah dibangunkan dengan pendekatan yang berbeza. WASA mengklasifikasikan pengguna berdasarkan faktor kadar-wajran mereka, yang lebih besar daripada keperluan minimum, untuk menentukan kadar data yang boleh dicapai untuk setiap sambungan dalam setiap slot masa dan frekuensi. Faktor kadar-wajaran ini mengambil kira kadar data boleh dicapai bersama-sama dengan keperluan QoS untuk memastikan peningkatan kapasiti sistem dan untuk menjamin keutamaan jenis perkhidmatan untuk masa nyata melalui sambungan masa bukan nyata. FDSA memperuntukkan sumber-sumber yang berdasarkan maklum balas kelewatan maklumat, yang menyesuaikan trafik dengan maklum balas untuk meneroka bilangan slot yang perlu diperuntukkan kepada jenis perkhidmatan yang sama.

Tujuan maklumat maklum balas kelewatan dalam perkhidmatan masa nyata adalah untuk menggunakan jalur lebar yang ada dengan cekap dan membahagikan sama rata antara sambungan aktif. Sumbangan ketiga ialah algoritma peruntukan bandwidth cekap untuk penghantaran muat naik (UL) yang dipanggil Fuzzy Penyesuaian Defisit Round Robin (FADRR). FADRR dinamik sepenuhnya, menggunakan pendekatan berasaskan fuzzy logik dan skim berdasarkan tarikh akhir penyesuaian trafik kelas pelbagai perkhidmatan di stesen pangkalan (BS). Algoritma ini menggunakan kawalan fuzzy logik yang tertanam dalam penjadual, di mana fungsinya adalah untuk mengawal dan mengemaskini secare dinamik bandwidth yang diperlukan oleh pelbagai kelas perkhidmatan mengikut keutamaan masing-masing, kependaman maksimum dan pemprosesan. FADRR juga membentangkan pendekatan berasaskan penyesuaian tarikh akhir baru bagi menjamin kependaman maksimum tertentu untuk sambungan masa nyata.

Sumbangan terakhir adalah algoritma penjadualan hierarki dengan Dua-Peringkat Peningkatan Defisit Round Robin (Dua-Peringkat EDRR) untuk mengemas kini dan menawarkan maklumat penjadualan baru untuk DL dan uplink (UL) subframe. Objektif utama adalah untuk memperuntukkan jalur lebar secara dinamik bagi keseluruhan kelas perkhidmatan DL dan UL menerusi sistem pemprosesan keseluruhan dioptimumkan tanpa mengorbankan keperluan QoS mereka. Ini dilakukan dengan memberikan jalur lebar secara adil di kalangan kelas perkhid-

matan yang berbeza dalam struktur hierarki. Ciri utama Dua-Peringkat EDRR adalah giliran rendah kependaman, di mana ia membenarkan giliran keutamaan yang ketat untuk data sensitif lewat seperti suara untuk digilirkan dan mula peruntukan sebelum paket di barisan lain digilirkan.

Keputusan simulasi menunjukkan bahawa WASA dan FDSA yang dicadangkan mencapai peningkatan prestasi yang ketara dari segi kecekapan spektrum, kebarangkalian gangguan, dan keadilan berbanding algoritma konvensional OFDMA-TDMA dan MAX-SNR. WASA mencapai kecekapan spektrum ketara jika dibandingan dengan OFDMA-TDMA sekitar 46% dan juga mengalami kebarangkalian gangguan yang paling rendah sebanyak 21%. FDSA mencapai kebarangkalian gangguan rendah penting daripada OFDMA-TDMA mencapai kira-kira 51%. Tambahan pula, keputusan dari segi keadilan menunjukkan FDSA mengatasi MAX-SNR sebanyak 51% dan OFDM-TDMA kira-kira 71%.

Keputusan simulasi menunjukkan prestasi FADRR yang dicadangkan adalah melebihi skema konvensional MDRR dan CDRR. Terutamanya, ia mengurangkan kelewatan dalam giliran paket sebanyak 72% dan 58% secara purata lebih daripada MDRR dan CDRR. Pada masa yang sama FADRR menunjukkan keadilan jangkauan yang lebih baik sehingga 86% dan 61% berbanding MDRR dan CDRR. Walaupun kendalian Usaha Terbaik (BE) dikekalkan sekurang-kurangnya terpelihara pada kadar yang tertentu, yang masih lebih tinggi kira-kira 27% dan 13% berbanding dengan CDRR dan MDRR. FADRR mencapai prestasi pemprosesan atasan Khidmat Pengumpulan masa nyata (rtPS) aliran berbanding dengan algoritma MDRR dan CDRR sebanyak 18% dan 11%.

