Performance Analysis of Wimax Networks: A Survey

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ABSTRACT

The IEEE 802.16 standard is one of the promising technologies that provide broadband wireless access for the metropolitan area network (MAN). Several performance analysis techniques exist for performance evaluation of this network. Simulation is one of the most widely used in both academia and Industry. Different Simulation tools are available including public, private and standalone simulators. However, due to the numerous number, complex structure and enormous cost of these Simulators. In this paper, we provide a survey on existing IEEE 802.16 simulators available in the public domain as well as standalone simulators. The goal of the survey is to reduce the burden of searching for the appropriate simulator to be used by researchers.

Keywords: *WiMAX simulator, Public simulator, Standalone simulator*

1. INTRODUCTION

The IEEE 802.16 standard [1], widely known as worldwide interoperability for Microwave Access (WIMAX), addresses broadband access technology for wireless metropolitan area networks (WMANs). The standard sets out two specifications, the physical (PHY) and media access control (MAC) layers. It has several advantages, including ease and cost of deployment, first-mile/last-mile access, and quality-of-service (QoS) support for multimedia applications at the MAC layer [1],[2]. Because multimedia applications must support different types of traffic simultaneously, each of which has different QoS requirements from the network, such as bandwidth, delay, jitter, and packet loss, providing QoS to these traffic classes represents a challenge [3]. Therefore, an appropriate resource allocation technique is highly needed to provide network-level QoS.

The performance evaluation of resource management algorithms plays a crucial role in the design of a WiMAX system. Several performance analysis techniques exist for the performance evaluation of WiMAX networks. These techniques consist of experiment, computer simulation, and mathematical analysis [4, 5]. An experiment is conducting experiments with actual test beds, and is the most suitable for monitoring the status of a system for a specific network configuration. Although the technique provides the most accurate performance assessment, building test beds is costly, reconfiguring and sharing them is complex, and they are relatively inflexible [6]. Furthermore, it can be difficult to replicate some network phenomena, such as wireless interference, signal attenuation, noise, and fading. A mathematical analysis uses a simple mathematical model. This technique provides a theoretical background for a given technology, but only provide a limited insight into the technology. It has a lower cost and requires less effort than the other two techniques. However, mathematical models often become intractable [7].Finally, Computer simulation provides a real-world process where the system is `imitated' over time [8, 9]. This technique produces replicable results [5]. Thus, simulation has become a powerful technique used by researchers in conducting performance evaluations of emerging technologies [4, 5]. Recently, most of the research conducted on IEEE 802.16 networks has relied on simulations for the performance evaluations [3,10,11].The importance of network simulation is thoroughly described in [12]

In this paper, a survey on existing IEEE 802.16 network Simulators in WiMAX network is presented. The aim of the survey is to reduce the burden of searching for an appropriate simulator to be used by researchers. It focuses only on the public available and standalone simulators.
The rest of the paper is organized as follows, Section 2 the overview of IEEE 802.16 Standard. In section 3 Survey on IEEE 802.16 Simulators proposed in the network community. Finally, Section 4 provides the conclusion.

2. OVERVIEW OF WIMAX NETWORKS

WiMAX networks consist of several standards such as 802.16-2004[1] and 802.16e [2]. The standards defined PHY and MAC layers in order to support WMANs. The MAC layer sits atop the PHY layer and mediates between it and the layers above. The protocol that operates the MAC layer performs the main tasks of the standard, such as QoS provisioning, CAC, bandwidth allocation, and scheduling. It supports two modes of operation: Point-to-Multipoint (PMP) and mesh. The former is a cellular-like structure that supports communication between a BS and a set of a set of clients in broadcast fashion. The client represent Subscriber Station (SS) for the fixed WiMAX and MS is both fixed and mobile WiMAX. The BS is the central controller, regulating all communications between itself and a set of MSs. Each MS can represent a single or multiple users. The two paths of communication between the BS and the MSs are the uplink ("UP"; from MS to BS) and downlink ("DL"; from BS to MS) directions. In contrast, mesh mode supports multihop communication between MSs. In this paper, we consider PMP as the main operational mode.

The PHY layer is responsible for transmitting bits over the wireless channel by means of the adaptive modulation and coding (AMC) technique. AMC supports two transmission modes, frequency-division duplexing (FDD) and time-division duplexing (TDD). In FDD mode, uplink and downlink data are sent on different frequencies. In contrast, in TDD mode both UP and DL data are sent using the same frequency but in different time slices. Both duplexing modes operate in a frame format. Each frame is partitioned into DL and UP subframes. The DL subframe is used by the BS to transmit data and manage messages to an MS, while the UP subframe is used by all MSs to transmit data. it's uses an Orthogonal Frequency Multiple Access (OFDMA) slot as its smallest unit of resource.

