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A Review on IEEE 802.16 Standards and their comprehensive analysis

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Abstract- *In the new era of communication, WiMAX (IEEE 802.16) is the most emerging technology that enables ubiquitous delivery of broadband wireless access for fixed and mobile users. It is a more innovative and commercially viable alternative to cable modems and DSL technologies as it is cost effective, easy to implement, high performance and high resource utilization technology. This economic environment has led to the development of the IEEE 802.16 standards [1] to support broadband wireless multi-service access in metropolitan area. In addition, the Worldwide Interoperability for Microwave Access (WiMAX) Forum [2] has been formed which promotes the technology and provides compatibility and interoperability for 802.16 -based products. Accordingly, the term WiMAX is often used interchangeably with IEEE 802.16 technologies. WiMAX a wireless standard which uses orthogonal frequency division multiple access (OFDMA) and promises to offer mobile broadband services even at a vehicular speed of up to 120 km/h. WiMAX complements the third generation (3G) wireless standards and the wireless local area networks (WLANs) on coverage and data rate. IEEE 802.16e-based WiMAX is the standard that is likely to dominate the fourth generation (4G) wireless world. WiMAX needs no line of sight for a connection and covers a larger coverage area than WLAN and is comparatively less costly compared to the current 3G cellular standards. Although the WiMAX standard supports both fixed and mobile broadband data services, the latter have larger demand. In WiMAX, quality of service (QoS) is provided through scheduling of the different types of traffic classes defined by the standard. Each class has its own bandwidth requirements as well as its QoS, which has to be maintained. This paper reviews and compares different types of connections defined in the WiMAX standard and provides an overview of the state-of-the-art mobile WiMAX technology and its development, the Mobile WiMAX standard, the development of the standards to support mobile multihop relays in a WiMAX network and applications of WiMAX are provided.*

Keywords- *IEEE 802.16, WiMAX, QoS, OFDMA, Scheduling.*

1. Introduction

Before the development of IEEE 802.16 standard, the effective ways to obtain access to broadband internet services were mainly through T1, Digital Subscriber Line (DSL), or cable modem based connections. However, these wired infrastructures are costlier, especially for deployment in rural areas and developing countries. This limitation propelled the industry to devise an alternative means of obtaining broadband internet access and the wireless medium was selected as the viable approach. In the

hierarchical architecture, base stations (BSs) are connected to the core network by one or many centralized network elements, such as the radio network controller (RNC) and the general packet radio service (GPRS) serving node (GSN) in Universal Mobile Telecommunications System (UMTS) networks [3], or the access service network gateway (ASN-GW) in mobile WiMAX networks [4]. Such centralized controllers manage all the control contexts of mobile nodes (MNs) that are attached to the BSs under their supervision. They also handle data traffic flow between the core network and the BSs, so all user traffic always goes through these centralized controllers. The name WiMAX was proposed by the WiMAX Forum, a consortium of about 420 members including major corporations like AT&T, Fujitsu, Intel and Siemens, was set up in June 2001 to promote conformance and interoperability of the technology and promote its commercial use in the market. The WiMAX Forum and IEEE 802.16 subcommittee are both involved in the development of open standards based broadband wireless networks. The IEEE 802.16 subcommittee is purely a technical body that defines the 802.16 family of broadband wireless radio interface standards. IEEE 802.16 defines the layer 1 (physical, also referred asPHY) and layer 2 (data link or Media Access Control - MAC) of the (Open Systems Interconnection) OSI seven layer network model. The IEEE 802.16 standard provides specification for the MAC and PHY layers for the air interface. The standard includes details about the various flavors of PHY layers supported and characteristics of the MAC layer such as bandwidth request mechanisms and the scheduling services supported. It does not define standardized network architecture beyond the base station. The WiMAX Forum fills this gap and creates an end-to-end broadband wireless network, so it prepares profiles for systems that comply with the IEEE 802.16 standard and create interoperability tests to ensure different vendors' implementation can work together. WiMAX supports high data rate applications with a variety of Quality of Service (QoS) requirements. Companies like Motorola and Samsung are already developing WiMAX phones and PDAs and they are already in use in Korea with WiMAX cousin technology, WiBRO (Wireless Broadband) [5].

The paper is broadly divided into eleven sessions. The first session opens with a brief introduction to networks and its types. A description of WiMAX (IEEE 802.16) networks is given in the first session and second session deals with literature review. The related research work published in this field WiMAX networks is properly reviewed and given in chronological order. Also, Standards, Certification profile, structure of the standard, comparison with other standards, QoS, QoS mechanism and services classes as prescribed by WiMAX are presented, this is followed by the applications of WiMAX. In last conclusions drawn and also an insight into the future work is presented.

