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AN APPROACH TO VIDEO-STREAMING TESTS IN MOBILE WIMAX USING LOW-COST TIME-REFERENCE

Summary. This work concentrates on appropriate set-up and initial validation of a mobile WIMAX testbed that will be used to validate the performance of modern video-streaming solutions for surveillance and multimedia deployment. Detailed discussion of the testbed and measurement instrumentation is made together with careful validation of tools in this paper. Especially a reliable but low-cost approach to precise time synchronization is presented. Authors provide the reference measurements in a WiMAX test network using IP performance metrics. The tests performed provide preliminary validation of the campus testbed and validates measurement experience that will be further followed in selected commercial WiMAX networks in Poland. It has been shown that (irrespective of the WIMAX modem) given two sample locations within a 1km range from base station, for tests with mobility there is a trend of decreasing delay (ca. 50% decrease) when the throughput increases. The scenario shows that from the delay perspective, the speed ranges between 10-30 km/h do not influence measurements significantly.

Keywords: Raspberry Pi, WiMAX, 802.16, drive tests, measurement, video, hardware in the loop

EFEKTYWNA METODYKA TESTÓW USŁUG STRUMIENIOWANIA WIDEO DLA SYSTEMÓW MONITORINGU WIZYJNEGO W MOBILNYCH SIECIACH WIMAX

Streszczenie. Artykuł ten koncentruje się na przygotowaniu odpowiedniej konfiguracji i wstępnej walidacji mobilnego środowiska testowego WiMAX, które będzie wykorzystane do testowania wydajności nowoczesnych systemów strumieniowania wideo na zastosowaniach do monitoringu wizyjnego. Przedstawiono ponadto szczegółowe omówienie środowiska testowego i aparatury pomiarowej, razem z dokładną walidacją narzędzi testowych. W szczególności zaprezentowana została propozycja rozwiązania problemu precyzyjnej synchronizacji czasu na podstawie urządzenia niskobudżetowego opartego na platformie Raspberry Pi. Autorzy przedstawiają pomiary referencyjne w testowej sieci WiMAX, posługując się metrykami typowymi dla pomiaru wydajności w sieciach IP. Przeprowadzone testy umożliwiły z jednej strony walidację środowiska testowego, a z drugiej pozwoliły zdobyć niezbędne doświadczenie, które zostanie wykorzystane w dalszych pomiarach (i budowie modeli), dla wybranych sieci komercyjnych w Polsce. Wykazano, że (niezależnie od użytego modemu WiMAX) w dwóch przykładowych lokacjach, znajdujących się w promieniu 1 km od stacji bazowej, dla testów mobilnych występuje trend malejącego opóźnienia (ok. 50% mniejsze) wraz ze wzrostem przepływności. Użyty scenariusz wykazał, że z punktu widzenia opóźnienia różnice prędkości poruszania się mobilnego urządzenia w granicach 10-30 km/h nie wpływają znacząco na wyniki pomiarów parametrów wydajnościowych transmisji danych w sieci WiMAX.

Słowa kluczowe: Raspberry Pi, WiMAX, 802.16, testy terenowe, strumieniowanie wideo, platforma testowa

1. Introduction

The main motivation behind this paper is to define a reliable testbed for evaluation of novel congestion control/adaptive streaming mechanisms in WiMAX networks. The key use-case that is considered is the transmission of surveillance video feeds from remote, rural locations to command and control room. Authors assume that e.g. multiple parking lots are co-located in an urban area which is served by WiMAX base station (BS). In order to be able to perform realistic evaluations of congestion control mechanisms in simulation environment it is of utmost importance to build a reliable environmental model for future tests. It is assumed that experimental campaign should be performed in order to get better insights into particular WiMAX deployment. There is a number of publications on video and audio streaming performance evaluation in the IEEE 802.16 networks Still most of this research concentrates on testing various QoS mechanisms but applied in a simulation environment and only video-traffic sources rather than in real-life WiMAX set-ups. Researchers nowadays are provided with powerful capacities for performing real-life experiments using facilities provided by so called “open laboratories” (e.g. Fire[1], OpenLab[2], PlanetLab[3], PL-Lab). This

