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Performance Optimization with Efficient Polling Mechanism in IEEE 802.16 Networks with Cross-Layer Consideration

Fei Yin · Guy Pujolle · Jong Hyuk Park · Han-Chieh Chao

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Abstract IEEE 802.16 standard suite defines a reservation-based bandwidth allocation mechanism. A SS (Subscriber Station) has to be polled to request bandwidth reservation before transmits uplink data to a BS (Base Station). In this mechanism exist two main polling modes: the unicast polling mode and the contention-based polling mode. The different polling operations in MAC (Medium Access Control) result in different PHY (PHYsical layer) frame structure that deeply affect the performance. Therefore, there should be an optimal scheme to adopt these two polling modes in order to optimize the performance. Although the standard defines five service classes to adaptively use the polling modes to fit the QoS (Quality of Service) requirements of different applications, it does not specify exactly a scheme to adopt these two polling modes efficiently and fairly during the polling process. In this paper, we investigate the polling mechanisms in IEEE 802.16 networks, and focus the attention on the performance caused by different adoption schemes. We also propose a simple but efficient polling mechanism to optimize the performance. The simulation results verify

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F. Yin (✉) · G. Pujolle
LIP6, University Paris 6, 104 Avenue du Président Kennedy, 75016 Paris, France
e-mail: Fei.Yin@lip6.fr; Fei.Yin@univ-paris13.fr

G. Pujolle
e-mail: Guy.Pujolle@lip6.fr

Present Address:
F. Yin
L2TI, Institut Galilée, University Paris 13, 99 Avenue J-B Clément, 93430 Villetaneuse, France

J. H. Park
Department of Computer Science and Engineering, Kyungnam University, 449 Wolyoung-dong, Masan, Kyungnam, 631-701 Korea
e-mail: parkjonghyuk1@hotmail.com

H.-C. Chao
College of Electrical Engineering and Computer Science, National Ilan University, I-Lan, Taiwan, ROC
e-mail: hcc@mail.niu.edu.tw

that the performance is conditioned to the fulfillment of the polling mechanisms and our proposed optimal polling scheme can allocate bandwidth more efficient and achieve better performance.

1 Introduction

BWA (Broadband Wireless Access) has gained a particular attention during the past decades. Many technologies have been developed to offer BWA solutions to the end users. The IEEE 802.11 WLAN (Wireless Local Area Network) technologies are the most successful in recent years, the high-speed large data transmission, for the first time, was realized in an indoor environment. Although IEEE 802.11 WLAN-based BWA technologies are suitable for indoor BWA solution, they suffer from the disadvantages of the short range, bad QoS and non mobility support that do not work well in outdoor environments.

Outdoor BWA technologies promise to deliver a wide range of data and information services to business and residential customers quickly and cost-effectively. Unfortunately, that promise has been imperfectly met in the past because of both the immaturity of the existing technologies and the relatively high cost of networking equipment. In response to the demands of outdoor BWA solution, the IEEE 802.16 working group was set up to develop global standards and recommended practices to support the development and deployment of BWA solutions in WMANs (Wireless Metropolitan Area Networks). That emerges IEEE 802.16 standards, a suite of air interface specifications intended for providing high bandwidth wireless voice, video and data for residential and enterprise in fixed, portable and mobile environment. From this time, the outdoor BWA has gained the maturity it lacked and is truly ready for utilization within metropolitan networks.

The original IEEE 802.16 standard, IEEE 802.16-2001, defines the air interface and MAC protocol for LOS-based (Line-Of-Sight) wireless broadband system operating in the 10-66 GHz millimeter wave band. The standard specified a PHY layer named Wireless-MAN SC that used single-carrier modulation technique, and a MAC layer with a burst TDM (Time Division Multiplexing) structure that supported both FDD and TDD. The standard supports multiple services simultaneously with full QoS, including IPv4, IPv6, ATM, Ethernet, etc. A connection-oriented bandwidth on demand mechanism is defined to efficient use of spectrum. In 2003, an amendment named IEEE 802.16a was developed, which covers enhanced MAC specification and additional OFDM-based (Orthogonal Frequency Division Multiplexing) PHY specifications in support of the NLOS-based (Non-Line-Of-Sight) wireless broadband services at both licensed and license-exempt 2-11 GHz frequency bands. In 2004, the IEEE 802.16-2004 [4] was published, which is actually an amalgamation of all previous standards. It defines the air interface and MAC protocol for a current fixed wireless metropolitan area network to provide high bandwidth wireless voice, video and data for residential and enterprise in licensed and license-exempt frequencies bands for the both LOS and NLOS transmission. In 2005, the IEEE 802.16e [5] was completed to support the BWA from fixed to mobile service provision up to vehicular speeds. These standards offer a variety of fundamentally different design options in PHY and MAC specifications. They were developed to suit a variety of applications and deployment scenarios, and hence offer a plethora of design choices for system developers. The summary of basic characteristics of various IEEE 802.16 standards is shown in Table 1.