In the new era of communication, WiMAX (IEEE 802.16) is the most emerging technology that enables ubiquitous delivery of broadband wireless access for fixed and mobile users. The IEEE 802.16 standard widely known as WiMAX (Worldwide Interoperability for Microwave Access), has been developed to accelerate the introduction of broadband wireless access into the marketplace. Prior to the introduction of the IEEE 802.16 standard, the most effective ways to obtain access to broadband internet service were mainly through T1, Digital Subscriber Line (DSL), or cable modem. However, these wired infrastructures are considerably more expensive, especially for deployment in rural areas and developing countries. This limitation propelled the industry to devise an alternative means of obtaining broadband internet access and the approach taken was via the wireless medium. The traditional wireless cellular networks have a hierarchical architecture in which centralized controllers facilitate resource management and mobility support in a highly efficient manner, typically for voice call services. Although they are designed primarily for wireless internet access, currently deployed mobile WiMAX networks also adopt this cellular-style hierarchical architecture, but they use less hierarchy. It is one of the most emerging technologies and provides an exciting range of additional features to the existing techniques for the broadband. It can also be treated as an alternative to the existing cable and DSL technologies as it has low cost and can be easily implemented. It also provides high data rate applications with a variety of Quality of Service (QoS) requirements. The famous companies like Motorola and Samsung are already developing WiMAX phones and PDAs and they are already in use in Korea with WiMAX cousin technology, WiBRO (Wireless Broadband) [5]. Nowadays

WiMAX is considered as one of the main technologies for next generation high speed wireless access networks. It gives a larger coverage compared to Wi-Fi while supporting string QoS and security mechanism because of its optimizable physical layer and too many adaptable capabilities. This latest innovative WiMAX technology is considered as one of the main standards for future wireless networks. Several technologies used by WiMAX, such as Orthogonal Frequency-Division Multiple Access (OFDMA) and resource allocation methods with differentiated QoS are parts of Next Generation Networks (NGN) standards [7]. Mobile WiMAX standard offers scalability in both radio access technology and network architecture; thus, it provides flexibility in network deployment and service offerings [8]. WiMAX can be convenient for Hybrid Networks, Local Area Networks or long range transmission thanks to MAC relays defined in 802.16j [9].

Key Features of WiMAX Networks [10]. The eight key features of WiMAX networks that differentiate it from other metropolitan area wireless access technologies are: use of Orthogonal Frequency Division Multiple Access (OFDMA), Scalable use of any spectrum width (varying from 1.25 MHz to 28 MHz), Time and Frequency Division Duplexing (TDD and FDD), Advanced antenna techniques such as beam forming, multiple input multiple output (MIMO), Per subscriber adaptive modulation, Advanced coding techniques such as space-time coding and turbo coding, Strong security and Multiple QoS classes suitable not only for voice but designed specifically for a combination of data, voice and video services.

2. Literature Review

In recent years, there has been a rapid growth in various wireless networks. Along with it, there is a multifold increase in demand for wireless data services and multimedia applications. To meet the growing demand and provide better services, there has been a lot of research in this field. In this session, a brief summary of current work in this field is presented.

Guerin and Peris [11] studied basic mechanisms and directions for providing Quality of Service in packet networks. They have investigated control path mechanisms that are needed to allow the users as well as network to agree on service definition and data path mechanisms which will enable to provision of differentiated services. These concepts have been adapted into IEEE 802.16 standard in providing the QoS support.

Chu *et al.* [12] proposed QoS architecture for the MAC protocol of IEEE 802.16 BWA system. It includes the traffic classifier, the SS's upstream scheduler and the BS's upstream and downstream schedulers. The architecture that provides QoS guarantees for 802.16 systems is based on priority scheduling and dynamic bandwidth allocation. It also proposes efficient scheduling strategy for the schedulers.

Wongthavarawat and Ganz [13] present an integrated scheduling algorithm and an admission control policy by which the bandwidth is allocated among different service classes according to the fixed priority of each traffic class strictly. They propose a centralized system, where the QoS architecture is based in the BS and the scheduling or the admission control algorithms are also managed by the BS.

Nair *et al.* [14] present the MAC protocols used in the WiMAX networks and discuss the types of provisioning and Quality of Service (QoS) that can be achieved using the features of this MAC protocol to facilitate the WiMAX deployments. They cover implementation challenges of the WiMAX MAC to achieve QoS goals.

A general framework of a cross-layer network-centric solution is presented by Zhang *et al.* [15]. They have described the recent advances in network modeling, QoS mapping and QoS adaptation in term of providing end-to-end QoS for video delivery over wireless internet.

Alavi *et al.* [16] present an inclusive QoS architecture for IEEE802.16 standards. The architecture supports QoS mechanisms in IEEE 802.16 standards. They contend that although the IEEE 802.16 standard defines different mechanisms to provide QoS requirements, the challenge lies in developing efficient design to meet those requirements. This makes providing QoS, a challenging issue. To overcome this issue, they put forward a design approach to implement the proposed architecture for all kinds of traffic

classes defined in the standard.

