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GSM MOBILE PHONE IN DISTRIBUTED VIRTUAL INSTRUMENTATION

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Abstract − Remote, wireless controlling of distributed virtual instrument (DVI) using GSM mobile phones is considered. Interactive WAP service is applied to configure measuring system, to control measurement process and to access to measurement data. The service is based on ASP technology and dynamic databases. National Instruments PC-1200 DAQ card, programmed with *LabVIEW*, was applied to design a wireless DVI (WDVI).

Keywords: DMS, DVI, GSM.

1. INTRODUCTION

The rapid development of radiocommunication, observed on the turn of the 20^{th} and 21^{st} century influenced the development of new measurement techniques, which employ the capabilities to connect the elements of measurement instruments and systems in the wireless manner.

The increasing capabilities of the GSM mobile phones make it possible to consider using them for the purposes different than strictly communicational. One of those, standing on a junction of measurement, telecommunication and computer science domains, is using the mobile phones as elements of distributed measurement systems, as well as wireless DVI end terminals [1-9]. In the majority of such systems, they will provide basic control and presentation functions, while in the process of their communication with the measurement equipment there will be an intermediary measurement server, which is a computer, often connected to the Internet, interpreting the phone's requests, triggering the measurement process, receiving the results and passing them back to the phone in an appropriate format. An important factor influencing the capabilities and limitations of the virtual instrument build in the described manner, is the way of communication between the phone and the server.

Data transmission in the GSM system may be conducted in one of the following ways: using SMS (*Short Message Service*), SDT (*Switched Data Transfer*), HSCSD (*High Speed Circuit Switched Data*) and GPRS (*General Packet Radio Service*).

The functions of the mobile station may be provided by both the mobile phone or a laptop computer with a PCMCIA card having the mobile phone capabilities. A typical structure of a WVMI using the GSM telephony is shown on Fig. 1. The measurement equipment is connected to the computer, hereafter referred to as the measurement server, using a local bus (e.g. IEC-625, RS-232, VXI).

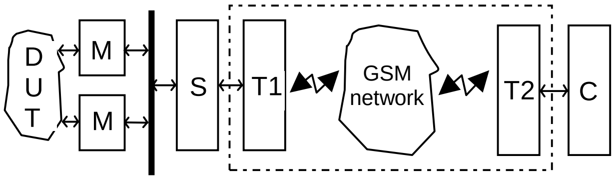


Fig. 1. The wireless DVI structure employing the GSM telephony. DUT is the object under test, M – the measurement hardware VI part, S – measurement server, T1 and T2 – mobile terminals, C – client computer

The measurement server controls the measurement devices, collects the results and send them to the T1 wireless terminal in the wired (e.g. using RS-232 for MT2 type terminal [4] or a terminal adapter – for the MT1 type terminal) or wireless manner (e.g. using IrDA or Bluetooth for MT2 type terminal). The data is sent over the air from the T1 terminal to the GSM base station and switching centre, and eventually to the T2 terminal, which is connected to the client computer in either wired or wireless way. Instead of the T2 GSM terminal, one might use a stationary telephone connected to the GSM system by the public telephony switching centre. In this case, the client computer must be connected to the telephone using a modem. It is also possible not to use the client computer, provided the T2 terminal is a device that may be directly operated by the measurement system user.

Another method of designing the wireless VMI is using the WAP-enabled (*Wireless Application Protocol* enabled) GSM mobile phones. WAP protocol is based on the Internet technologies such as XML (*Extensible Mark-up Language*) and IP (*Internet Protocol*) and allows the wireless equipment users to access the Internet services.

2. A CONCEPT OF DVI USING A GSM PHONE WITH WAP PROTOCOL

2.1 Analysis of using GSM telephony in measurements

The known up-to-date, still not numerous attempts to use the mobile telephony in measurements employed the configuration shown on Fig.1, in which GSM modems were connected to a computer, and the system control was conducted only from the client machine. The first solutions used short messages [5]. The main elements of the system were: laptop PC with a digital multimeter connected with RS-232 interface, located at the measurement station, and another PC located at a distant measurement system centre. The Nokia 2110 mobile phone used in the system required a terminal adapter for the data transmission. The terminal adapter functions were provided by a PCMCIA extension card named Cellular Data Card for Nokia 2110.