In IEEE 802.16 networks, two kinds of stations are defined: BS and SS. The BS and the SSs can operate in two modes: a mandatory PMP (Point-to-MultiPoint) mode and an optional mesh mode. In the PMP mode, a centralized BS is capable of connecting multiple

Table 1 Basic characteristics on IEEE 802.16 standards

	802.16-2001	802.16a-2003	802.16d-2004	802.16e-2005
Frequency bands	10-66 GHz	2-11 GHz	2-11, 10-66 GHz	2-6 GHz
Operation modes	LOS	NLOS	LOS, NLOS	LOS, NLOS
Topology	PMP	PMP, mesh	PMP, mesh	PMP, mesh
Air interface	SC	SC	SC	SC
		SCa	SCa	SCa
		256-OFDM	256-OFDM	256-OFDM
		2048-OFDMA	2048-OFDMA	SOFDMA
Modulation	QPSK	QPSK	QPSK	QPSK
	16QAM	16QAM	16QAM	16QAM
	64QAM	64QAM	64QAM	64QAM
Data Rate	134.4 Mbps	75 Mbps	75 Mbps	28 Mbps
Multiplexing	TDMA	TDMA	TDMA	TDMA
		OFDMA	OFDMA	OFDMA
Duplexing	TDD, FDD	TDD, FDD	TDD, FDD	TDD, FDD
Mobility	Fixed	Fixed	Fixed	Mobile

SSs to various public networks, the traffics can only occur between the BS and the SSs. In the mesh mode, the SSs can also serve as routers by cooperative access control in a distributed manner. The communication between the BS and the SSs has two directions: uplink (from the SSs to the BS) and downlink (from the BS to the SSs). The downlink transmission is on a broadcast basis to all SSs, while the uplink bandwidth is shared by the SSs on a demand basis. The uplink and the downlink transmissions can operate in different frequencies using FDD (Frequency Division Duplexing) mode or at different time using TDD (Time Division Duplexing) mode. Figure 1 illustrates an example of general architecture of PMP mode IEEE 802.16 networks. The fixed or mobile CPEs (Customer Premise Equipment) connect to the central BS; the BS receives the transmissions from multiple sites and sends them to internet directly or via other BSs. The end users (laptop, telephone, computer, etc) inside the building, through in-building networks such as Ethernet or WLAN, can connect to an outside CPE and then link to the IEEE 802.16 network.

Since the spectrum is a scarce resource, resource management is always a crucial issue for guaranteeing QoS in wireless networks. Several technologies are defined in IEEE 802.16 to efficient utilize the resource. A Polling-Request-Grant mechanism is such a method, which is used to allocate bandwidth in uplink channels: the SSs first have to be polled to request uplink bandwidth before it can transmit data during certain granted bandwidth. In order to accommodate a variety of traffics (including data, voice, and video), the standard also define five scheduling service classes to support different QoS requirements from the traffics: UGS (Unsolicited Grant Service), ertPS (extended real-time Polling Service), rtPS (real-time Polling Service), nrtPS (non-real-time Polling Service) and BE (Best Effort). Although the MAC operations are well defined in the IEEE 802.16 standard, the efficient resource management is still an open issue. In this article, we focus on the evaluation of performance with different polling mechanisms in a PMP mode. We want to find out a polling mechanism, to efficiently allocate resource in PHY uplink channel in order to optimize the performance.

The rest of the paper is organized as follows. In Sect. 2 we present an insight of some general MAC features in the IEEE 802.16. In Sect. 3 we describe the problem of polling