Dua-Peringkat EDRR mempunyai prestasi yang lebih baik daripada algoritma konvensional dari segi akhir-ke-hujung kelewatan, pemprosesan, dan kelewatan ketar untuk perkhidmatan Pemberian Service Tetap (UGS), Peningkatan Khidmat Pengumpulan masa nyata (ertPS), rtPS, Khidmat Pengumpulan masa tidak nyata (nrtPS) dan BE. Jelas sekali, pengurangan kelewatan paket masa nyata membawa kepada meningkatkan nisbah penghantaran paket serta membolehkan sistem untuk menunjukkan daya pemprosesan yang lebih tinggi.

ACKNOWLEDGEMENTS

First and foremost, praise is for Allah Subhanahu Wa Taala for giving me the strength, guidance and patience to complete this thesis. May blessing and peace be upon Prophet Muhammad Sallalahu Alaihi Wasallam, who was sent for mercy to the world.

I would like to express my sincere gratitude to my supervisor Prof. Dr. Borhanuddin Mohd Ali, my advisor. His continuous support, his theoretical insight, his technical awareness, his immense knowledge and his patience helped me in all the time of research and writing of this thesis. The completion of this thesis would not be possible without his reading and correction patience, as well as technical advices.

I would also like to thank the supervisory committee members, Prof. Dr. Norkamariah Noordin for her helpless advices, her guidance that gave me all the confidence. My special thanks go to Dr. Hafizal Mohamad for his encouragement and his essential aid throughout the research. He always has time for me to provide technical expertise during my study.

I would like to extend sincere gratitude to Dr. Nordin Ramli who stood behind me and gave me all support, he deserve from me all thanks.

I am very grateful to the Faculty of Engineering office, Library and Universiti Putra Malaysia, for providing the research environment.Thanks to every person who has supported me to produce my thesis. I also wish to extend my thanks to the helpful academic and the technical staff of MIMOS, for their support throughout my internship period.

I am very grateful to my family: my father, Mohammed, my mother, Aisha, my brothers and my sisters for their unflagging love and support throughout my life. I have no suitable words that can fully describe my everlasting love to them except, I love you all.

Words fail me to express my appreciation to my lovely wife Mona whose dedication, love and persistent confidence in me, has taken the load off my shoulder.

I owe her for being unselfishly let her intelligence, passions, and ambitions collide with mine.

Special thanks goes to my kids Mohammed, Osama and Layan, you are my joy and guiding lights. Thanks for giving me your valuable time through all this long process. I promise I will never let you alone any more.

Finally, I would like to thank everybody who was important to the successful realization of thesis, as well as expressing my apology that I could not mention all.

APPROVAL

I certify that a Thesis Examination Committee has met on 16 October 2014 to conduct the final examination of Ali Mohammed Mansoor Alsahag on his thesis entitled "ADAPTIVE RESOURCE ALLOCATION ALGORITHMS WITH QOS SUPPORT IN OFDMA-BASED WIMAXbNETWORKS" 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 Doctor of Philosophy.

Members of the Thesis Examination Committee were as follows:

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Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Shamala Subramaniam, PhD
Associate Professor
Faculty of Computer Science and Information Technology
Universiti Putra Malaysia
(Internal Examiner)

Ekram Hossain, PhD
Professor
Department of Electrical and Computer Engineering
Manitoba University
(External Examiner)

NORITAH OMAR, PhD
Associated Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Nor Kamariah bt Noordin, PhD
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

Hafizal Mohamad, PhD
Senior Staff Researcher
Wireless Communications
MIMOS BERHAD
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DECLARATION

