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CHANNEL- AND DELAY-AWARE SCHEDULING ALGORITHMS FOR WIMAX

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IEEE 802.16 introduces scheduling algorithm to manage and allocate network resource in order to achieve Quality of Service (QoS) of different services. Scheduling algorithms can be categorized into two main types: channel-unaware and channel-aware. Channel-unaware schedulers assume the wireless channel condition is always perfect and error-free. This assumption is impractical due to the nature of the wireless medium. Meanwhile channel-aware schedulers exploit the variation of the wireless channel by taking the wireless link quality into scheduler's decision making mechanism. Thus it can handle the variation of wireless medium in the better manner to achieve optimum network performance.

In this thesis, the proposed channel-aware Weighted Fair Queuing (CWFQ) and Queue Duration Awareness (QDA) algorithm have been developed and investigated. CWFQ improves the goodput performance of WFQ through exploitation of wireless medium to achieve better spectral efficiency. Packet with better link quality is given

higher service priority. Meanwhile QDA algorithm improves the delay performance of the CWFQ scheduling algorithm by giving higher service priority to packet that has longer queue duration. This helps to reduce packet waiting time for service.

Extensive simulations have been done using QualNet simulator to investigate the performance of CWFQ and QDA algorithms. The results show that CWFQ has achieved better goodput and packet delivery ratio (PDR) for real time polling service (rtPS) flow compare to WFQ, with improvement of 19.4% and 21.5% in static scenario, 12.4% and 13.5% in mobile scenario. This shows that CWFQ is able to exploit wireless channel and improve spectral utilization. For QDA algorithm, the results show that CWFQ+QDA has outperformed the existing Garroppo-WFQ (GWFQ) by 36.3% and 79.4% in static and mobile scenario. This is because QDA algorithm awards higher priority to packet that has long queued to avoid starvation of service. This shows that QDA is able to improve CWFQ's delay performance.

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PENJADUALAN DENGAN KESEDARAN SALURAN DAN KELAMBATAN UNTUK WIMAX

Oleh

YOU SIN YONG

Februari 2013

Pengerusi: **Aduwati Sali, PhD**

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Piawaian IEEE 802.16 memperkenalkan penjadualan untuk mengurus dan mengagihkan sumber rangkaian supaya Perkhidmatan Berkualiti (QoS) dapat dicapai untuk aliran yang berbeza. Penjadualan boleh dibahagikan kepada dua jenis yang utama, iaitu jenis tanpa kesedaran saluran dan jenis dengan ciri kesedaran saluran. Penjadualan yang berjenis tanpa kesedaran saluran menganggapkan bahawa saluran jaringan tanpa wayar adalah sempurna dan tidak mempunyai kesilapan. Anggapan tersebut adalah tidak praktikal disebabkan oleh ciri semulajadi jaringan tanpa wayar yang sentiasa berubah. Penjadualan dengan kesedaran saluran mengeksploitasi perubahan jaringan tanpa wayar dengan mengambil kira kualiti saluran semasa membuat keputusan pengagihan sumber rangkaian. Oleh sebab itu, ia dapat mengendalikan perubahan jaringan tanpa wayar dengan lebih baik untuk mencapai prestasi rangkaian yang optimum.

Dalam tesis ini, penjadualan yang dicadangkan, iaitu *Weighted Fair Queuing* dengan Kesedaran Saluran (CWFQ) dan algorithma Kesedaran Tempoh Beratur (QDA) telah

dihasil dan disiasat. CWFQ meningkatkan prestasi *goodput* melalui eksploitasi pada jaringan tanpa wayar untuk mencapai penggunaan spektrum yang lebih cekap. Paket data yang mempunyai keadaan saluran yang lebih baik akan diberi keutamaan servis yang lebih tinggi. Manakala algorithma QDA meningkatkan CWFQ dari segi prestasi kelambatan dengan memberi keutamaan yang tinggi kepada paket yang telah lama beratur dalam *buffer*. Ini dapat mengurangkan tempoh paket data menunggu untuk mendapatkan serviks.

