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WiMax quality-of-service estimations and measurement

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ABSTRACT

Nowadays WiMax is considered as one of the main technologies for next generation high speed wireless access network. It provides a larger coverage compared to WiFi while supporting string QoS and security mechanism. However, this technology needs fine configurations tuning to achieve its performance, which implementation in different environments is very difficult for operators willing to deploy it.

This paper presents QoS estimation methods and measurements over WiMax networks and highlights the complexity of this process. It presents performance measurements in term of achievable rate of an operational WiMax network to evaluate its capability to support different types of media transmission. Finally, it highlights the importance of an accurate time synchronization in the measurement process which is difficult to achieve and therefore proposes a time synchronization method to derive end-to-end delay measurements with appropriate accuracy.

1. Introduction

Thanks to its optimizable physical layer and to many adaptable capabilities, WiMax 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 [1]. WiMax can be convenient for Hybrid networks, Local Area Networks or long-range transmission thanks to MAC relays defined in 802.16j [2].

As the majority of wireless communication systems, the exact coverage of these networks along with the corresponding QoS are very difficult to predict, especially in none free space. Thanks to OFDMA, WiMax can adapt the transmission over each bandwidth sub-channel in order to compensate transmission perturbations such as anisotropic attenuation and sometimes multipath transmission. However, this adaptation requires a small but no negligible delay in order to reconfigure and, if the path characteristics changes during this delay, the system cannot reach a stationary state. Moreover, it is impossible to adjust the power of the channels in some situations due to the dynamic property of the obstacles between transmitter and receiver (e.g. trees). In order to evaluate and understand the real performance of WiMax, we have conducted a campaign of measurements of an operational network.

Though there is few performance studies dealing with measurements obtained from real WiMax networks, some interesting information and publications can be found in the literature. In [3], the paper describes a real testbed settled up to transmit video. In [4], Durantini et al. show that it is possible to achieve 1–1.8 Mbps data rate with WiMax up to several kilometers between the base station and the mobile station. Authors in [5] succeed in achieving seamless hand over of VoIP sessions within a hybrid WiFi and WiMax network. They were able to setup up to 12 simultaneous G711 communications or 20 simultaneous G729 calls. In [6], 50 bidirectional speex-encoded voice communications and 5 IPTV flows could be handled simultaneously in Line of Sight (LOS) and 50 voice calls with 1 IPTV flow in non-LOS. The paper also compares a PTP synchronization mechanism with a GPS one. In [7], the authors discover that the round trip delay could be very large when using TCP over WiMax. However, they could setup seamless communications with a moving car in a city. The developed system manages the quality-of-service per user but not per flow. This has a strong impact on their performance results. In [8], large throughput variations are noticed in non-LOS channel conditions in an urban street-level environment due to the existence of moving vehicles in the radio path.

In [9], the authors highlighted the discrete nature of the jitter attributed to retransmission mechanisms (ARQs). The authors in [10] noticed that there are few correlations between the distance and the performance, but in contrary, there are many correlations between the performance and the carrier to interference noise ratio (CINR). They have shown that an elevation of the base station

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increases the performance but not the coverage until a certain height above which the coverage is also improved. The measurement in [11] show that it is possible to have satisfactory throughputs up to 10 km, but the SNR or the RSSI are very sensitive to small vertical or horizontal changes (even as small as 1 cm) and to weather conditions. In [12], the asymmetry of the uplink and downlink are endorsed to the difference of the gains of the antennas. Therefore the authors propose a model that links the UDP bit rate and the RSSI to the logarithm of distance. The authors in [13] give interesting statistical models for the performance criteria like jitter, end-to-end delays,

Tran et al. [14] have observed a street level range up to 300 to 2100 m in urban environment, depending on the emission power. They also compared their measurements with simulations and noticed a good correlation between the computational results and the empirical results. In [15], Schwenger et al. have found a good correlation between the Stanford University Interim (SUI) channel model and measurements which they performed in an urban environment.

In [16], the accuracy of propagation models is analyzed in a more thorough manner. The authors concluded that no model can well account for all environments: different models are required for LOS or non LOS.

