Abstract The IEEE 802.16e standard specifies a connection-oriented centralized Medium Access Control (MAC) protocol, based on Time Division Multiple Access (TDMA), which adds mobility support defined by the IEEE 802.16 standard for fixed broadband wireless access. To this end, Orthogonal Frequency Division Multiple Access (OFDMA) is specified as the air interface. In OFDMA, the MAC frame extends over two dimensions: time, in units of OFDMA symbols, and frequency, in units of logical sub-channels. The Base Station (BS) is responsible for allocating data into the frames so as to meet the Quality of Service (QoS) guarantees of the Mobile Stations’ (MSs) admitted connections. This is done on a frame-by-frame basis by defining the content of map messages, which advertise the position and shape of data regions reserved for transmission to/from MSs. We refer to the process of defining the content of map messages as frame allocation. Through a detailed analysis of the standard, we show that the latter is an overly complex task. We then propose a modular framework to solve the frame allocation problem, which decouples the constraints of data region allocation into the MAC frame, i.e. the definition of the position and shape of the data regions according to a set of scheduled grants, from the QoS requirements of connections. Allocation is carried out by means of the Sample Data Region Allocation algorithm (SDRA), which also supports Hybrid Automatic Repeat Request (H-ARQ), an optional feature of IEEE 802.16e. Finally, we evaluate the effectiveness of SDRA by means of Monte Carlo analysis in several scenarios, involving mixed Voice over IP (VoIP) and Best Effort (BE) MSs with varied modulations, with different sub-carrier permutations and frequency re-use plans.

Keywords IEEE 802.16 · Medium access control protocols · Resource allocation
3.1 Introduction

During the last few years, we have witnessed a daunting increase of the use of electronic communication devices in everyday life. This is due to the spread of sophisticated handheld equipments, such as mobile phones and palmtops, which are available at an increasingly lower cost. This has boosted a technology advance in the area of mobile Broadband Wireless Access (BWA), since these devices, by necessity, cannot rely on the use of wired connections. A by-product of these two factors is that people are becoming more and more accustomed to portable communication devices, which, in turn, produces unforeseen needs and requirements. For instance, the well-known GSM technology, primarily targeted at traditional voice applications, has recently moved towards the GPRS/EDGE architectures for packet-based data transmission. Packet access is also implemented for multimedia services in UMTS, by means of High-Speed Downlink/Uplink Packet Access (HSDPA/HSUPA), in addition to the legacy code-division multiple access (CDMA) based circuit-switched mode.

In the context of mobile BWA, a novel standard has been published recently by the IEEE, namely IEEE 802.16e [1], which extends the 2004 version of IEEE 802.16 for fixed BWA [2,3], so that high transmission efficiency for mobile users is coupled with Quality of Service (QoS) support to enable multimedia services. A non-profit association, the Worldwide Interoperability for Microwave Access (WiMax) forum, was formed to define the specifications for compatibility and interoperability of the IEEE 802.16 wireless equipments. According to the WiMax forum, Orthogonal Frequency Division Multiple Access (OFDMA) is the target air interface for mobile BWA with IEEE 802.16e. In fact, OFDMA has been shown to provide mobile users with an improved resilience against multi-path fading in non-line-of-sight environments, with respect to alternative technologies, like FDM/TDM and CDMA, which are used in competing mobile wireless standards, respectively GPRS, EDGE, and UMTS [4]. Furthermore, a multiple access technique based on OFDMA has been proposed by the 3GPP consortium as the downlink air interface in the context of the Long Term Evolution (LTE) project, which is an ongoing effort to lead the current UMTS standard towards 4G wireless technologies [5].

An IEEE 802.16e cell consists of a number of Mobile Stations (MSs) served by a Base Station (BS), which controls the access to the wireless medium in a centralized manner. Before transmitting to/receiving from the BS, any MS must request the admission of a new connection. If the connection is accepted, the BS is then responsible for meeting the requested QoS guarantees. The access to the medium is scheduled on a frame basis. MAC frames extend over two dimensions: time, in units of OFDMA symbols, and frequency, in units of logical sub-channels [4]. Data packets are thus conveyed into bi-dimensional (i.e. time and frequency) data regions, which are advertised by the BS via specific in-band control messages, which share the same resources as data. In the following, the process of defining the content of maps is referred to as frame allocation, which is left unspecified by the standard. Since the frame allocation problem is a complex task, which can significantly impact on the overall performance of the system, we propose a modular framework