The MAC layer is a connection-oriented protocol that has the advantage of controlling network resource sharing among individual connections. The protocol maps both connected and connectionless traffic to a unique connection identifier (CID). If traffic coming from an upper layer arrives at the MAC layer, the MS attempts to establish a connection with the BS. The BS employs a CAC scheme that checks whether the resources available can ensure the QoS of the new connection while maintaining the QoS guarantees for the existing users. With the acceptance of a new connection, the BS responds to the MS with a CID to use for the UP and DL directions. Once a connection is set, the MS can request bandwidth from the BS. The BS grants bandwidth using the grant per subscriber station (GPSS) approach. Once the MS receives its bandwidth from the BS, its packet scheduler distributes the bandwidth among its own active connections. The CAC and request grant bandwidth allocation components of the BS provide support to different applications with various QoS requirements. The 802.16 standard partitions applications into service classes as follows.

The unsolicited grant service (UGS) periodically generates constant-size data packets for real-time traffic such as VoIP without silence suppression. UGS is sensitive to transmission delays, and the BS allocates grants to the MS in an unsolicited fashion using the maximum sustained traffic rate (MSTR), traffic priority, and maximum latency tolerance as its QoS requirements.
The real-time polling service (rtPS) generates variable-size data packets for real-time traffic such as MPEG video. It has less stringent delay requirements and is periodically polled by the BS for each MS to individually determine its bandwidth requirement. Its mandatory QoS specifications are the minimum reserved traffic rate (MRTR), MSTR, traffic priority, and maximum latency tolerance.

The extended real-time polling service (ertPS) generates variable-size data packets for real-time traffic such as VoIP with silence suppression. It combines features of both UGS and rtPS and has strict, guaranteed delay requirements and provides unicast grants in an unsolicited manner by the BS, as with UGS. Because UGS grants are of constant size whereas ertPS grants vary in size, an MS can request a change of its bandwidth grant to suit its requirements. The ertPS QoS requirements are MRTR, MSTR, traffic priority, maximum latency tolerance, and delay jitter tolerance.

The non--real-time polling service (nrtPS) generates variable-size data packets for non--real-time traffic such as FTP. It has minimum bandwidth requirements that are delay tolerant. It is polled by the BS in order for each MS to state its desired bandwidth. The QoS requirements are MRTR, MSTR, and traffic priority.
The best-effort service (BE) is designed to support traffic for which delay and throughput are not guaranteed, such as HTTP. It requests bandwidth through contention request opportunities and unicast request opportunities.

3. A SURVEY OF WIMAX SIMULATORS

A broad range of network simulators have been developed in order to evaluate the performance of the various aspects constituting 802.16 networks. These simulators are classified into three types [13] : public domain, private domain and standalone. The ns-2 [14] is one of the public domain simulators used in academia and industry [15,16,17,18]. It implements a rich set of Internet protocols that include both wired and wireless networks [17]. So far, ns-2 has lacked a definitive 802.16 module [16]. Thus, modules should be added to ns-2 [19] in order to serve the intended objective. Herein, several modules for ns-2 and ns-3 available in the public domain and the standalone simulators are discussed and analysed according to the resource management algorithm used to implement the simulator and traffic types used. The private domain such as OPNET [30]and Qualnet [20] are excluded in this analysis due to the unavailability to the public of their source codes.

Several researchers have developed ns-2 modules for 802.16 based networks [15,18,21,22]. The Network and Distributed Systems Laboratory (NDSL) [15] proposed the first IEEE 802.16 modules for ns-2, called MAC 802. The module focuses on MAC protocol development by supporting different service flows and the WRR scheduler as well as a simple CAC scheme that follows FIFO to admit an incoming connection. However, it fails to consider several implementation details because of its high simplicity and hence the module is not standard compliant [18] . Although the module has some good features, its further improvement has stopped [22]. Then, the National Institute of Standards and Technology (NIST) [21]. proposed another ns-2 module, called the NIST module, that supports the default RR scheduler for the UP allocation of bandwidth to the registered MSs. However, it lacks the implementation of a MAC QoS [16, 23, 24].

