Results of Evaluation of Time Signals Received from NTP Servers in Poland

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INTRODUCTION

Answering the demand of different enterprises and institutions for accessible and cheap sources of time signal, research on the NTP performance on the Internet in the area of Poland was carried out. The observation results indicate that the signals from NTP servers are characterized by different reliability. This can be caused by the number of intermediate servers with which a given server is connected to a time standard (stratum is the quantity which tells us about that). There are also another reasons for different reliability of servers, such as the reliability of network access, network overload depending on a time of the day, etc. All this makes up the reliability of a given server; such reliability was evaluated in the present research. The NTP servers were examined in a two-fold way. The first method concerned the performance of NTP itself in network communication with particular servers over Poland. The other method was devoted to examine the physical time signal obtained on the COM interface of a computer synchronized with NTP server. The effects and results of the research will be presented in further part of the paper.

STATISTICAL RESEARCH ON NTP

In the present research a fundamental assumption was taken: the research on NTP was carried out with the use of a standard PC with average technical parameters, with Windows XP and elementary software installed: virtual Java machine Java JRE 1.5_06 and a calculation sheet Microsoft Excel 2003, as well as an implementation of NTP client – a program written in Java language. The Java program makes use of standard libraries of this language concerning NTP, which are actually a ready-to-use implementation of NTP client. For the needs of the present research, the potential of Excel 2003 package is sufficient because the range of acquired data was limited to samples collected during one week.

Principles and aims of the research

The research consisted of a few experiments. Two servers, with known stratum [1], were always tested simultaneously. In each series of experiments a request was continuously sent to NTP servers, to one and another server alternately, in constant intervals of time, e.g. 5 seconds (i.e. each server will get requests every 10 seconds). The results were taken as timestamps. Therefore, for every request it was possible to determine when the request was sent, when it reached the server, when it was replied, and when the response reached the computer sending the request. The server's response time was thus examined by comparing the timestamps at the moment when the request and the response to that request were received by the server. Also the delay was examined in the network through which the requests were transmitted to the server, and the network's responses. The results of all the series were compared because they were obtained under the same conditions. Thanks to that procedure, we could find out the performance of which server is the best in practice, i.e. we could take into consideration not only the stratum itself of NTP server but also its behavior in the network [5]. A list of the examined servers is presented in Table 1.

Table 1. List of examined NTP servers

Item	Server name	Server IP address	Server stratum
1	vega.cbk.poznan.pl	150.254.183.15	1
2	ntp.nask.pl	195.187.244.4	2
3	ntp.icm.edu.pl	193.219.28.149	2
4	ntp.task.gda.pl	153.19.0.141	3
5	info.cyf-kr.edu.pl	149.156.2.100	2
6	sunflower.man.poznan.pl	150.254.173.2	2
7	tempus1.gum.gov.pl	212.244.160.67	1
8	ucirt.agh.edu.pl	149.156.121.250	3

The research procedure was the following:

- Simultaneously 2 NTP servers are examined
- Time interval between the examination of each server equals 10s
- Time shift between the collecting of successive samples from the servers is 5s.

Description of program applied to the research

Every series of experiments generates two object files – one of them contains timestamps in a version convenient for immediate verification of the validity of the obtained data, because the date and hour is written using a text and digits. It requires some transformations to expand the obtained results into the number of milliseconds that passed since 1 January 1900 (beginning of the countdown of timestamps in NTP) till 1 January 1970 (beginning of the countdown of timestamps in Unix system). The reason for presenting the results in the form of a number is the usage – in the implementation of NTP client – of a standard function of Java language (getTime), which works according to the Unix system standards. A fragment of Excel sheet with numeric data is shown in Fig.1.