[1] http://www.ict-fire.eu/home.html
[2] https://openlab.fm/

enables a great deal of progress in practical experiments that empower research activities. As indicated in [2] "*in the last few years, there has been an increasing awareness of the need to evaluate new mobile applications and protocols in realistic wireless settings and platforms such as the GENI WiMAX testbeds have been developed to fulfill this need*". The [2] concentrates on the performance measurement of several popular wireless applications in the GENI WiMAX testbed environment. Current findings of that paper show some surprising results delivered using the testbed e.g. with increasing signal quality a reduction in application throughput is observed. The authors there indicate that the results obtained using such a realistic testbed can differ significantly from the expected results, often giving counter-intuitive results. It is therefore crucial for any testbed to provide reference measurements that will enable a baseline for valid analysis of results obtained in more complex scenarios. Experimental research concentrating on the video traffic performance in the IEEE 802.11 networks can be found e.g. in [3] as well as in numerous other research. On the other hand it is much harder to find a similar research with the use of real equipment for the IEEE 802.16 networks. Moreover since mobile drive-tests are faced with challenges of its own (equipment, geotagging of results, synchronization etc.) the extra cost associated with capable equipment for appropriate time synchronization of the measurement devices should be considered when preparing for such tests.

An interesting set of comments covering experimental campaign in the production WiMAX networks is provided in [4]. Authors have deployed mobile WiMAX in the Wielkopolska Region in Poland in the years 2011-2014. The network provides ca. 5500 users with broadband Internet access. It is highlighted that in such a dense deployment in the city centre and its surroundings like it happened in Poznań major challenge is the coverage prediction. Especially that channel conditions of different users might actually require different propagation models. Authors in [4] indicate that despite three years of effort in selecting and tuning appropriate propagation models (also contributing to the ITU-R P.1546 and ITU-R P.1892) they were not able to match real live conditions with the theoretical results. All in all the decision was made to build own model based on the broadcast models used in Germany [5]. The operator has assumed that in order to better analyse capabilities of introducing new subscribers in a location, each sector (site) can be characterized using two coverage zones: zone near base station (with high probability of good signal reception) and outer ring where the risk of unsuccessful (CPE) installation is higher but still reasonable ground to attempt to acquire new subscribers in the location. The [4] highlights the importance of good radio planning and also present some methodological approaches used by

[3] https://www.planet-lab.org/

them to avoid interferences (as suggested by the HW equipment vendor). As the capacity of the WiMAX network is not fixed [6], mainly because of the changes in spectral efficiency that changes in time as a product of: modulation (AMC), FEC coding and MIMO mode. It is of course also in the absence of CPEs mobility. Due to frequent changes of the latter parameters the capacity of WiMAX channel and its utilization also changes significantly (e.g. adding two new subscribers to the sector of 10 CPEs with 4.3Mbps each may actually degrade the effective throughput of the subscribers by 50%). The simple network maintenance procedure is presented to mitigate this effect (e.g. use of fixed frequency for CPE, assignment of CPE to sector, monitoring of radio capacity). Part of the approach in [4] is also restricting installation conditions to an extent that guarantees quality of signal. Only then the operator can fully exploit the MIMO and OFDMA to provide maximum throughput in a multi-path environment. It is also shown that even in a fixed location the variation of propagation conditions (in the highly urbanized environment) may be quite large.

Given the conclusions from [2] this paper concentrates on the set-up and the initial validation of our WiMAX testbed. The first step is to provide the reference measurements without background traffic in a university campus WiMAX test-network. These tests will:

a) provide validation of the performance of the campus testbed and
b) the experience gained through these test will be used in the future tests scheduled in commercial WiMAX live-network deployment.

Ultimately in the future work this approach will be used to validate the performance of video-streaming solutions created by the MITSU project [1]. Moreover to perform the simulations and necessary tuning of the simulation environment there is a need for input data (e.g. real-scenarios terrain wireless coverage, sample data for traffic generators, etc.). Therefore, although typically the tests in real environment may generally be used as "next step" in mechanisms verification formerly tested in e.g. simulations, the use of the testbed can also provide a valuable feedback for the simulations themselves. The data collected during the live-tests can include e.g. information about the conditions experienced by mobile terminals such as ACM, or the traffic characteristics as generated by the traffic sources etc. This kind of information can in turn be used again in order to improve the level of fidelity of the future simulations (enhanced with real-life data).

This paper is organized as follows – section 2 presents the approach to validate measurement tools used before progressing with the drive-tests. This section 3, 4 and 5 provide the details on the approach, equipment used and provides the results of reference measurements and validation. Especially section 3 assesses the accuracy of measurement done with packet analysers and measurement software as compared to dedicated expensive hardware equipment. Section 4 provides a view on the use of virtual machines in the measurement architecture, and discusses their impact on the measurement accuracy. Section 5 provides the information on the time-synchronization issues faced in mobile measurements. Especially this section provides information on choosing and applying a low-cost time reference for the measurements. Finally section 6 provides the summary and the information on the future work.