Simulasi yang menyeluruh telah dijalankan untuk menyiasat prestasi algorithma CWFQ dan QDA. Bagi CWFQ, hasil kajian menunjukkan bahawa CWFQ dapat meningkatkan prestasi goodput dan ratio penerimaan paket (PDR) bagi aliran *real time polling service* (rtPS) berbanding dengan WFQ, dengan peningkatan sebanyak 19.4% dan 21.5% dalam senario statik, 12.4% and 13.5% dalam senario bergerak. Ini menunjukkan bahawa CWFQ dapat mengeksploitasi rangkaian tanpa wayar dan meningkat penggunaan spektrum dengan lebih effektif. Bagi algorithma QDA, hasil kajian menunjukkan bahawa CWFQ+QDA telah mencapai peningkatan sebanyak 36.3% dan 79.4% dari segi purata kelambatan dalam senario statik dan bergerak, berbanding dengan GWFQ yang telah wujud. Pencapaian ini disebabkan oleh algorithma QDA memberi keutamaan kepada paket data yang telah lama beratur dan menunggu untuk mengelak kebuluran serviks ke atas paket-paket data tersebut. Ini menunjukkan algorithma QDA dapat meningkatkan prestasi kelambatan CWFQ.

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LIST OF ABBREVATIONS

AMC	Adaptive Modulation and Coding
BS	Base Station
CBR	Constant Bit Rate
CINR	Carrier to Interference and Noise Ratio
CSI	Channel State Information
DL	Downlink
FN	Finish Number
FTP	File Transfer Protocol
GWFQ	Garroppo-Weighted Fair Queuing
HOL	Head-of-Line
MAC	Medium Access Control
MRR	Minimum Reserved Rate
MS	Mobile Station
nrtPS	Non-real Time Polling Service
OFDM	Orthogonal Frequency Division Multiplexing
OWFQ	Opportunistic Weighted Fair Queuing
PDR	Packet Delivery Ratio
PHY	Physical
PMP	Point-to-multipoint
QoS	Quality of Service
rtPS	Real Time Polling Service
SS	Subscriber Station
UL	Uplink
WFQ	Weighted Fair Queuing

CHAPTER 1

INTRODUCTION

1.1 Background

Worldwide Interoperability for Microwave Access (WiMAX) is one of the best alternatives to provide the last mile broadband access due to its ability to provide large coverage area, high data rates, low cost of system deployment, and support of Quality of Service (QoS) to various types of network traffic. The basic WiMAX network architecture consists of one base station (BS) and several subscriber stations (SSs) or mobile stations (MSs). In general two types of network topologies are supported in WiMAX, mesh and point-to-multipoint (PMP). In mesh network topology, a SS is allowed to communicate directly to the BS and other SSs. In PMP network topology, the SS has to communicate and interchange packets and data through the BS. This type of network setup gives the ultimate authority to the BS to control the network activities and allocate network resources. Traffic from the BS to the SSs is defined as the downlink (DL) traffics while traffic from the SSs to the BS is classified as the uplink (UL) traffic.

To ensure an efficient and effective resource management and allocation as well as the provisioning of QoS, WiMAX introduces connection admission control (CAC) and scheduling mechanisms at the Medium Access Control (MAC) layer. CAC regulates the admitted and incoming connections or service flows to control the traffic loads. This helps to ensure the congestion and QoS of the packet-level and connection-level are manageable and sustainable (Jinchang & Maode, 2009). A SS is admitted into the network only if the QoS requirement of its service flow can be satisfied without affecting other existing service flows. On the other hand, the primary task of the scheduling algorithm is to distribute and allocate network resource fairly and adequately to all SSs. The allocated resource to each SS must be able to cater the diverse QoS requirements of different service flows. Since different types of applications and service flows can co-exist in the network, this increases the challenge to design and implement an effective and efficient scheduling algorithm into the network system. Some of the desirable characteristics for an efficient scheduling algorithm are discussed in the literature (Skrikar, 1999; Yaxin & Li, 2001; So-In, Jain, & Tamimi, 2009). One of characteristics is the flexibility of the scheduler's design, where the scheduler can be deployed in different scenario and network setup without affecting the network performance. Besides, the ability to provide optimum fairness performance in terms of the resource allocation and service opportunity among the service flows is crucial to avoid starvation. Most of the scheduler designs give high priority of service opportunity and resource allocation to real-time service flows due to its delay stringent property. Nevertheless, the QoS requirement of non-real time packet should not be neglected. The service of non-real time packet should not be starved and has to be treated accordingly. Lastly, the scheduler has to be able to utilize the network resource efficiently because the network resource is scarce and limited.