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WiMAX	Worldwide Interoperability for Microwave Access
BWA	Broadband Wireless Access
GSM	Mobile Communications
4G	4th Generation Partnership Project
ITU-T	International Telecommunication Union
QoS	Quality of Service
CID	Connection Identifier
CSI	Channel State Information
CAC	Connection Admission Control
SFID	Service Flow Identifier
UGS	Unsolicited Grant Service
rtPS	real-time Polling Service
ertPS	extended real-time Polling Service
nrtPS	non-real-time Polling Service
BE	Best Effort Service
MPEG	Moving Picture Experts Group
MAC	Media Access Control
PHY	Physical Layer
OFDMA	Orthogonal Frequency Division Multiple Accesses
TDMA	Time-Division Multiple Access
AWGN	Additive White Gaussian Noise
BS	Base Station
SS	Subscriber Station
PMP	Point-to-Multi Point
LOS	Line-of-Sight
NLOS	Non Line-of-Sight
BPSK	Binary Phase-Shift Keying
DFPQ	Deficit Fair Priority Queueing
DRR	Deficit Round Robin
EDF	Earliest Deadline First
RR	Round Robin
WRR	Weighted Round Robin
WFQ	Weighted Fair Queuing algorithm
SCFQ	Self-Clocked Fair Queuing
SP	Strict-Priority
WASA	Weighted-rate Adaptive Slot Allocation
FDSA	Feedback Delay-based Slot Allocation

FADRR	Fuzzy Adaptive Deficit Round Robin
ADRR	Adaptive Deficit Round Robin
MDRR	Modified Deficit Round Robin
CDRR	Customized Deficit Round Robin
AMC	Adaptive Modulation and Coding
BE	Best Effort
IEEE	Institute of Electrical and Electronic Engineers
IPv4	Protocol version 4

CHAPTER 1

INTRODUCTION

This chapter introduces a general background about this research and identifies the research problems and motivation. It also presents the research objectives and describes the scope of this research. Furthermore, this chapter highlights the research contributions, justifies the benefits, and clarifies the implications of this research. Finally, this chapter summarizes the organization of the thesis.

1.1 Background

Wireless networks have experienced tremendous progress over the last few years. The pace of evolution of providing ever higher data rate from 2G to 2.5G, 3G and beyond never seem to have abated. Nevertheless, it is a consensus that future wireless networks, known generically as beyond 3G (B3G), are targeted at supporting various applications such as voice, data, and multimedia over packet-switched networks as shown in Figure 1.1. On these networks, high bandwidth and quality of service (QoS) provisioning is the critical goals to provide different services to mobile devices.

In recent years, the proliferation of mobile devices and technologies provides voice service, data and multimedia to subscribers (SSs) gives rise to need for seamless, ubiquitous broadband wireless access (BWA) technologies to support diverse applications such as VoIP, streaming and interactive multimedia such as gaming. This remarkable growth in the demand for high data rates has driven current and future wireless communications infrastructure, to innovate robust techniques to provide high data rates and guarantee better services.

To respond to this demand, the IEEE 802.16 family of standards has been developed for BWA over a metropolitan area, initially covering a fixed Line-of-Sight (LoS) wireless access. IEEE 802.16e adds the support of mobility [1] and uses orthogonal frequency division multiplexing access (OFDMA) as its air interface technique [2], and further to that IEEE 802.16m has been developed to meet IMT-Advanced network specifications defined by ITU-T [3]. Mobile WiMAX enables several interesting features including support of high data rate, coverage of large areas, corporate-grade security, dynamic Quality of Service (QoS) and good spectral efficiency. It also provides better support for Non Line-of-Sight (NLOS) technologies, multiple services with different QoS policies and inexpensive deployment of last mile access to public networks.