It appears from these results that the diversity of parameters that influence communication makes it difficult to obtain general results and a lot more experimental work is necessary. This purpose of current research falls into this experimentation and aims at contribution towards experimentation and efficient measurement. To achieve this objective, we have performed measurements on an operational WiMAX network provided by a French operator [24]. The operator allowed us to run several tests in different operating conditions (weather, distance, line of sight or non line of sight, influence of metal, speed, etc.) to understand better the signal propagation properties in the used frequency band. The accuracy of the measurements can only be achieved with appropriate time synchronization. Therefore, a synchronization mechanism allowing us to measure the end-to-end latency is proposed. This mechanism has been implemented and tested and is described in the second part of this paper.

The structure of this paper is as follows: the second section of this paper provides an overview of WiMax QoS functionalities and the corresponding performance criteria. The third section presents our first measurement campaign as well as the measurement results. The following section presents a new approach to estimate performance over asymmetrical networks by GPS. Finally, a conclusion is presented along with some future perspectives.

2. Measurement method

In accordance with the WiMax network operator, we built a test plan containing different sets of measurements to perform in order to estimate the global performance of the network. All the captured packets are recorded in a PCAP [17] trace file and measurements were performed at different levels of the communication stack (Physical, MAC, IP, and Application). All the measurements have been performed in the 3.5 GHz WiMax band as permitted in the operator license.

There were some constraints imposed by the operator as the network is an operational one. It was not possible to test WiMax network scheduling performance as described in [18]. This is due to the fact that the operator has a very restricted QoS differentiation between services. Only two modes were actually implemented for the modulation and MAC FEC on the uplink channel: QPSK & FEC 1/2 and 16QAM & FEC 1/2. Geographical relief is one of the main constraints in wireless communications. In order to characterize it properly, we used 3D maps [19]. Based on this map, it is possible to estimate the free space distances between any two points.

2.1. MAC & physical layer

Using to the recorded PCAP trace, it is possible to retrieve MAC layer information such as connection phase, signal power, used modulation and resource allocation plan.

It appears that the Maximum Transfer Unit (MTU) is 1400 bytes at IP-Level plus 14 bytes at MAC level. The distribution between uplink and downlink channel is 15:30. OFDMA symbols allocation for the implemented two modes are reported in Table 1.

The 16QAM-1/2 modulation is used when the signal over noise ratio is between 21 and 24 dBm, as defined in the 802.16e standard.

2.2. IP Level

To estimate the end-to-end latency, we have developed a hrping script. The same script is also used to estimate the jitter and available bandwidth. The script initiates the emission of sequences of ping with different time interval. We increase the IP packet size in these sequences and measure the latency corresponding to each IP packet size. This set up allow us to estimate the available end-to-end throughput.

We have performed this test over several specialized sites: testadsl.net, echosdunet.net and zdnet.fr. These different tests aim to estimate the throughput over each directional channel. Globally, the end-to-end latency time in good condition is around 100 ms. Note that this latency has the same order of magnitude as WiFi transmission time and 60% less than 3G data transmission time in the same conditions.

The transmission rate varies between 800 kb/s and 2 Mb/s for uplink transmission and 200–800 kb/s for downlink transmission. Because of the 15:30 resource allocation plan between the uplink capacity and the down link capacity, this network has eventually asymmetrical performances.

2.3. Applicative level

We have also performed several measurements at the application level. The QoS of selected applications such as FTP, IMAP, SMTP, HTTP and multimedia streaming were tested to highlight the efficiency of WiMax technology for traditional network applications (i.e. file transfer, email, web).

Hence we have performed some tests for multimedia streaming applications. Several videos, encoded with different codecs, were remotely streamed and received at a WiMax terminal in order to evaluate the user's Quality of Experience (QoE). The QoE was also estimated for internet browsing activities.

3. Measurement results

This section will present the results of the measurement campaign performed following the previously presented approach.

Table 1
Modulation and MAC allocation.

Modulation	QPSK	16QAM
Bits per symbol	2	4
FEC efficiency	0.5	0.5
Spectrum efficiency bits/symbol	1	2
Bits per MAC allocated unit	6	12
Allocated bits after FEC coding	12	24
Symbols par allocation plan unit	12	12