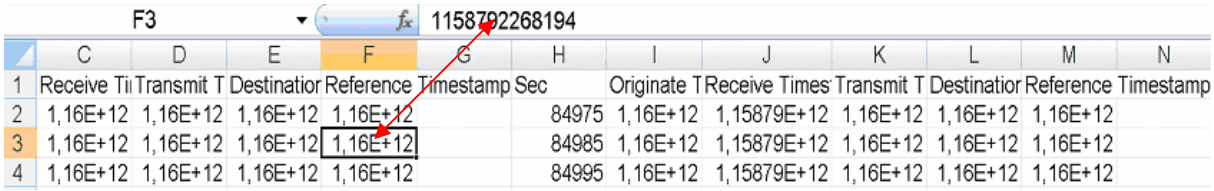


Fig. 1. Appearance of output file in the expanded format for: line 3 and column F

Summarizing the description of data format in output files, we should emphasize that:

- For statistical calculations the time format of output data is not convenient.
- The numeric format is developed by changing time into the number of milliseconds, with reference to the initial point for the day 1 January 1970, 00:00:00 (UNIX notation).
- Correction for NTP requires adding 2.209.988.800 s, which concerns the beginning of NTP timestamps since the day 1 January 1990, 00:00:00. The first six columns (columns A-F) show the results concerning the first server, then there is a free column (column G), and in the next six columns we can find the results concerning other server (columns H-M). The relations among the timestamps are shown in Fig. 2.

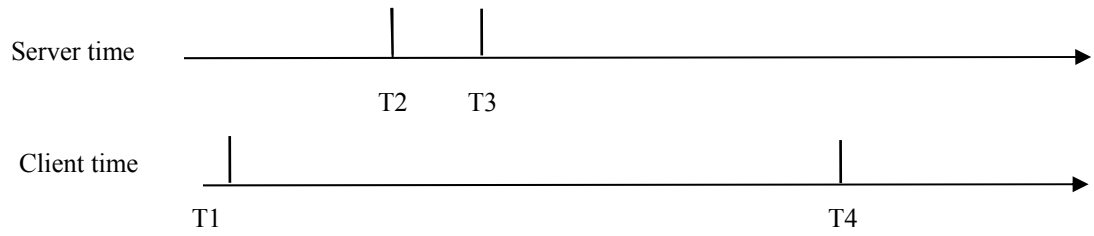


Fig. 2. Relations among timestamps with division into client time and server time
T1 – timestamp of sending a message by the client (*originate timestamp*)
T2 – timestamp of receiving the response by the server (*receive timestamp*)
T3 – timestamp of transmitting a message by the server (*transmit timestamp*)
T4 – timestamp of receiving a message by the client (*destination timestamp*)

Research scope

A great number of results were obtained in the experiments for the duration of one year. This enabled us to compare different standards with one another in time intervals from single minutes up to a week, because such was the longest time interval of the observation time. A list of selected servers under observation was presented in Table 1. The pairs of simultaneously tested NTP servers were put together.

The properties examined were the following**:**

- Evaluation of time needed for the server to generate a response (T3 – T2), in a cross section of hours, in the frames of 24 hours and days of the week, for all the servers.

- Evaluation of the results of examining the response time of NTP servers (T4 – T1)**,** in a cross section of hours, in the frames of 24 hours and days of the week, for all the servers.

Results of examining the NTP waiting time in servers during 24 hours

The process of waiting of a query about time in the NTP servers was evaluated in 2 series. The results were set up in a table and presented in the form of histograms. Table 2 shows the evaluation of NTP waiting times in the server under investigation. Due to scatters in the results between servers, the part of the table containing the results was divided in 4 columns, which show the properly grouped times, determined in the measurement, and present the calculated average time.

Table 2. Waiting time of query in server

Item	Server name	Average time of generating a response during the whole test [ms]		Average time of generating a response on a selected day [ms]	
		I series	II series	I series	II series
1	vega.cbk.poznan.pl	0,032	0,031	0,026	0,036
2	ntp.nask.pl	0,929	1,083	0,962	1,074
3	ntp.icm.edu.pl	0,036	0,037	0,031	0,057
4	ntp.task.gda.pl	0,049	0,486	0,039	0,393
5	info.cyf-kr.edu.pl	0,239	0,241	0,221	0,258
6	sunflower.man.poznan.pl	0,086	0,092	0,106	0,118
7	tempus1.gum.gov.pl	0,09	0,011	0,075	0,08
8	ucirt.agh.edu.pl	0,012	0,011	0,019	0,015

A histogram illustrating these relations, which concerns the average 24-hours response time of particular servers, is shown in Fig. 3.