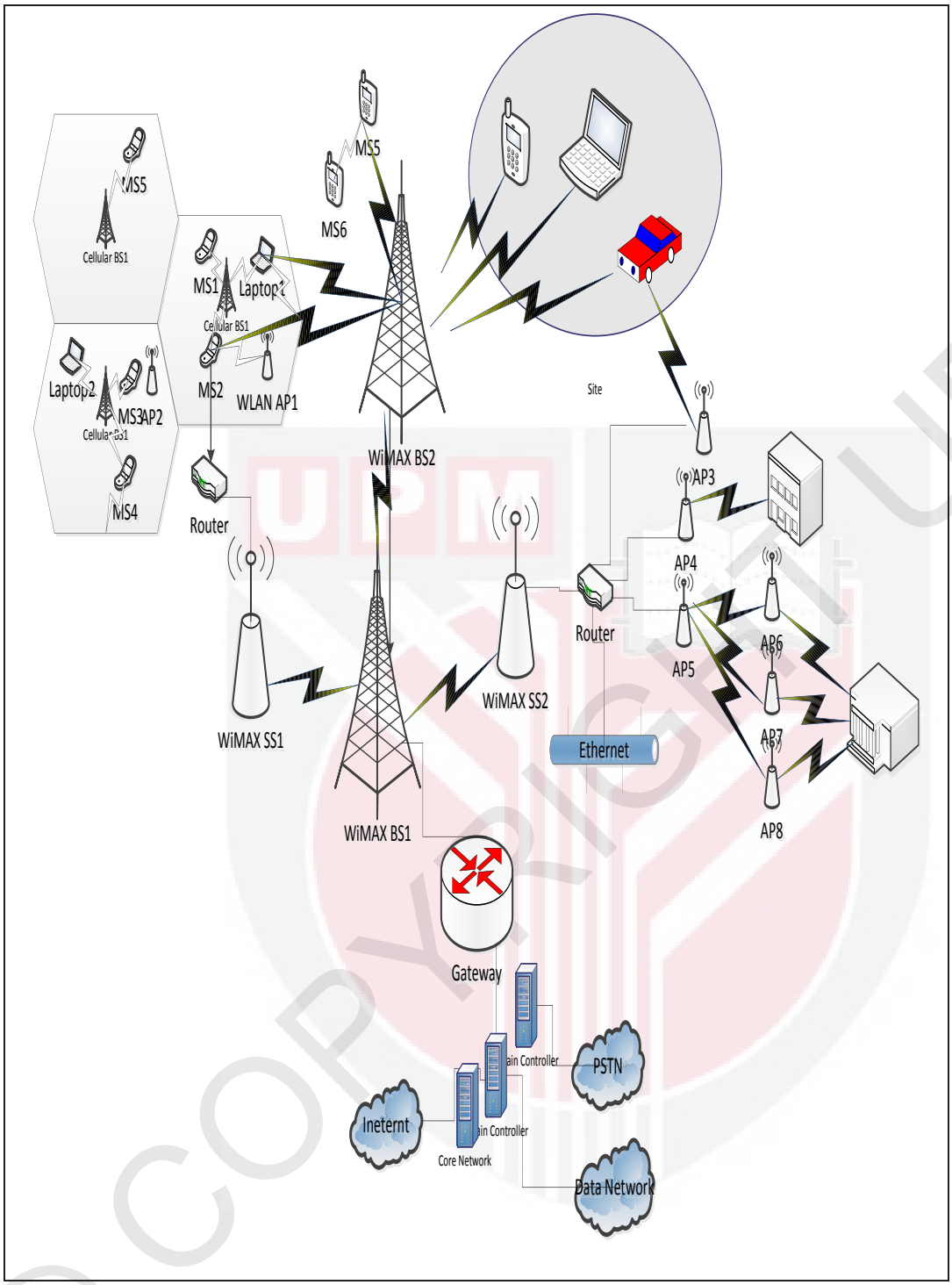

Figure 1.1: Next Generation Wireless Networks

Support for a variety of multimedia services, some with high QoS requirements, have become increasingly sophisticated. This implies that increasingly more users have to share the available wireless spectrum, thus necessitating the use of highly efficient and robust schemes for wireless resource allocation. Judicious allocation

of these radio resources becomes an important research area in wireless communications and networking with the objective of managing the network more effectively.

In wireless communications, different resources can be allocated simultaneously depending on the technology and demand. Sample technologies include time-division multiple access (TDMA), frequency-division multiple access (FDMA), and code-division multiple access (CDMA). The current literature, however shows that OFDMA is becoming increasingly more important[4]. One advantage of OFDMA over the other technologies is that it dynamically allocates larger amounts of radio resource to users that are capable of making the best utilization of the resource considering the prevailing channel conditions.

OFDMA also makes it possible for users to operate with smaller power amplifiers. With these advantages, OFDMA has been adopted for various standards such as IEEE 802.11n [5] and 4^{th} generation cellular systems such as IEEE 802.16m and 3GPP long term evolution (LTE)[6]. Therefore, the question of how to fulfil the QoS requirement and service differentiation in IEEE 802.16 networks is one of the most important and open issues.