2. Assessing the accuracy of the measurements with off-the-shelf equipment

The starting point of target measurements was the assessment whether the accuracy offered by solutions (software generators, do-it-yourself HW solutions) to be used in the drive-test was good enough to provide reliable results. The use of the simplest, affordable and fast method is crucial to minimize the time and human resources required for the drive-tests. Still the professional packet generator and analyser IXIA XM2 has been used to perform compliance/validation and performance testing (especially in pre-tests) of the freeware generators. Its measurement capabilities span across various protocols (ISO OSI layers 2-7) such as RTSP, RTP/UDP for streaming video, VoIP, simple CBR UDP packet generation, performing RFC2544 and RFC2889 tests and many others. The open source tool Multi-Generator[4] (MGEN) has the ability to generate traffic patterns (using TCP and UDP) and use information attached to message for performance tests and measurements. It is also often used to generate background traffic as in [3]. Wireshark[5] is a well-known open-source packet analyser. In case of our measurements the crucial part is the accuracy of the time-stamps associated with each packet. Wireshark, similarly to other sniffers, such as tcpdump, nast, snoop, nettl uses libpcap to get the relevant information about e.g. time of the packet arrival. Although this approach is simple, it is done in kernel (see Fig. 1) therefore the timestamp is available only after the packet has been processed in the NIC. Please not that in the figure dotted lines denote different elements of the wireless node (HW, OS-kernel space and so called “user space”). The topmost output of card driver box refers to the measurement instrumentation (e.g. using the iptables hooks) while the bottom line indicates data transfer. In case of using e.g. USB based network card this can become an issue, since the timestamp becomes inaccurate as indicated in [7].

The main objective of authors for the ultimate tests is the measurement of traffic generated with video-streaming applications (instead of a generic traffic generator) in the

[4] http://www.nrl.navy.mil/itd/ncs/products/mgen
[5] https://www.wireshark.org/

environment with background traffic generated by real-life users. Therefore we decided that the measurement method should not attach additional information to packets not to increase the traffic load on the network. This means that there was no additional information generated with the traffic itself. We refer to standards RFC2679 ([15]), RFC3393 ([16]) and RFC6349 ([17]) for the methodology on measuring the IP packets performance metrics: delay (one way delay - OWD), jitter (IP Packet delay Variation- IPPV) and throughput. Figure 2 presents the overall architecture used in the validation of MGEN measurements with IXIA.

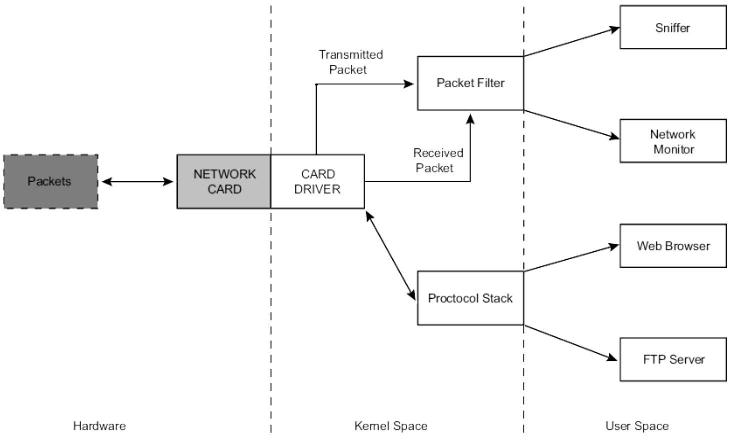


Fig. 1. Capture process employed by sniffers/packet analysers [8]
Rys. 1. Proces przechwytywania pakietów realizowany przez analizatory pakietów [8]