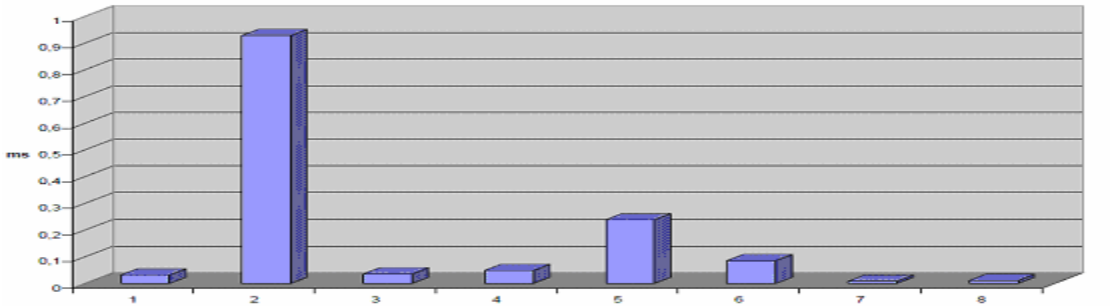


Fig. 3. Average 24-hours response time of particular NTP servers

In another series the test duration was 1 week. It enabled us to evaluate the behaviour of the examined time on particular days of the week. The average 24-hours waiting time of NTP information in the server does not precise the time for every hour.

Conclusions

- Summarizing all the series of 24-hours and weekly tests, the authors observed some common tendencies.
- Neither the server stability nor the speed of generating responses were significantly affected by the fact whether a given test day was a working day or not.
- It was not confirmed that the server with the shortest time for generating responses is at the same time the most stable one.
- The influence of the stratum level of the server cannot be noticed, and sometimes a server with better stratum shows worse results.
- Statistically, the response times of servers are within the range of 100μs.

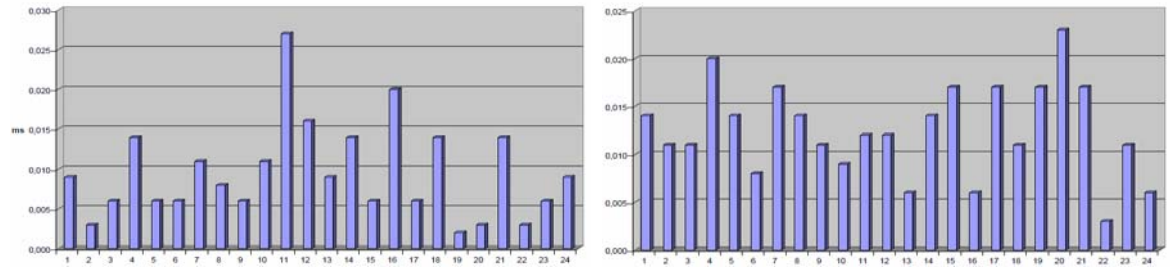
Exemplary 24-hours histograms for servers stratum 1 and stratum 3 are presented in Fig. 4. The weekly test results are shown in Fig. 5.

Research on the NTP waiting time in the system

The scope of the research on NTP waiting time in the system comprises:

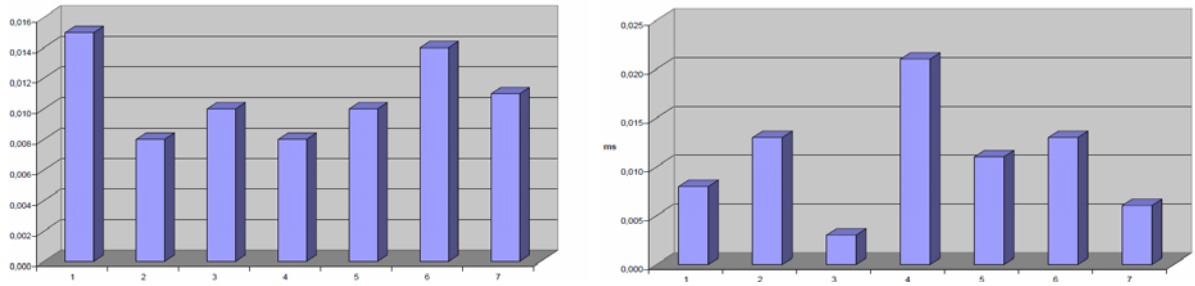
- Measurements of time interval between sending a client's query to the time server and receiving a response, i.e. the interval of times T4–T1, as it is shown in Fig. 2;
- Evaluation of results in a cross section of particular hours within 24 hours and particular days within a week.