In such a multi-service environment, BWA networks are challenged to meet the diverse QoS requirements in terms of bounded delay, jitter, packet loss rate, guaranteed throughput and spectral efficiency. In order to achieve QoS provisioning, several key modules including the adaptive resource allocation, packet scheduling and queue management, must be carefully designed.

Packet scheduling and resource allocation algorithms are two key mechanisms in WiMAX that are used to support the required QoS. The mechanisms must be effectively designed to maximize efficient utilization of spectrum and of systems resources. Scheduling is the problem of determining which users that will be given priority for the bandwidth; whereas adaptive resource allocation refers to the problem of allocating physical layer (PHY) resources such as rectangular slots and power among these priority users. This thesis focuses on packet scheduling and adaptive resource allocation algorithms for QoS provisioning in WiMAX networks especially in the MAC and PHY layers.

The rest of the Chapter is organized as follows. First, the problem statement of this thesis is discussed. This is followed by a listing of the objectives, contributions of the thesis, and its scope. Finally, the organization of the thesis is presented.

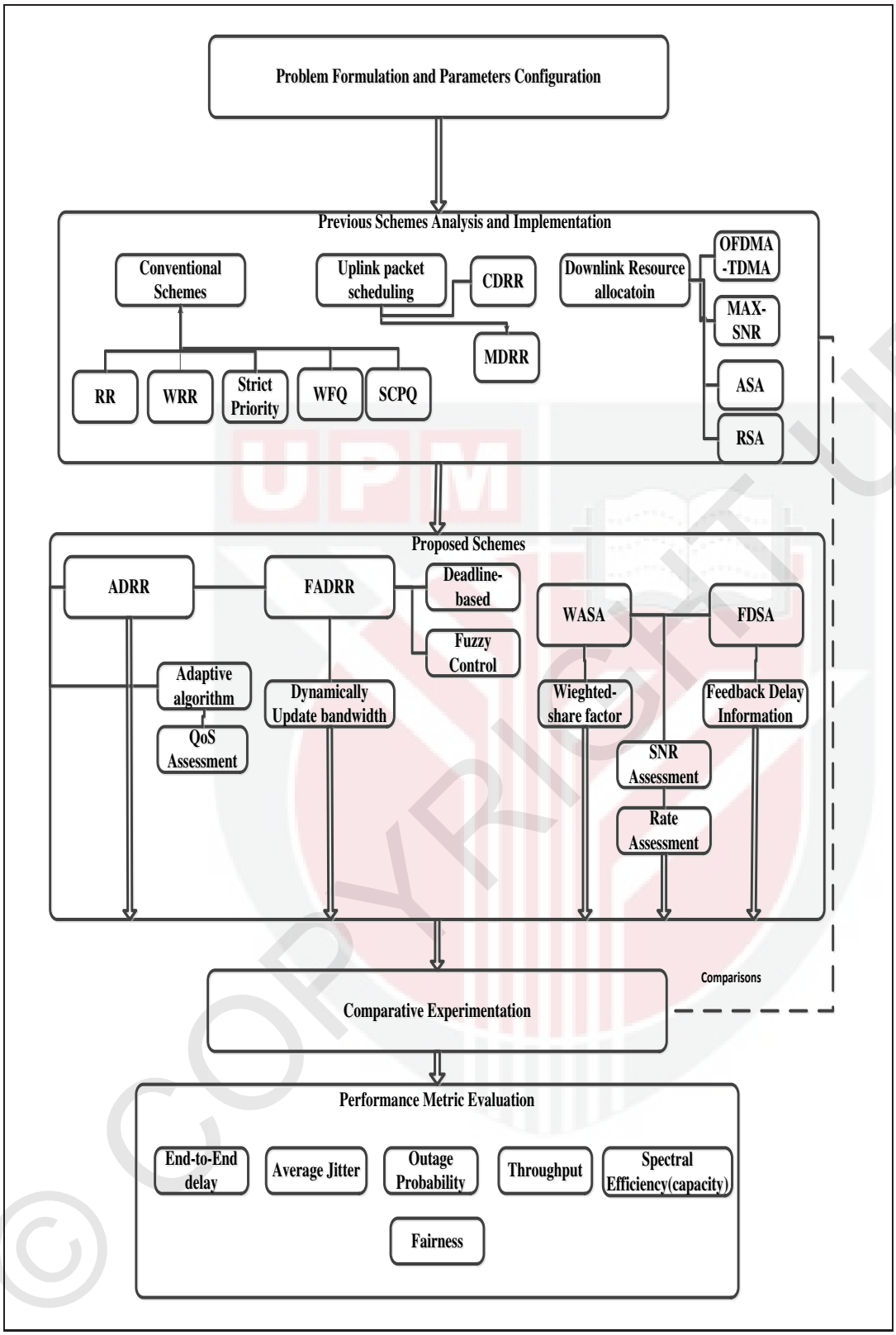

Figure 1.2: The Framework of the Research

1.2 Research Problem

EEE 802.16 has the ability to provide high transmission data and QoS for diverse demand of users. However, IEEE 802.16 standard does not specify a bandwidth allocation algorithm, this opens opportunities for vendors and researchers to innovate in this area. The resource allocation algorithms in 802.16 are concerned about maintaining traffic scheduling continuity without much of service disruption. However, for high priority flows, system throughput degradation may happen due to bandwidth allocation disorder. Also, instability in real-time and non real-time services leads to degradation in latency guarantee and deterioration of overall system utilization. Prioritizing non real-time service will impact real-time service negatively. Therefore, an efficient fair packet scheduling and a bandwidth allocation algorithm need to be developed towards improving the throughput and providing seamless QoS.

At the same time adaptive resource allocation at the PHY Layer must maximize spectral efiňĄciency, reduce outage probability and maximize utilization of system resources. OFDMA was developed to manipulate a multicarrier transmission that is time-shared among contending users. However, transmitting at different time slots to different users reduce system efficiency and affect the mapping of the required resources. Therefore, the rectangular slot must be fully allocated in a two dimensional domain of time and frequency. Furthermore, in a given bandwidth, the rectangular slots transmit to different users considering the channel gain responses by applying Adaptive Modulation and Coding (AMC). However, to satisfy a higher achievable data rate and fairness, further appropriate trade-off of resource allocation need to be developed towards providing seamless QoS as well as improving system performance. The research framework of this thesis is depicted in Figure 1.2.

1.3 Research Objectives

