Journal of Network and Computer Applications 35 (2012) 2092–2104

Contents lists available at SciVerse ScienceDirect

Journal of Network and Computer Applications

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

A best block exploring algorithm for two-dimensional downlink burst construction in IEEE 802.16 networks

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ARTICLE INFO

Article history:
Received 30 April 2012
Received in revised form
26 July 2012
Accepted 20 August 2012
Available online 1 September 2012

Keywords:
IEEE 802.16
Burst construction
Downlink
OFDMA

ABSTRACT

Various burst construction algorithms for Orthogonal Frequency Division Multiple Access (OFDMA) were proposed. However, these algorithms did not consider the downlink burst characteristics that are specified in IEEE 802.16 standard. This work therefore presents the Best Block-Oriented (BBO) algorithm. BBO not only complies with the downlink burst characteristics, but also addresses three further issues that are important to obtain high throughput: BBO reduces external fragment by shrinking a burst to fit into the available bandwidth area if the available area is otherwise insufficient to accommodate it; BBO shrinks the burst area to minimize internal fragment if the requested bandwidth has been satisfied; to find the subchannels that have good channel quality, BBO evaluates the channel quality of subchannels and constructs the burst in the subchannels that provide the highest throughput. Simulation results show that BBO yields 1.2–9 times the throughput that has been achieved using previous algorithms under a heavy load.

1. Introduction

Since IEEE 802.16 standard adopts Orthogonal Frequency Division Multiple Access (OFDMA) to provide the wide radio coverage and high bandwidth for data transmission, the bandwidth resources are represented as a two-dimensional area of slots (Lu and Ma, 2011; Batistatos et al., 2012; Domingo, 2012; IEEE P802.16Rev2/D1, 2007). The two dimensions are time which takes a symbol as a unit and frequency which takes a subchannel as a unit. Accordingly, the bandwidth allocation in IEEE 802.16 must involve the construction of a two-dimensional bandwidth area, called a burst which is assigned to a connection.

Subchannel diversity and the burst structure must be taken into account in the construction of bursts. Subchannel diversity refers to the fact that a connection uses a different modulation coding scheme (MCS) in various subchannels because the connection encounters various channel qualities in the different subchannels (Einhaus et al., 2008). Hence, the burst of each connection should be constructed in its best-quality subchannels, which are the subchannels in which the connection encounters the optimal channel quality in order to maximize the bandwidth utilization. However, the burst structure must also comply with the specifications in the IEEE 802.16 standard to reduce the overhead of management messages (IEEE P802.16Rev2/D1, 2007; Ben-Shimol et al., 2006). These specifications are as follows: (1) the burst must be a continuous bandwidth area; (2) the shapes of the bursts that are used in downlink and uplink transmission must be rectangular and multi-rectangular, respectively, and (3) one burst must use only one MCS based on the worst signal-to-noise ratio (SNR) of the assigned subchannels.

Some researchers have therefore treated the burst construction problem as a variant of the Bin Packing problem (Ben-Shimol et al., 2006). The Enhanced One Column Striping with Non-Increasing Area First Mapping Algorithm (eOCSA) constructs each burst from the bottom right to the top left of the available bandwidth area (So-In et al., 2009). The Weighted Less Flexibility First (WLFF) algorithm constructs each burst on the best edge in the free bandwidth area[1] (Wang et al., 2008). The best edge is the edge on which a constructed burst generates the minimal variance of the sub-areas in the free bandwidth area. Accordingly, constructing the burst on this best edge maximizes the flexibility of the subsequent burst construction. However, eOCSA and WLFF conform to the above specifications (1) and (2), but they completely neglect subchannel diversity and fail to conform to specification (3). Therefore, Channel-aware Downlink Burst Allocation (CDBA) considers the subchannel diversity and the above three specifications, and it constructs the burst on the continuous subchannels that all use the highest MCS (Shih et al., 2010). However, commonly, only a few continuous subchannels that

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[1] Free bandwidth and available bandwidth are used interchangeably in this paper.

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http://dx.doi.org/10.1016/j.jnca.2012.08.012

adopt the highest MCS, and these subchannels are too few to accommodate the bursts, resulting in unacceptable throughput.

To maximize throughput, three further issues must be addressed. First, external fragmentation may occur because the downlink burst is a continuous rectangular bandwidth area. Therefore, the available slots suffice to satisfy a burst's requested bandwidth, but lack of contiguity may prevent their use by this burst. Hence, the external fragment must be minimized. Second, internal fragmentation, which means a burst has a capacity that exceeds the required bandwidth, may occur because of the rectangular shape of downlink burst or improper slot allocation. The internal fragment should be minimized because unused slots inside a burst are wasted. Third, the burst should find continuous subchannels that all have good SNRs to provide a satisfactory MCS. For convenience, these continuous subchannels are treated as a block.

This work proposes a heuristic downlink burst construction algorithm, Best Block-Oriented (BBO), to maximize the throughput. BBO conforms to the IEEE 802.16 downlink (DL) burst specifications and considers the above three issues. To minimize internal fragment, BBO shrinks the area of the burst (if the requested bandwidth has been satisfied) in order to enable other bursts to use unused slots that are inside this burst. To minimize external fragment, BBO also shrinks a burst to fit in the available bandwidth area if no available area is large enough to accommodate it. To find the optimal block, BBO evaluates the adopted MCS of each available block and constructs the burst in the block in which the burst can provide the highest throughput.