The research was carried out in 2 series. A set up of all samples of both test series is shown in Table 3. In the first series the servers were tested in the mode of 24-hours examination, with focus on determining the influence of a time of the day on the results of delay times, introduced by the servers and Internet network. In the other series the measurement times for a pair of servers were prolonged to one week. It enabled the authors to examine the distribution of times, resulting from waiting of the protocol in the system for particular days of the week, without losing examinations in particular 24-hours periods. Out of numerous measurements carried out for all the servers, the histograms were presented for server: tempus1.gum.gov.pl with stratum 1 and server: ucitr.agh.edu.pl with stratum 3.



tempus1.gum.gov.pl (stratum 1) ucitr.agh.edu.pl (stratum 3)

Fig. 4. Selected histograms of the 24-hours examinations of the NTP waiting time in servers with different stratum



tempus1.gum.gov.pl (stratum 1) ucitr.agh.edu.pl (stratum 3)

Fig. 5. Histograms of the 24-hours examination of the NTP waiting time in servers with different stratum

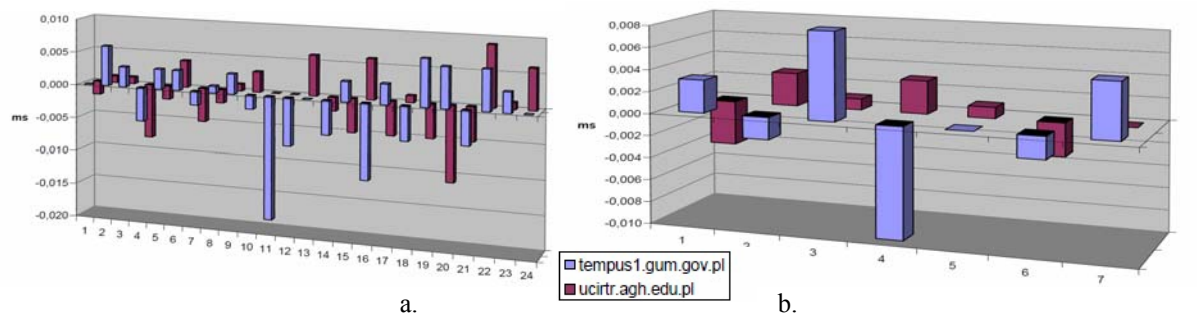
Table 3. Average waiting time of a query in the system for I and II test series

Item	Server name	Average time of generating response during the whole examination time for all samples [ms]		Average time of generating response on a selected day for all samples [ms]	
		I series	II series	I series	II series
1	vega.cbk.poznan.pl	25,812	22,991	24,459	21,759
2	ntp.nask.pl	15,638	15,945	14,234	14,089
3	ntp.icm.edu.pl	70,875	13,794	65,168	11,376
4	ntp.task.gda.pl	76,985	31,910	44,734	36,511
5	info.cyf-kr.edu.pl	79,665	19,420	68,791	14,007
6	sunflower.man.poznan.pl	82,134	17,272	42,084	12,954
7	tempus1.gum.gov.pl	63,639	14,949	56,237	15,619
8	ucirt.agh.edu.pl	67,430	19,277	47,248	19,697

Response times for all the examined servers are set up in Fig. 7.

Comparison of 24-hours and weekly errors of selected servers

The delay errors of both servers are set up in one histogram for the results of both servers from Fig. 6. The histograms show the differences between the values: average and current. The error distribution indicates no common tendencies. Server tempus1.gum.gov.pl has shorter response time intervals, especially in the evening when delay errors are the smallest. For server ucitr.agh.edu.pl in the same hours errors are bigger. The results of weekly comparisons are also interesting.



a. b.

Fig. 6. Comparison of delay results in particular hours (a) and delays in particular days (b)

Despite better stratum, server tempus1.gum.gov revealed a greater scatter than server ucitr.agh.edu.pl. However, as it results from Table 3, average delay time in the period of a week for server with stratum 1 is by 20% shorter than for server with stratum 3.