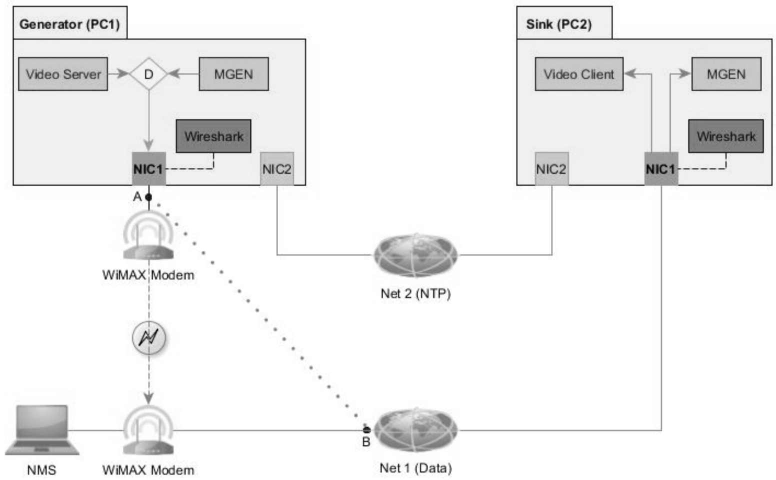


Fig. 2. Initial system set-up for validation measurements
Rys. 2. Wstępna konfiguracja systemu dla pomiarów walidacyjnych

Table 1 shows comparison of average delays and jitter between measurements with IXIA and MGEN. For each measurement the average results are estimated and then compared to estimated average results of the whole test. The ping tool does not allow measurements of jitter at all, and IXIA seems not to support directly the jitter variation. All measurements have been performed with the CBR traffic in uplink direction, and packet size is equal between tests and set to 1370B. This is selected to mimic the size of RTP video packets. All measurements have been repeated at least 10 times and each flow lasts 15 seconds.

Table 1

Validation results for MGEN (using commercial generator IXIA)

Packet stream	**Pkts/sec**	**OWD_{avg}**	**OWD (std. dev.)**	**$IPPV_{avg}$**
Mgen 1024 kb/s	93	39.23	10.00	7.24
IXIA 1024 kb/s	93	36.48	6.68	-
Mgen 512 kb/s	47	45.63	13.60	11.95
IXIA 512 kb/s	47	42.53	10.94	-
Mgen 256 kb/s	23	54.61	10.21	17.28
IXIA 256 kb/s	23	53.08	17.98	-
Mgen 128 kb/s	12	60.14	4.30	5.85
IXIA 128 kb/s	12	59.84	7.94	-
PING (32B)	-	72.61	5.26	-

It can be observed that the measurements performed using IXIA and MGEN in laboratory conditions are close to each other with ca. 3-8% inaccuracy (given same bitrate of a stream for pairwise comparison). The difference between measurement values can be explained by the 30-60us additional delay per packet that is introduced when performing readings with MGEN. A clear trend can be identified that with the decrease in traffic rate (from 1024 to 128 kbps) the OWD increases (from ca. 40ms to ca. 60ms). The value of delay measured using ICMP traffic (PING) would actually need to be divided by two (as this is round trip delay and not OWD) and it has to be noted that it was made for a small packets of 32 bytes. It has to be underlined that the measurements were repeated with WiMAX modem of another vendor (GreenPacket DX350) and the trend of increasing delay with smaller traffic rates has also been observed. The same behaviour of OWD characteristics has been confirmed in numerous mobile tests (see section 5). It has to be noted that average delay measured in downlink direction is on the opposite stable independent on the rates/speeds and equals ca. 20ms. This way it seems that there is either a delay introduced by sleep modes of the WiMAX modem or there is some delay due to TDD scheduling at the BS. This however needs yet to be verified in future tests.

Next step was to assess whether measurements using Wireshark provide satisfactory measurement accuracy as compared to IXIA and MGEN assuming identical network setup. Both source and destination hosts (PC1, PC2) were running Wireshark and collecting all the packets transmitted through network interface. Captured packets were processed offline by a dedicated script used to calculate IP packets end-to-end performance statistics. The script uses files created on source and destination hosts, de-encapsulates both data sets there, and from each packet identifies information about its length, timestamp, and some additional statistics for higher-layer protocols such as RTP e.g. sequence number of RTP packet. This information is then used for calculating delay, throughput and jitter. Source and destination packets were correlated by using RTP sequence number, and for such a pair of packet delay and jitter were calculated.

Table 2

Comparison of accuracy between MGEN and Wireshark

	OWD_{avg} [ms] (std.dev.)	$IPPV_{avg}$ [ms]
MGEN	43.52 (14.66)	9.2
Wireshark	43.11 (14.66)	9.1

The delay was obtained by subtracting destination timestamp from source timestamp, which is consistent to an approach defined by the RFC2679 with the exception that timestamps were not included in transmitted data but were added by Wireshark. The IPPV metric was calculated in compliance with the RFC3393 and throughput was calculated by summing up all packet lengths in defined period of time what is compliant with the RFC6349. Measurements collected in Table 2 have been derived from a stream of 2800 thousands packets. The clear conclusion can be made that it has been positively validated that the derivation of packet statistics using data captured with either with MGEN or Wireshark exhibits only differences at the level of microseconds. Such inaccuracy is negligible for the IP packet measurements needs.