1.2 Problem Statements and Motivation

Weighted Fair Queuing (WFQ) is one of the premier queuing techniques used by Cisco in the routers (Bollapragada, White, & Murphy, 2008). It provides the optimum throughput performance as well as achieving fairness to all active flows (Cisco, QoS Congestion Management (Queueing) - WFQ). Nevertheless, WFQ has inferior delay performance due to the lack of delay control mechanism (Asadi & Wei, 2011). A few researches have focused on the opportunistic based WFQ (Khawam & Kofman, 2006; Iera, Molinaro, & Pizzi, 2007; Garroppo, Giordano, Iacono, & Tavanti, 2012), where the opportunistic feature is embedded into the WFQ scheduling structure. Most of the research works focus on the achievement of network goodput. Other important benchmark parameters, such as average end-to-end delay and packet delivery ratio (PDR) are overlooked. These performance parameters are equally important as they indicate the ability of the scheduler to meet the QoS of the service. The challenges are in light of the following problems and motivations.

1.2.1 Opportunistic Mechanism

The previous research works done by Khawam et al. and Garroppo et al. have used the similar concept to embed the opportunistic feature into the WFQ scheduling structure. Khawam et al. (Khawam & Kofman, 2006) defines the link capacity as the weight, and the opportunistic parameter is represented by a random variable that is used to indicate the strength of link due to the casting of Rayleigh fading. On the other hand, Garroppo et al. (Garroppo, Giordano, Iacono, & Tavanti, 2012) uses the number of bits per symbol of the type of modulation and coding used by the link as the opportunistic parameter.

For the proposed CWFQ, Carrier to Interference and Noise Ratio (CINR) is used as the opportunistic parameter. CINR is the ratio of carrier or signal power to the total noise power, including the white noise and interference in a specified bandwidth (Cisco, 2006). In WiMAX system, CINR is the main parameter to dictate the burst profile used by the connection in link adaptation mechanism (Nuaymi, 2007) whose main principle is to choose the most appropriate modulation and coding scheme (MCS) in order to achieve optimum physical data rates for the transmission links. Thus, CINR represents the robustness of the link to contend with the variation of the wireless medium. Moreover, the support of the wireless technology for the mobility of the devices has become essential due to the immense increase of the mobile telecommunication devices such as laptops, smart-phones and tablets. With the receivers' movement, multipath fading influences the transmissions of data packets and affects the network performance such as system throughput (Kaarthick, Yeshwenth, Nagarajan, & Rajeev, 2009; Ahmad & Habibi, 2008). Therefore, there is a need to conduct a performance study of the schedulers in mobility scenario to observe the impact of receivers' mobility into the network performance.

1.2.2 End-to-end Delay Issue

WFQ operates on the concept of Generalized Processor Sharing (GPS), which promotes simultaneous share of the sessions in terms of the service and resource for multiple sessions (Garroppo, Giordano, Iacono, & Tavanti, 2012). The scheduler serves several tasks at the same instant. While this concept provides outstanding fairness performance, it may compromise the ability of the scheduler to satisfy delay requirement of the real time service flow, which has the stringent delay requirement and requires extra care and treatment to meet its QoS condition.

1.3 Research Aim and Objectives

In this thesis, an opportunistic based WFQ, called channel-aware WFQ (CWFQ) scheduling algorithm is proposed. Different to the previous research works, CWFQ uses CINR as the opportunistic parameter to allow the scheduling algorithm to exploit the variation of the wireless channel. Secondly, a duration awareness algorithm called Queue Duration Aware (QDA) algorithm is proposed to improve the delay performance of CWFQ. QDA observes the packet queue duration and gives high priority to packet with longer queue duration.

In light of the problem statement and the challenges, objectives have been determined to achieve the aim of this thesis. These are as follows:

- To design and develop the proposed CWFQ algorithm to improve the performance of goodput and PDR
- To improve the performance of the average end-to-end delay of CWFQ using the proposed QDA algorithm.
- To evaluate the effectiveness of CWFQ and QDA algorithm with respect to WFQ and GWFQ (Garroppo, Giordano, Iacono, & Tavanti, 2012) scheduling algorithms in static and mobile scenario.

1.4 Research Module

Figure 1.1 shows the direction of the research module for the proposed algorithms. The bold lines from the figure represent the direction followed in this thesis to achieve the stated objectives and aims whereas the dotted lines represent other existing researches.