In the measurements carried out, apart from properly collected samples with measured delay time, also erroneous and delays samples appeared in the results. Exemplary 24-hours histograms for selected servers stratum 1 and stratum 3 are shown in Fig. 8. The results of weekly tests are shown in Fig. 9.

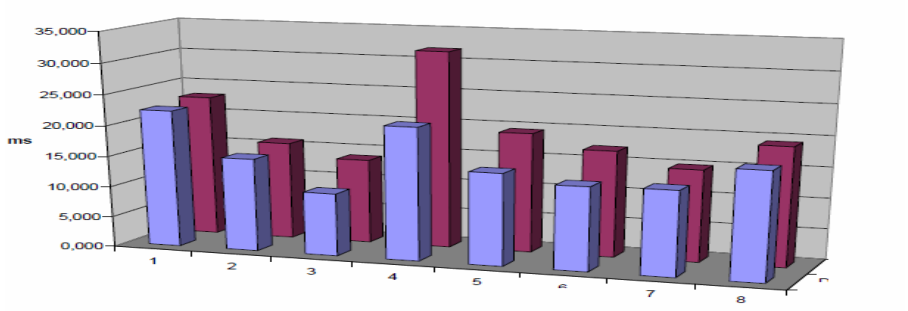
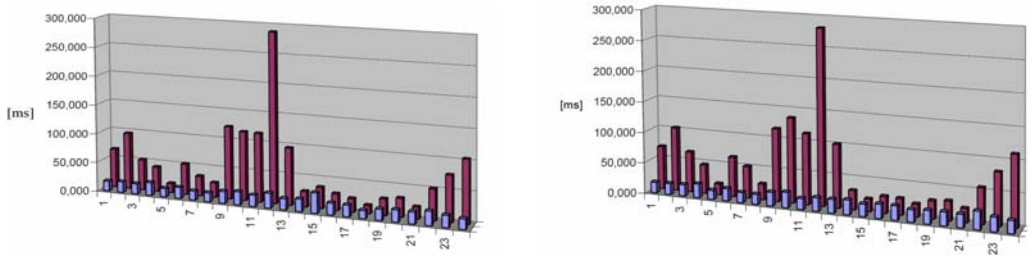
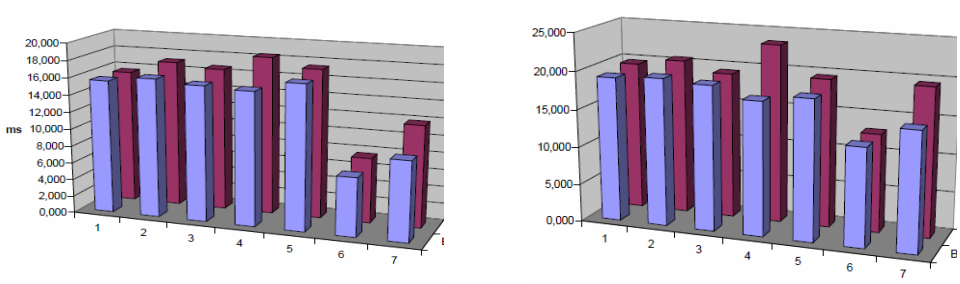


Fig. 7. Average weekly NTP waiting time in the system (first row – without samples >100 ms, second row – all samples)



tempus1.gum.gov.pl (stratum 1) ucitr.agh.edu.pl (stratum 3)

Fig. 8. Comparison of histograms from 24-hours research of the NTP waiting time in the system (first row – without samples >100 ms, second row – all samples)



tempus1.gum.gov.pl (stratum 1) ucitr.agh.edu.pl (stratum 3)

Fig. 9. Comparison of histograms from weekly research of the NTP waiting time in the system (first row – errors free, second row – erroneous and delayed >100 ms)

Summary of the results of research on the NTP waiting time in the system

Summarizing the examination of the NTP waiting time in the system, we can formulate the following conclusions:

- A time of the day affects the system performance. This is a factor common for all time servers and it results from the Internet network (over)load in the peak hours.
- Also a day of the week influences the system performance, but this influence is different for particular time servers and depends on their location.
- The whole waiting time of NTP procedure in the system does not depend significantly on the level of server stratum.
- The number of delayed and lost samples, or those regarded as erroneous, depends on the level of server stratum and is greater for higher stratum.
- There is no relevant correlation between a day of the week and the longest waiting time of the protocol in the system, although Wednesday, Thursday and Friday proved the greatest number of erroneous samples.
- There is a certain strong correlation in the results of examining a pair of servers, which means that the effect of the Internet network itself on the waiting time of the protocol in the network is all-important, although not always confirmed.
- Not always the number of lost samples appears in the same time as the number of delayed samples. It points to different reasons behind those phenomena.
- The difference between a working day and a holiday is not relevant for the distribution of samples without errors.