The aim of this thesis is to develop new packet scheduling techniques and adaptive multiuser frequency-time domain resource allocation algorithms to provide the QoS support for real-time and non real-time services. This scheduling framework encompasses prioritization of traffic at the MAC layer and adaptive multiuser frequency-time domain resource allocation model at the OFDMA downlink. To fulfill this aim the following objectives are established:

- To design an adaptive slot allocation algorithm for a multiuser diversity in downlink direction for mobile WiMAX networks called Weighted-rate Adaptive Slot Allocation (WASA). The aim is to improve system performance by exploiting the available resources in a two-dimensional domain and to optimize the subcarrier with the number of bits to ensure the system

capacity.

- To develop an algorithm for a trade-off between fairness and capacity called Feedback Delay-based Slot Allocation (FDSA). This will improve fairness in slot assignment and maintain higher data rates.
- To propose an efficient bandwidth allocation algorithm for the uplink direction in mobile WiMAX referred to as FADRR. This will control and update the bandwidth required by the various service classes information for QoS support such as guarantee a maximum latency for real-time traffic.
- To develop a Two-Tier hierarchical scheduling algorithm with Enhanced Deficit Round Robin (Two-Tier-EDRR) to update and offer new scheduling information to DL and UL sub-frames. The main objective is to dynamically allocate the overall bandwidth to DL and UL service classes in such a way that the overall system throughput is optimized without sacrificing their QoS requirements.

1.4 Research Contributions

The contributions of this thesis are as follows:

- An adaptive slot allocation algorithm for multiuser diversity in downlink direction called WASA. It exploits the available resources in a two-dimensional domain to maximize system capacity.
- An algorithm called FDSA that finds a trade-off between fairness and capacity. It mainly relies on MAC and PHY layers of each service type by updating the resource allocation algorithm of real-time and non real-time classes efficiently, using a feedback delay information mechanism.
- A prioritized user function assessment for guaranteeing QoS requirements called weighted-rate factor. It enables users to use the wireless resources efficiently in order to maximize the achievable data rate and distinguish the service type priority for real time over non real-time connections.
- An efficient bandwidth allocation algorithm in the uplink referred to as FADRR. This is based on an intelligent systems approach for increasing the reliability by means of control and updating the bandwidth during a communication session. It is based on two concepts:
    1. Fuzzy logic control which is embedded in the scheduler. This utilizes service class information and dynamically updates the bandwidth required to support QoS.
    2. Adjust the service queue weights for real-time and non real-time connections. It exploits the new traffic, according to their respective priorities, maximum latency and throughput to confirm and verify the

optimal bandwidth required for real-time and non real-time connections, taking the maximum throughput that satisfies the maximum delay objective.