This paper is organized as follows. Section 2 reviews the literature on the IEEE 802.16 network and downlink burst construction. Section 3 presents the problem of downlink burst construction and related issues. Section 4 describes the proposed BBO algorithm. Section 5 demonstrates by simulation that BBO outperforms eOCSA, WLFF, and CDBA. Finally, Section 6 draws conclusions.

2. Background

2.1. IEEE 802.16 network

The IEEE 802.16 network is composed of a base station (BS) and several subscriber stations (SSs). The BS provides connectivity, radio resource management, and control of SS, which supports connectivity with the BS.

The two layers in the IEEE 802.16 protocol stack are the physical layer, which transfers raw data, and the MAC layer, which supports the physical layer by ensuring that the radio resources are efficiently used. The three duplex modes in the physical layer with OFDMA are Time Division Duplex (TDD), Frequency Division Duplex (FDD), and Half-duplex Frequency Division Duplex (H-FDD). The TDD is the preferred duplex mode because it is the most flexible. The modulation method – quadrature phase shift keying (QPSK), 16 quadrature amplitude modulation (16QAM), or 64 quadrature amplitude modulation (64QAM) – is selected along with the associated coding rate for data transmission based on the channel quality, which is determined by the signal-to-noise ratio (SNR).

An IEEE 802.16 frame for downlink and uplink transmissions is divided into downlink (DL) and uplink (UL) subframes in the time domain of the TDD (right part of Fig. 1). A burst is an allocated bandwidth that is assigned to one dedicated connection of one SS, and a burst is formed by slots. A slot is the smallest unit of allocated bandwidth, and it comprises one subchannel and one to three symbols. A subchannel is the smallest allocation unit in the frequency domain, and a symbol is the smallest allocation unit in the time domain. Some other fields in a frame perform specific functions. For example, Preamble synchronizes each SS; DL/UL-MAP specifies the position and area measurement of each downlink/uplink burst, and Frame Control Header (FCH) specifies both the DL subframe prefix and the length of DL-MAP message.

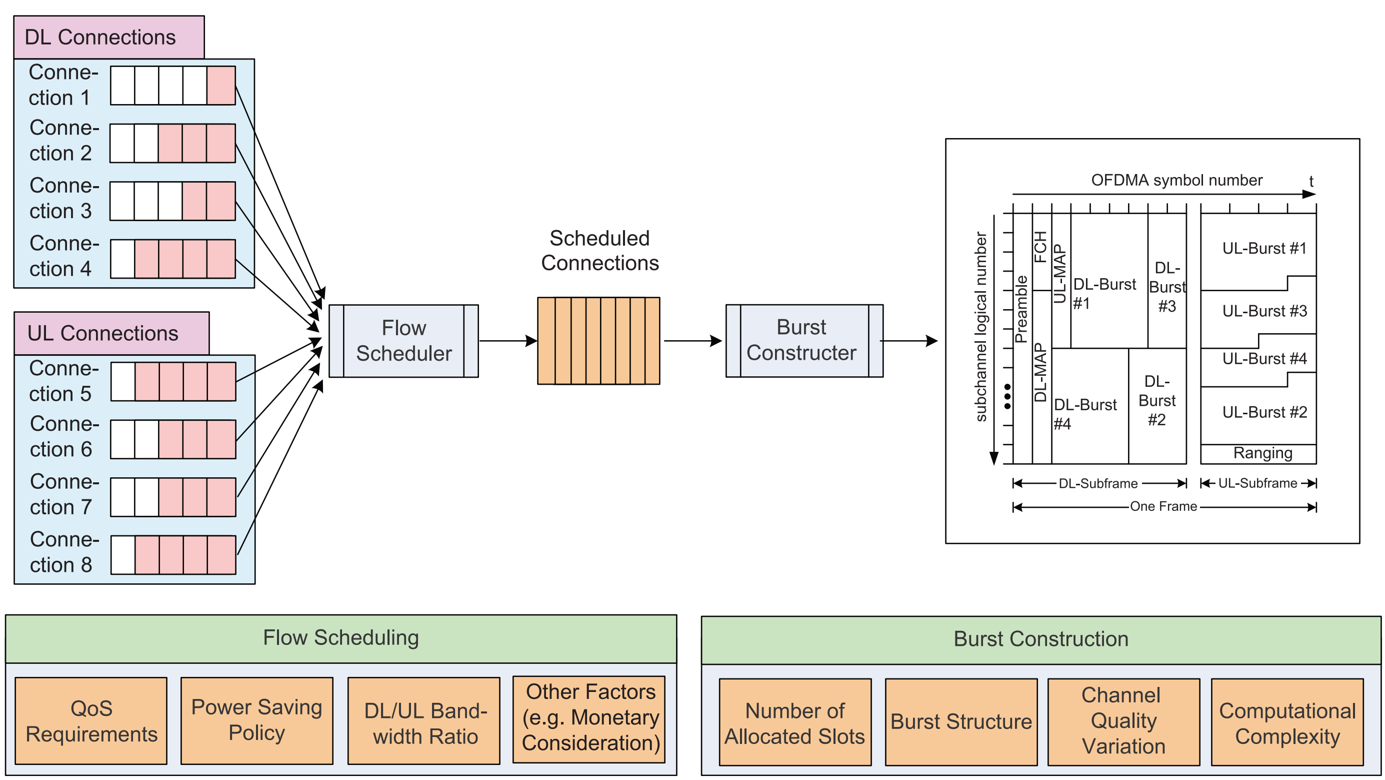

Fig. 1. Bandwidth allocation in IEEE 802.16 network.