3. Verifying the impact of using virtual machines

Virtualization offers the ability to create complex networks set-ups without the need for a large laboratory and hardware “backstage”. An example of using virtualization for setting-up measurement environment can be found e.g. in [9] and [10]. Moreover, since the virtual machines offer a high level of portability, they make a very convenient alternative to traditional set-ups, where the measurement software has to be installed on a dedicated hardware resource. The most obvious advantage of virtualization is the (high level of) independency from the host system resources. In case of more precise measurements, this may become a disadvantage, as precise time-stamping usually requires an access to lower-level NIC properties. Moreover, in case of e.g. live video streaming, an additional barrier may be the sometimes unpredictable behaviour of network buffers. The authors have thus contacted the developers of the streaming server liveMediaStreamer[6] to exchange their lessons learnt. It has been found that developers of liveMediaStreamer had experienced problems when adjusting network buffers in kernel to support high bit rate data

[6] https://github.com/ua-i2cat/liveMediaStreamer/wiki/Deployment-guide

(e.g. high-definition video) in a configuration with virtual machines. Our tests were done in simple environment with two computers connected back to back via Ethernet cable. It was exactly the same setting as shown in Fig. 2 but the nodes PC1 and PC2 were virtual machines hosted by physical machines each. These tests were run only with VBR traffic generated by the VLC streaming server (i.e. with no use of MGEN, PING and IXIA). The Wireshark tool was used to gather results. The plot showing instantaneous delay readings is depicted in figure below (Fig. 3).

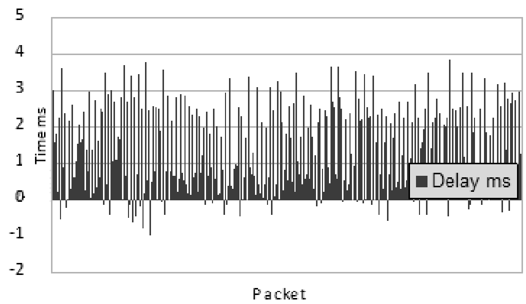


Fig. 3. OWD measurement with virtual machines connected over Ethernet
Rys. 3. Pomiary referencyjne dla maszyn wirtualnych połączonych kablem Ethernet

The analysis of results shows that the approach to use of NTP protocol for synchronization in local network (LAN) in preliminary tests, provides satisfactory results in Ethernet and WiFi networks (without background traffic). We found that synchronization through Ethernet cable is slightly more accurate than through wireless link (ca. 200-500 microseconds offset with use of Ethernet and 0.5-2.0 milliseconds with the use of WiFi network). In case of using virtual machines we found that they have negative impact both on results and synchronization accuracy (due to clock skew between hosts and VM nodes). Probably it is dependent on information exchange between host computer and virtual machines. Using computers with more computation power may probably reduce this impact but still we recommend performing tests using physical machines.

4. Time synchronization for mobile measurements

Accurate end-to-end measurements in outdoor environment require a precise time-synchronization solution. In wired networks this is generally less problematic, as standard network-time-protocol (NTP) and precision-time-protocol (PTP) can be used. In fact in good conditions, PTP is able to provide accuracy even up to nanosecond [11]. Although for our measurement such extreme accuracy is not needed, in case of wireless networks the aforementioned protocols may not be sufficient as they can suffer from loss introduced in the wireless channel. In [12] authors found that the error in measurements can easily achieve over

50ms in a bad channel conditions with peak values of de-synchronisation exceeding 1second. In the paper authors did not test in real environment, but used a WLAN emulator to test high loss ratio. Although the authors propose a remedy tactics for PTP, the achieved delays are still too high to be used in our measurements. NTP suffers a similar problem. Therefore the best way to cope with the issue of time synchronization is to get an accurate time reference on both sides of the measurements. In case of mobile measurements, the wireless connection should not be assumed reliable. To cope with this issue we focused on establishing a reference time source on each end of the connection. After initial analysis it was decided to use the PPS (pulse-per-second) signal for synchronizing a local instance of a NTP server. PPS accurately signals the beginning of each second and can be provided by selected GPS receivers. As the mobile drive-tests have to log also the geo-spatial data it seems as a good choice for drive tests.