QoS support in IEEE 802.16 networks has been covered by Cicconetti *et al*. [17]. They have evaluated performance of the networks using a prototypical simulation for IEEE 802.16 protocol.

An analysis and discussion of the performance of the five scheduling algorithms, namely UGS, ertPS, rtPS, nrtPS and BE, is discussed by Lee *et al*. [18]. Through the analysis of resource utilization efficiency and VoIP capacity, they have identified some of the bottlenecks in Unsolicited Grant Service (UGS) and real-time Polling Service (rtPS). The performance of UGS suffers due to waste of uplink resources. In rtPS there is an additional access delay and MAC overhead due to bandwidth process in rtPS algorithm for delivery of VoIP services.

Sayenko *et al*. [19] put forward a paper for ensuring the QoS requirements in 802.16 scheduling. They describe a scheduling solution for the WiMAX base station. The scheduling policy i.e. the algorithm to allocate slots in not defined in WiMAX specifications. It is open for alternative implementation. Their simulation results reveal that the proposed scheduling algorithm ensures QoS requirements for all WiMAX service classes.

3. Structure of The Standard

The Mobile WiMAX specifications basically consist of the document for the fixed system (IEEE 802.16-2004 Air Interface standard), the document for the mobile system (IEEE 802.16e amendment), and the document for the higher-layer networking from the WiMAX Forum. The first two documents define specifications for the PHY layer (such as the frame structure, OFDMA, modulation, and coding) and the MAC layer (such as data and control plane and the sleep mode for the terminals). The higher-layer networking document specifies how wide-area roaming and handoff protocol are being addressed. A licensed spectrum is a spectrum leased by an operator(s) for a given locality, whereas the licensed-exempt spectrum is the so called "free" spectrum in which anybody can use the spectrum provided certain rules are followed [38].

4. Comparison with other Standards

WLAN standards such as IEEE 802.11a and IEEE 802.11g provide user throughput of 1 Mb/s or more, and allow broadband access to the Internet within a cell radius of a couple of hundred meters. On the other hand, current 3G cellular networks, which are optimized for voice, provide paging and low-data-rate services within a very large area. As stated earlier, Mobile WiMAX is a metropolitan access technique that was developed to provide not only broadband wireless access but also larger area coverage. Both WLAN and Mobile WiMAX provide high-data rate services but with quite different area of coverage; therefore, they complement each other. However, in the long run, the existing 3G networks may be threatened by the emergence of a successful Mobile WiMAX. To respond to this threat, another competing standard - 3GPP long-term evolution (LTE) is currently being developed to include advanced antenna technology, OFDMA, and flexible transmission bandwidth. Both 3GPP LTE and Mobile WiMAX share many common technologies and architectures, but also exhibit differences [39].The main common technology is orthogonal frequency-division multiple access (OFDMA [40]. In WiMAX, OFDMA is used on both the downlink and the uplink, whereas in LTE it is used only on the downlink. However, the technology used in the uplink of LTE, single-carrier frequency division multiple access (SCFDMA), is nothing but a simple modification of OFDMA [41]. Therefore, many of the OFDMA related points are valid for SCFDMA as well, and we shall point out the minor differences as we go. There are many good reasons for choosing OFDMA such as multipath handling capability, scalability of operation in different bandwidths, the ability to handle different data rates, and the ability to easily combine with multiple antenna techniques [42]. Mainly, OFDMA enables relatively simple channel compensation techniques in frequency selective fading channels, which makes it popular [42]. In addition, frequency diversity and channel feedback can be used effectively to improve robustness and throughput. One of the main differences is in the uplink, where the single-carrier FDMA (SC-FDMA) is being adopted. The SC-FDMA signal carries a lower peak-to-average power ratio and hence has better power efficiency for the subscriber

units compared to OFDMA (as used in the Mobile WiMAX standard).

Quality Guaranteed Applications: For a variety of applications, it is essentially desired that the network layer should provide a sufficient quality of service (QoS) guarantee, mainly in terms of bandwidth, data rate, delay and delay jitter. It is difficult to provide such a guarantee in a wireless networks as they are generally error prone. In order to address this issue, multipath routing has been studied by many researchers. Multipath routing can provide excellent quality of Service (QoS) than single-path as put forward by Zhang and Mouftah [49].

Multihoming Applications: Multihoming [50] is a technology that can provide services similar to those of multipath routing with a difference that in multi-homing, one station has two or more IP addresses and generally has the same number of interfaces. In this manner, the station can have multiple paths to access the same resources. In short, the application layer requirements routing must be addressed in the network layer design.

5. Conclusion

Confucius already quoted 'Study the past if you would define the future'. Therefore, an in-depth investigation, historical review of WiMAX standard and an overview of the state-of-the- art mobile WiMAX technology and its development is provided in this paper. The results of some recent work on WiMAX networks are reported and an extensive survey of recent and relevant literature published in this field WiMAX networks is properly reviewed and given in chronological order.

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