Conclusion of examining the NTP performance in Polish Internet network

For reasons of space, the paper has presented only a small number of results comprised in the developed tables and histograms. Results were obtained for all the servers. Therefore, the generalizations presented above concern all the experiments, not only the results for two exemplary servers. The research proved a very relevant influence of the Internet network load on the waiting time of the protocol in the system. Important correlations have been found during the research between political events, the Internet network load and the waiting time of the protocol in the system. This can be noticed in Table 3 among the results of comparing the tests of series I and II. The correlations concern the duration of response time and the number of lost samples; those statistics have not been placed in the paper. The examination of the waiting time of the protocol in the server proved that the waiting time has a slight influence on the accuracy of time acquiring in millisecond intervals and a relevant influence on the accuracy in microsecond intervals.

EXTRACTION OF THE TIME SIGNAL CONTROLLED BY NTP ONTO A COMPUTER EXTERNAL INTERFACE

Basic premises for acquiring time from NTP in the form of physical time signal as a 1pps pulse and a package with information

The operations described in the previous section made it possible to achieve a vast number of results. The analysis presented in the paper does not exhaust all information acquired and that which is worth acquiring. The form of presenting the results as Excel files enabled their analysis, comparison and graphic presentation as histograms. It was also possible to make histograms illustrating waiting time of NTP protocols in time servers and in the system. However, these operations are extremely time-consuming. It can be estimated that for weekly tests the processing of results will take over 2 weeks of time-consuming work. Computer, connected to the Internet, is supplied with a specialized

software installed. Output data from COM1 interface on pin no 3 contains a time packet, and on pin no 4 1 pps signal which determines the moment of arriving of the examined second. In order to make the measurements objective, a method of measuring every collected NTP second with reference to a GPS second was assumed. The difference between the moments of arrival of these signals determines the width of time interval T, which is the measure of delay /acceleration of 1pps signal from NTP in relation to the reference being 1 pps from the GPS system source. The investigated difference is caused by a measuring module in which separate time signals from both sources are converted into a time interval. The width of the time interval under investigation, if the signals of devices generating 1 pps pulses from NTP and GPS are present, is equal to maximally 1 s. The width of this time interval is measured every second by a specialized measuring card. The fact that measuring the time signal acquired from NTP is related to the reference signal from the GPS system not only makes it possible to instantaneously measure the timestamp location of every NTP second, but in relation to e.g. the measurements of the period of frequency of signals from NTP allows us to detect their direct relation with reference to the UTC time, which is connected with the GPS time by a constant relation. A block diagram of that system is shown in Fig. 10.

Description of the performance of a program acquiring 1 pps signal from NTP

The basic purpose of the software (being simultaneously an NTP client) is the service of acquiring 1 pps signal. Because the packet generated by NTP does not have a specified location on the time scale, the software – based on data from NTP and the timing of system clock – generates this 1 pps signal.
Configuration parameters:

- Period between the synchronization of time from NTP [ms]
- Value of time shift added to the value acquired from NTP [ms]
- NTP signal is transmitted in the form of 8-bit pulse with a speed of 57600b/s
- Timer applied to trigger 1pps signal is the Multimedia Timer Microsoft
- Synchronization consists in changing the period of 1pps signal at the moment of collecting information from NTP in the time of 1 period (only 1 period is corrected).

To examine time signals from NTP protocols, we utilized measuring modules that determine the time interval T between 1 pps signals from GPS system and 1 pps from NTP transmitted onto COM computer interface. The computer is equipped with a specialized measuring card, enabling the measurement and recording of this interval [6].