Table 3

Solutions considered for accurate (Stratum1) time synchronization

No	Equipment	Comment
1	Time Standard Acutime GG P/N 92626-00[7]	Too expensive, about 370EURO per one item. Requires dedicated interface TrimTim IF2
2	Time Standard Acutime 2000[8]	Cheaper equivalent of above, about 130EURO, requires RS232 interface, which is not available in computer used in research.
3	ZTI Communications z050 USB GPS dongle[9]	Too expensive, 380EURO per one item, USB interface which does not support Real Time PPS (Pulse Per Seconds) signals.
4	Garmin solutions. (GPS 16x, GPS 19x HVS, GPS 18x LVC)[10]	Variety of products, prices from 75-150EURO per item. All devices equipped with RS232 interfaces, not all with connectors.
5	Raspberry Pi B+ with Adafruit Ultimate GPS MTK3339[11]	Requires self-assembly and configuration. Communication through Ethernet interface, price 100EURO per one set (approx. 65 Euros excluding Raspberry Pi)

Equipment that can provide a PPS signal can be either costly, use proprietary interface or require custom software. This obviously does not fall into line with the initial assumption for choosing the simplest and most affordable approach for minimizing resources needed for establishing drive-tests framework. Therefore, we defined the following main constraints for our search:

- the total cost of a unit should be under 100 euros,
- the solution has to be portable to be used for mobile measurements,
- the unit should be easy to reproduce (if not sold as assembled unit),

[7] http://www.dpie.com/gps/trimble-acutime-gg-gnss-gps-glonass-qzss-sbas-smart-antenna.html
[8] http://www.tecnogps.com/archivos/productos/acusync.pdf
[9] http://censintechnology.com/USB-GPS-Dongle-with-PPS
[10] https://buy.garmin.com/en-US/US/oem/sensors-and-boards/gps-19x-hvs/prod100686.html
[11] http://www.satsignal.eu/ntp/Raspberry-Pi-NTP.html

- the unit should be easy to connect with modern computers/laptops (e.g. proprietary /dedicated interfaces should be avoided),
- there should be a good availability of documentation and/or an active and well-organised user-community,
- the solution's architecture should be flexible and open.

The Table 3 presents a short summary of these solutions. According to the results there are only two solutions that meet the first requirement – namely some of the Garmin solutions (see point #4 in Table 3) and Raspberry Pi with Adafruit GPS solution (see point #5 in Table 3). Although Garmin solutions fall into the defined price range and usually have a decent documentation available, they offer only connectivity through RS232 interface which is not common in modern laptops and computers. For drive-tests this may be an issue, since this would mean, that additional equipment would be required for the mobile tests e.g. RS232 adapter, increasing the target cost. Similarly the Time Standard Acutime 2000, although very close to the price-range offers only RS232 interface. There are solutions which provide PPS signal via USB interface, which is much easier to connect, but USB may seriously impacts time accuracy. It is because USB is not designated to transmit real-time signals but all signals are multiplexed, serialized and handled in certain order. Therefore as a final result of authors' investigation the Raspberry Pi (RP) equipped with Adafruit Ultimate GPS MTK3339 receiver was chosen as equipment for synchronizing clocks of both measurement end-terminals. Although there is no official documentation, there is an active user-community and descriptions about how to build clock server based on Raspberry Pi and GPS modules [13] [14]. This solution is also the most flexible one. As the Raspberry Pi already acts as the time server, the synchronized machine only needs to be configured to use the time server and no additional software needs to be installed. Another argument that made this choice was the low price which is about 100 euros for a unit. It has to be underlined, that this price already includes the Raspberry Pi itself, which after the tests can be reused for multiple other purposes, bringing the actual cost of a unit to approximately 65 Euros. We performed verification tests with 512kb/s traffic using the same architecture as for the measurements done before (please see Fig. 2). The only difference is that each end terminal was connected to a Raspberry's NTP server via Ethernet local connection (we refer to this as the "GPS synchronization"). Each test was initialized by the phase of synchronization. First the RP NTP server is synchronized using the PPS signal. Next the end-terminal is synchronized with the local RP NTP server. The logs in Ubuntu terminal (i.e. PC1 or PC2 in Fig. 2) show that accuracy of synchronization on Raspberry Pi tool with PPS signal stays at the level of 3 μs while accuracy of synchronization between Raspberry Pi and our computer was on level of 10 μs. The 10 μs synchronization means, that "GPS synchronization" provides a better accuracy than when one of the end-terminals acts as a NTP server, where we have experienced level of 200-500 μs synchronization (with Ethernet connection). Table 4 presents the results for average delay of one-hour test with MGEN generator.