Several modules have been proposed to extend the NIST module [21]. A joint effort among teams at Rensselaer Polytechnic Institute (RPI), Washington University in St. Louis (WUSTL), the WiMAX Forum, and the NIST, have proposed a WiMAX forum module [6]. This module also provides a default RR scheduler for the UP bandwidth allocation to registered MSs according to bandwidth requested and adds support to QoS scheduling services, i.e., UGS, rtPS and BE services. But nrtPS and ertPS are not included. Telecom Bretagne proposed a new ns-2 WiMAX [16] module. It supports

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three scheduling service classes, namely UGS, rtPS, and BE as well as various scheduling algorithms that include: RR, WRR, Temporary Removal Scheduler (TRS)+RR, Maximum Signal to Interference Ratio (mSIR), and TRS+mSIR. The Computer Networks Laboratory (CNL) of KAIST University proposed another WiMAX module [17,23] which supports all the five of the 802.16's QoS scheduling services. However, it does not support any scheduling and CAC algorithm. Therefore, the CNL module has been given less attention by the developers who aim to modify the module with new features and plug-ins, due to its high non-modularity [22]. Both the NIST module and its existing extensions lack an implementation of an ns-2 module that supports both WiMAX compliant mobility and QoS support. Next, the University of Siena proposed a new ns-2 Tool [24] that is based on the popular module described in [2] that implements all five QoS classes, but no scheduling algorithm is implemented.

Afterwards, several researchers also proposed other ns-2 modules for 802.16 based . The module from KAIST [25] in their earlier papers [26,27] considered only the best effort service with a simple RR scheduling algorithm among the various scheduling services. The authors extended that work to four different classes of service, an UP scheduling algorithm for bandwidth allocation, and simple CAC are also supported in [28]. The Eurocom Institute and ENSI proposed an 802.16 module [29] for an ns-2 simulator standard [1] and ns-2.29 versions. It supports a novel QoS architecture that consists of a CAC and a hierarchical scheduling algorithm. Although the authors presented it as a novel module with integrated QoS architecture, it is not different from the NIST implementation . The Research and Technology Platforms together with the Telecommunication Laboratory proposed another module called WiMAX ns-2 Extension (WINSE) [22] that implements 802.16 extensions for the ns-2 network simulator. The WINSE module supports all the scheduling services as well as the scheduling algorithms: RR and Proportional Fair. It was first used in scheduling and resource allocation research in [30,31]. Finally, among the earlier proposed IEEE 802.16 modules for ns-2, none have implemented the performance of various IEEE 802.16 scheduling algorithms and multi-hop relaying. The National Taiwan University of Science and Technology (NTUST) proposed a Light WiMAX Simulator (LWX) [32] that supports all the traffic classes and some scheduling algorithms for bandwidth allocation algorithms: Strict Priority, RR, and Simple Relay.

Due to the limitations of ns-2 with regard to newer versions of operating systems and compilers , the IEEE 802.16 ns-3 module [18] was released as a replacement for the IEEE 802.16 ns-2 module, by teamwork between the Institut National de Recherche en Informatique et en Automatique (INRIA) and the Dipartimento di Elettrotecnica ed Elettronica (DEE). It supports the four scheduling services defined by IEEE 802.16-2004 and simple priority/First Come First Serve (FCFS) based schedulers. However, it has the limitation of not implementing all the scheduling services, due to the absence of a full Packet Classifier to map the incoming packets to the appropriate queues. The module also lacks an efficient scheduling algorithm to serve flows with different scheduling types [28]. Furthermore, the INRIA and DEE team also added new features to enhance the existing 802.16 ns-3 module described in [18]. The module proposed in [32] supports an IP packet classifier, implements all the scheduling services defined in 802.16-2004, as well as an efficient UP and DL schedulers. The University of Central Florida also proposed the OFDMA Extension of the ns-3 module [13], which is implemented through the extension and modification of the original module created by the INRIA and DEE [18,32]. That module examined the effects of various scheduling algorithms in 802.16.