3. A scheme to identify the maximum latency for real-time service. This is done firstly, by introducing adaptive deadline-based approach to handle the bandwidth fairly for traffic that the maximum latency has been violated, and then to improve throughput of the overall system network when the non real-time service are granted their required bandwidth during a tolerated latency.

- two-Tier hierarchical scheduling algorithm with Enhanced Deficit Round Robin (Two-Tier-EDRR) to update and offer new scheduling information to DL and UL subframes, and to ensure effective scheduling to SSs.

1.5 Research Scope

This thesis covers packet scheduling and adaptive resource allocation algorithms at the MAC and PHY layers in the 802.16 standards for QoS provisioning, in both UL and DL directions of the Base Station (BS). The system model for this thesis is illustrated in Figure 1.3. A Point-to-Multipoint (PMP) network topology is considered, where one BS serves multiple SSs in a single cell. Throughout the simulation period, connections in the service class queues are assumed to be active in the network. Channel quality is assumed to be perfectly fedback by each SS to the BS. Here, resource allocation refers to the assignment of frequency-time slots in the OFDMA frame. Even though the allocation of power is also possible, they are not covered in this thesis. Note that there are other QoS related modules such as the admission control and buffer management, but they are outside the scope of this thesis.

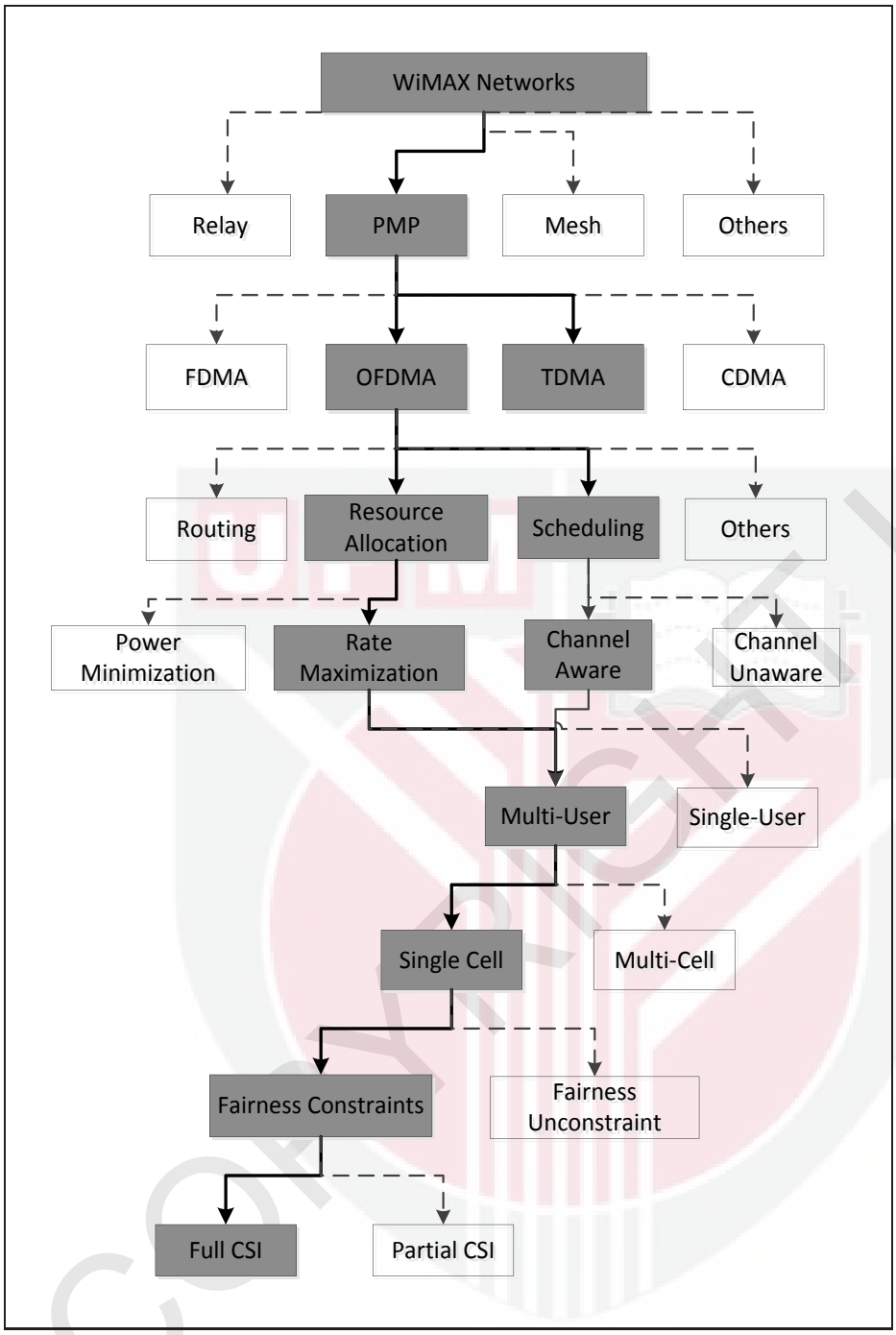

Figure 1.3: Study Model

1.6 Thesis Organization

This thesis is organized as follows: Chapter 1 provides a general introduction to the thesis with regards to the background of the subject and the problem statement; and it introduces the research objectives and highlights the contributions

and scope of the thesis.

Chapter 2 presents the literature reviews; it covers the concept of packet scheduling and adaptive resource allocation mechanisms based on channel awareness and OFDMA resource allocation algorithms for BWA. This Chapter also provides a general overview and classification of QoS resource allocation mechanisms that operate at different layers. Then, it describes the main techniques inspired by channel conditions that works in WiMAX, and focuses on the adaptive resource allocation algorithms that use the frequency-time domain allocation in WiMAX. Further, the Chapter describes briefly the ideas and concepts used in previous works and highlight the strengths and limitations of these schemes.