Table 4

Delay measurements for validating time synchronization

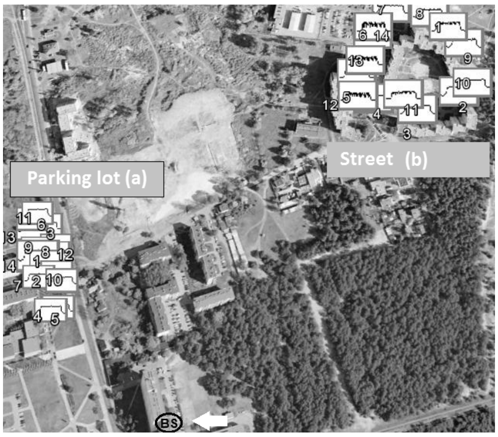
Average Delay [ms] each end-point connected to its local time server (on Raspberry Pi)	Average Delay [ms] one of the end points acting as NTP server
43.50	45.63

Performance metrics of WiMAX connection gathered with use of local (PPS-driven) NTP server appears to be similar with those of direct terminal-to-terminal NTP synchronization. Differences may simply originate from a fact of dynamically varying radio channel parameters or from a fact that NTP seems to be less accurate than GPS synchronization. According to gathered results we assume that use of Raspberry Pi GPS receiver may have very positive impact on accuracy of synchronization as compared to the use of NTP for synchronization via wireless network (WiMAX or LTE which are available in the measurement location). According to gathered insights and logs observed GPS synchronization seems to be a lot more accurate than NTP daemon solution (10 fold improvement in accuracy). Our test proved that such GPS solution is more trustworthy, also important to note is fact, that it will be a lot easier to adopt it in case of mobile tests, where usage of NTP daemon solution will be unavailable or may have suffer significant negative impact of weak, or dynamically changing wireless internet connection.

5. Mobile measurements

The main test performed by authors in the current preparatory campaign was to assess the connection quality (QoS) while end terminal is mobile. Traffic flow characteristics used was exactly the same as presented in Table 1(4 flows in uplink direction). Still the difference as compared to the laboratory (i.e. fixed location) tests was the use of WiMAX modem from Teltonika (miniPCI version). The modem was used with default settings with an external antenna providing additional gain of 5db and equipped with fitting magnet for rooftop mounting.

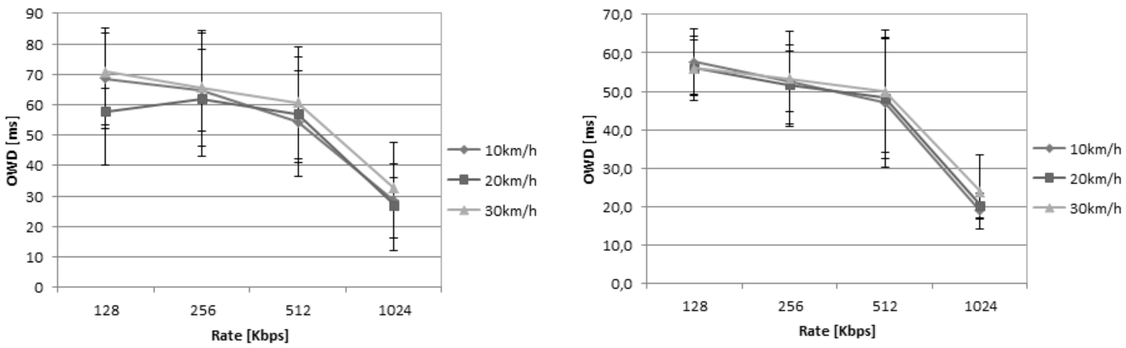
We have first performed drive tests to identify the geographical locations where the nominal signal quality was at least acceptable. The spectrum analyser Tektronix SA2500 has been used to identify regions with acceptable signal quality. Two locations have been selected in the range of 1km from base station. The first location was parking lot in a close vicinity of the base station and the second was the street among blocks.



Key:
"Location A" – parking lot (on the left)
"Location B" – street between houses (on the right)
"BS" – location of the base station (an eclipse at the bottom of the map)

Fig. 4. Measurement locations
Rys. 4. Lokalizacja pomiarów

It can be seen from the Figure 5 that with the increase in throughput (packet rate) the OWD decreases. The average delay (OWD) for 1024Kbps equals ca. 30ms and is two times smaller than the delay of the 128Kbps flow (i.e. eight times smaller rate). The same behaviour is observed for both locations and is rather independent within given speed range. The 10ms difference in average delay for lowest throughput (the "Street" location) may result from slight variety in radio conditions (fading) during car movements.