Other simulator platforms are also available for the performance evaluation of 802.16 based networks: including the New ubiquitous mobility basic analysis tools (Numbat) module [34], the National Chiao Tung University network simulation (NCTUns) tool [35], the Simulation module with management architecture and signaling exchanges (SimulX) [36], and the Comprehensive WiMAX Simulator [37]. Numbat is based on IEEE 802.16-2005, which supports mobility and IPv6 in the Omnet++ 4.0 environment. The NCTUns tool was developed by the National Chiao Tung University to facilitate WiMAX studies of network behaviour and performance analysis. The tool is compared with ns-2, Qualnet, and Modeler. Numbat and the NCTUns have little support for scenarios with diverse QoS requirements [18], because they support only the BE and UGS scheduling services. SimulX is an open source project developed under the joint efforts of many Universities and Research labs. The inherited problems of the IEEE ns-2 modules and Omnet++, which do not include the management parts of wireless technology specifications (including network management entities, signaling state machine and exchanges) have been addressed. The WiMAX simulator is developed by the American University of Beirut and Mobinet Corporation with the aim of implementing all WiMAX system components. Among the key contributions of the simulator is its comprehensiveness, as it implements all the components of the WiMAX QoS, which include: traffic generation, MAC and PHY layers, scheduling, and frame construction.

Table 1: The various ns-2 and ns-3 modules in WiMAX networks

Modules	Scheduling Service	CAC	Scheduling	Energy Saving	Source Code
NDSL [15]	all	simple CAC that follows FIFO	WRR	y	N
NIST [21]	no	no	Default RR for the uplink bandwidth allocation	n	y
WiMAX forum [6]	UGS, rtPS and BE	no	Default RR for the uplink bandwidth allocation	n	y
Telecom Bretagne [16]	UGS, rtPS and BE	no	RR, WRR, TRS+RR, mSIR and TRS+mSIR	n	y
CNL [17]	all	n	n	n	y
University of Siena [24]	all	n	n	n	y
KAIST [26,27]	BE	n	simple RR	n	y
KAIS extension [28]	UGS, rtPS, nrtPS and BE	simple CAC	Uplink scheduling algorithm for bandwidth allocation	n	y
ENSI module [73]	nrtPS and BE	CAC policy	a hierarchical scheduling algorithm	n	y
WINSE [29]	all scheduling services	n	RR and Proportional Fair	n	y
LWX [32]	all	n	Strict Priority, RR, and Simple Relay	n	y
ns-3 module [18]	UGS, rtPS, nrt PS and BE	n	priority/FCFS based schedulers	n	y
Improved ns-3 [32]	UGS, rtPS,nrtPS and BE	n	Efficient uplink and downlink schedulers	n	y
OFDMA Extension of ns-3 [13]	UGS, rtPS, nrtPS and BE	n	Efficient uplink and downlink schedulers	n	y

Table 2: The various standalone simulators in WiMAX networks

Modules	Scheduling service	CAC	Scheduling	Energy saving	source code
Numbat module [34]	UGS and BE	n	n	y	n
NCTUns Simulation tool [35]	UGS	n	RR and WRR	n	y
Comprehensive WiMAX Simulator [36]	all scheduling services	n	RR, and proportional fairness	n	n

In Table 1, we have presented how several non-profit organizations have contributed significantly to the ns-2 components library and its development process, which has proved to be quite successful[42]. The NIST, CNL, KAIST University, and many others have used ns-2 to develop simulation modules for IEEE 802.16, and these tools are widely used. Due to ns-2's limitations, ns-3 is currently under development and testing[17]. Thus, ns-3 is a replacement tons-2 and has been completely written from scratch [17]. The main benefit of these simulation modules for both the ns-2 and ns-3 is the availability of the source code for the public to use. However, only a few of these modules provide full QoS support and scheduling algorithms: the majority of them do not implement CAC and none of the modules also implement an energy saving scheme. Therefore, both the former and the latter have a complex structure that requires the addition of new modules and components [29] . As a result, it becomes a hard task that requires the user to have a good knowledge of the simulator.

In Table 2, standalone simulators are shown, such as Numbat, NCTUns, SimulX, and the WiMAX Simulator. Numbat and NCTUns provide their source code for free for the public, but do not provide full QoS differentiation for all the classes of service because only two scheduling services (BE and UGS) are supported. WiMAX Simulator has been developed to overcome this problem and integrate all the needed modules in one place, but the source code is not available for the public to use. It also supports several scheduling algorithms, but CAC and energy schemes are not supported.

4. CONCLUSIONS

In this paper, we presented a survey on simulators in WiMAX networks. The survey consider only the public and standalone simulators . In public simulators, several modules are discussed by highlighting strengths and weaknesses of each module. While in the standalone, several simulators are also discussed. The paper provided a better understanding of the WiMAX simulators and reduced time for searching an appropriate simulator to be used in academia.

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