Chapter 3 describes the methodology used in this thesis. The first section presents a brief description of our proposed algorithms. Then, the framework of the proposed schemes is presented with an illustration starting from the pre-analysis of the existing mechanisms of the evaluations and results. The stages of the research are depicted in the flowchart that shows the different patterns and their integration. The second part introduces the system models used in this study such as the channel capacity, queuing, traffic and network models. Finally, the Chapter gives an overview of the experimental parameters, environmental resources, and performance metric used.

Chapter 4 describes the architecture and evaluation of the proposed adaptive resource allocation algorithms, WASA and FDSA, in the downlink OFDMA. This Chapter describes in detail the structure and main operations of WASA and FDSA. The Chapter concludes with the results and observations of several experiments conducted to test and validate the proposed algorithms in terms of spectral efficiency, outage probability, and fairness.

Chapter 5 introduces a fair uplink bandwidth allocation and latency guarantee algorithm and provides its architectural design. The model presented in this chapter is an efficient bandwidth allocation algorithm for the UL transmission called FADRR. FADRR is fully dynamic, using fuzzy logic based proach and adaptive deadline-based scheme of the various service class traffic in the BS. The algorithm uses fuzzy logic control which is embedded in the scheduler; its function is to control and dynamically update the bandwidth required by the various service classes according to their respective priorities, maximum latency and throughput. The Chapter concludes with the results and observations of several experiments performed with simulations.

Chapter 6 describes in detail the proposed Two-Tier hierarchical scheduling algorithm with Enhanced Deficit Round Robin (Two-Tier-EDRR) and its structure. The main objective is to dynamically update and offer new scheduling informa-

tion to DL and UL sub-frames in such a way that the overall system throughput is optimized without sacrificing their QoS requirements. This Chapter also presents the performance evaluation of the Two-Tier-EDRR developed in this thesis.

Finally, Chapter 7 concludes the thesis with the description of features and capabilities of the proposed methodologies. This Chapter also includes some promising directions for future works that can be used as guidelines for further research.

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