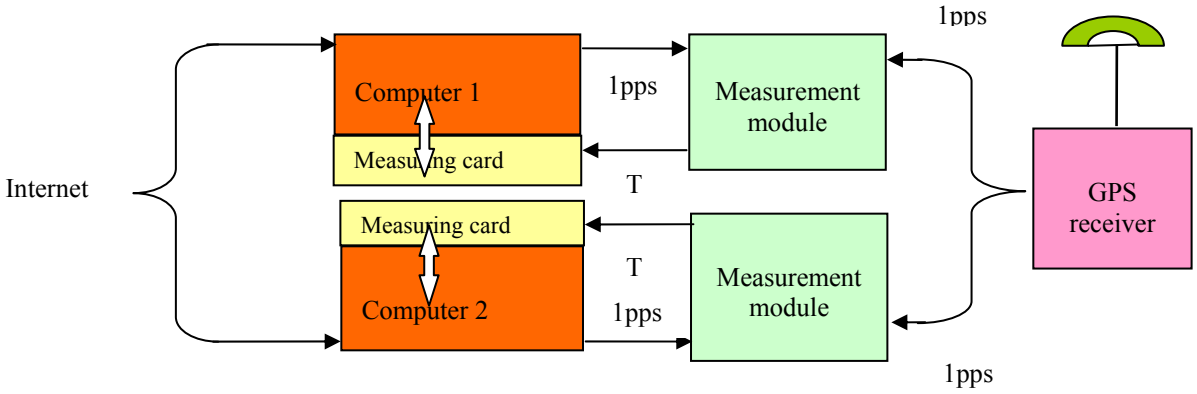


Fig. 10. Block diagram of a system designed to examine time signals from NTP protocols

Measurement results

An example of 20-hours measurement of the time error sequence between the signal obtained from NTP and reference signal controlled with the GPS system is shown in Fig. 11. After analyzing the results of examining the NTP performance and signal obtained on the external interface of a computer controlled with NTP, we are inclined to put forward the following conclusions:

- The quality of time signal acquired on the computer interface depends on appropriate selection of the parameters of software responsible for cooperation with NTP.

- Frequent reference to the NTP synchronization procedure makes the time signal more sensitive to jumps of the order of a few milliseconds, resulting from the influence of events in the Internet network.
- The fact that the references to time synchronization from NTP appear rarely causes the influence of poor quality of clock on the time signal generated.
- Obtaining a stable time signal is a result of finding an appropriate compromise between available correction parameters, i.e. time interval between successive synchronizations with NTP and the value of time added or subtracted from the value acquired from NTP.

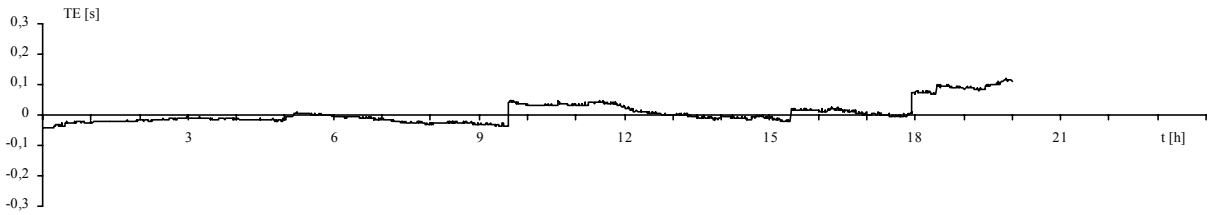


Fig. 11. Example of 20-hours recording of the location on the time scale of an NTP signal from server vega.cbk.poznan.pl

Further research

Further research will focus on attempts of achieving a compromise between the program parameters, improving and optimizing the existing software and examining the influence of the performance of other programs running simultaneously in computer. Including another computer stand will allow the researchers to utilize in parallel two NTP protocols for examining two time servers at a time, in different places of Poland. It will make it possible to evaluate the influence of the Internet network on the acquired time signals.

CONCLUSIONS

These works are performed in the frame of the project "Metrology and monitoring" sponsored by the Ministry of Science. One of the goals of this project is to make the reports of continuous analysis of the time signals available for public. This knowledge can be very useful for possible users, who want to choose the NTP server suitable for their requirements.

ACKNOWLEGMNET

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