(a) Street (b) Parking lot

Fig. 5. Overview of mobile results
Rys. 5. Zestawienie wyników pomiarów mobilnych: a) ulica, b) parking

It can also be seen from the plots that standard deviation bars are quite high and equal ca. 15ms in average case (i.e. between rates and speeds). Most probably the reason for such difference is the overhead incurred in transmission of small rates. In case of 128Kbps there is 12 packets sent per second, which means that each packet is using its own dedicated TDD time frame (and thus the additional delay is added). While in case of 1024Kbps there are 93 packets sent per second which means that at least two packets can be transmitted using single TDD frame (as each packet is sent every 10ms). Moreover as this behaviour was observed for at least three different WiMAX modems (Teltonika USB, Teltonika miniPCI, GreenPacket), it is likely that with small rates the modem transmitter applies optimizations of energy consumption (through activating sleep mode).

6. Summary and future work

This paper focuses on the preliminary approach to measurement campaign of video streaming services in WiMAX (802.16e). We have successfully prepared a complete environment that relies on low-cost IP performance measurement software. It has been shown that the software provides accurate measurements when validated using professional packet generator/analyser. It has been also shown that it is quite straightforward and cost effective to realize GPS synchronization using the DYI Raspberry Pi platform (cost of a unit ca 100 EUR) with GPS module attached. Moreover it has been shown that making the environment more portable with virtual machines is not feasible due to inherent problems with time synchronization between physical and virtual machines. During current stage of tests great number of laboratory tests was performed. These results show that current level of delays as well as the throughput is sufficient to enable video transmission in stationary conditions (and good radio coverage). The same behaviour has been confirmed for mobile tests with mobility in the range of 10-30km/h in the range of 1km from base station. As a next step authors plan tests in a commercial networks with traffic generated by real users. The streaming solutions (such as e.g. the liveMediaStreamer) developed in the scope of the MITSU project will be used. Therefore on a software side, the set-up will use the existing streaming services such as VLC (as tested in this paper) which will then be compared with MITSU streaming services as well. Further the set-up may also be used to accommodate the adaptive streaming solutions to assess the performance in WiMAX network.

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Omówienie

W artykule przedstawiono wyniki pomiarów adaptacyjnego strumieniowania wideo w sieciach mobilnego standardu WiMAX (IEEE 802.16e). Zaproponowano metodykę przygotowania oraz realizacji testów (oraz zestaw skutecznych narzędzi pomiarowych), pozwalających na ocenę jakości strumienia wideo. W pierwszej fazie badań wykonane zostały pomiary referencyjne sieci za pomocą ruchu syntetycznego, wygenerowanego za pomocą darmowych narzędzi do generowania i analizy ruchu (MGEN). Po pozytywnej weryfikacji i walidacji narzędzi z użyciem komercyjnego narzędzia IXIA XM2 oraz opracowaniu własnej wersji niskobudżetowego źródła czasu referencyjnego GPS (i testera sieci radiowej w jednym) przeprowadzono testy i pomiary w laboratorium oraz w terenie. Wyniki przedstawiają w sposób przekrojowy wydajność sieci mobilnego standardu WiMAX dla potrzeb transmisji danych wideo z monitoringu wizyjnego, dla różnych scenariuszy (stacjonarny, mobilny, transmisja w górę, transmisja w dół, różne przepływności). Pomiary pokazały zachowania sieci trudne do uchwycenia za pomocą dostępnych narzędzi do symulacji sieci. W szczególności udało się uchwycić wpływ minimalizacji zużycia energii w nadajniku w zależności od przepływności strumienia. Zwiększanie przepływności strumienia z 128 kb/s na 1024 kb/s powoduje sukcesywne zmniejszanie średniej wartości opóźnień z około 65 ms do 20 ms. Zachowanie to obserwowane jest dla różnych modemów WiMAX (Teltonika, Greenpacket), ale tylko w kierunku „w górę” (optymalizacja zużycia energii w nadajniku mobilnym). W kierunku w dół opóźnienia dla wszystkich testów kształtowały się na poziomie ok. 20-30 ms niezależnie od modemu oraz przepływności strumienia. Autorzy zamierzają kontynuować pomiary w komercyjnych sieciach WiMAX w Polsce (m.in. w Poznaniu oraz okolicach Szczecina), aby następnie na ich podstawie zbudować modele wykorzystywane przez mechanizmy z zakresu optymalizacji między-warstwowej (ang. cross-layer).

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