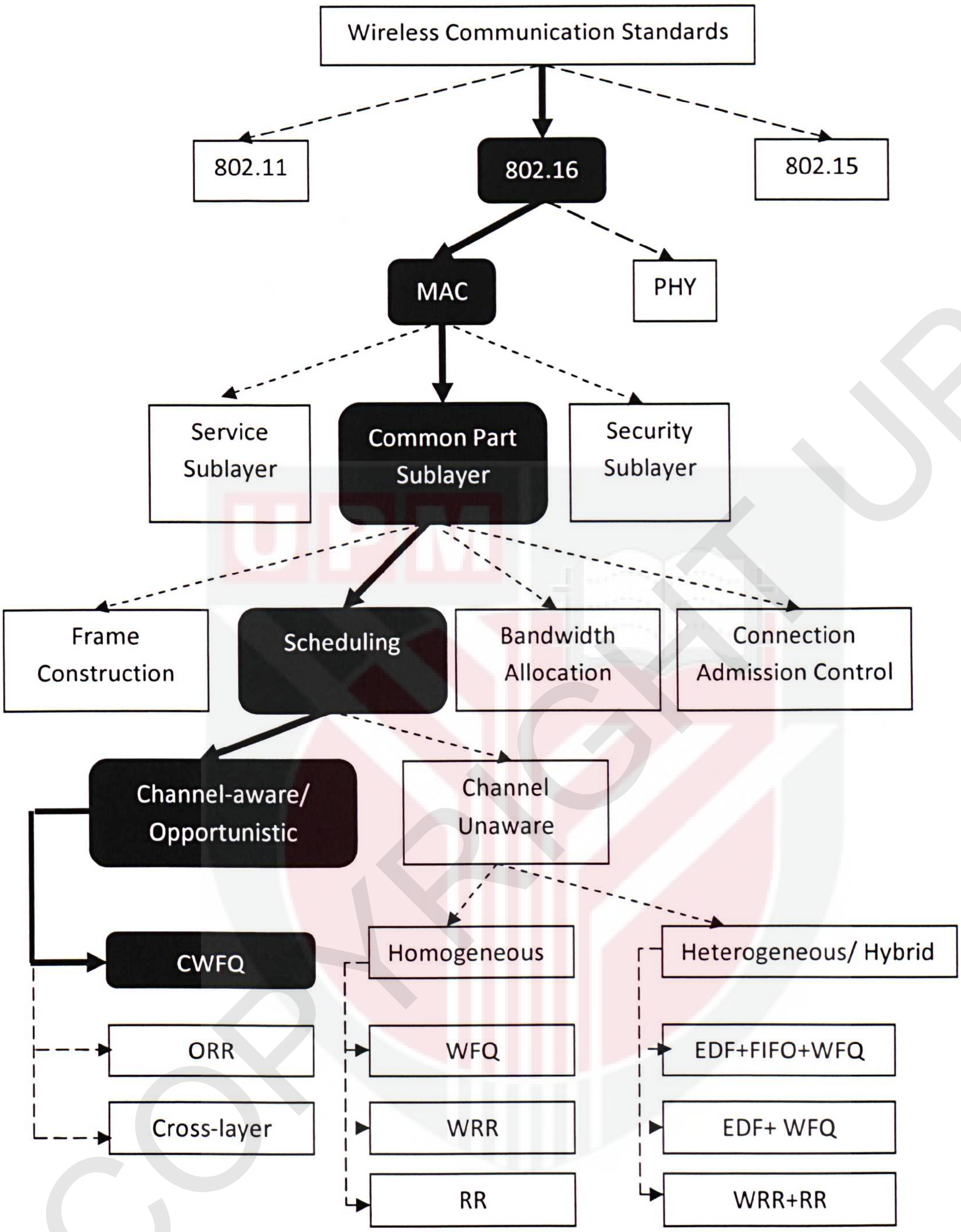

Figure 1.1: Research Study Flow

1.5 Thesis Organization

This thesis is organized into five chapters. Chapter one provides a simplified overview of this research together with several objectives outlined. A few problem statements are highlighted to provide an insight to the problem of WFQ researches.

Chapter two provides a literature review that explains the fundamental knowledge on WiMAX and the scheduling structure of WFQ. Chapter three explains the theory and the implementation of CWFQ and QDA algorithms in detail. In chapter four, the simulation parameter and the performance of CWFQ and QDA algorithms are discussed. The performance of the proposed CWFQ and QDA algorithms are compared to WFQ and GWFQ (Garroppo, Giordano, Iacono, & Tavanti, 2012). Finally, chapter five summarizes the findings of research, its contribution and recommendations for further study.

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