Similar in assumptions, but more sophisticated system was presented in [10]. A measurement station was realised using Siemens GSM modules, allowing for the short message based communication with the measurement system. The solution allows to control the system and to receive the measurement results using SMS or e-mails.

A solution based on the transmission through a switched data channel between two systems, one of which was functioning as a measurement station and the other as the system centre, was presented in [6]. There was presented a measurement system consisting of a set of sensors and a multimeter attached to a portable computer equipped with a GSM card (Nokia Data Card Phone 2.0), all forming a mobile measurement station. The station uses the GSM network to connect to the measurement system centre, responsible for acquiring and updating the data. The communication can be established in two ways. The centre establishes a connection to the mobile station, triggers the measurement and collects the results, or waits for the mobile station to connect. After establishing the connection the station receives the results and presents them in the chart form. Additionally, the data are stored in Excel spreadsheet files.

A similar system, employing both GSM network and the Internet for communication, was presented in [4]. It had been assumed that the GSM communication is conducted only on a given segment of the data channel, between the monitoring station and the nearest service giving the Internet access. The further communication was conducted using the Internet links. A separate part was the control and measurement system, to which the sensors were directly connected. In the described case, the system was used for remote electronic appliance testing. The tests consisted in designing a test signal on the local computer, sending it to the remote computer, to which the device under test was attached, and acquiring the output from the device being examined.

The majority of the systems designed up-to-date assumed that the GSM telephony would be used only as in information carrier between the distributed measurement system elements. As such, the GSM terminals were connected to the measurement systems as modems only. This approach does not however exploit the vast capabilities of the GSM terminals themselves. The first attempt to use a GSM terminal and WAP technology for accessing the measurement data was presented in [6]. A concept of publishing the measurement data for the mobile phones on the Internet was proposed. The concept did not however allow for controlling the measurement system using the mobile phone, only for presenting the results on the phone's display.

2.2. A proposal of a new structure of WDVI with GSM phone with WAP protocol

The virtual instrument concept proposed herein in an enhancement of the measurement data access from the mobile phone, which would allow for not only reading the measurement data, but controlling the measurement hardware as well. It is assumed that the presented instrument has the purpose of controlling and monitoring slowly alternating signals.

The following, new WDVI structure using a WAP-enabled mobile phones has been proposed. The general configuration of such instrument is shown on fig. 2. It is a modified measurement system configuration presented on fig 1. It has the advantage of reducing the client station to a small, mobile terminal in the form of a GSM phone.

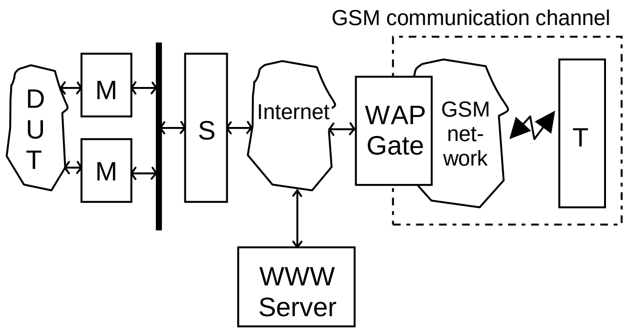


Fig. 2. The new structure of a WDVI employing the WAP protocol. DUT is the object under test, M – the measurement hardware VI part, S – measurement server, T – mobile GSM terminal

3. THE EXPERIMANTAL VERIFICATION OF THE NEW WDVI STRUCTURE

For the purpose of verifying the concept of a WDVI using a WAP-enabled mobile phone, a prototype of such instrument was realised and examined. It has been configured in accordance to the proposed structure; a set of applications giving the full system control from the mobile phone has been designed. The applications should allow for:

- the authorised access to the configuration data of the instrument, such as:
  - measured quantity selection
  - measurement count and frequency setting
  - triggering and aborting the measurement
- the authorised access to the measurement results at any given time:
  - reading the given number of measurements
  - reading the statistical measurement data
- triggering an immediate measurement and reading its results:
  - selecting the measured quantity
  - setting the measurement count and frequency
  - triggering and aborting the measurement
  - immediate presentation of the results.

It has been assumed that the instrument will have the purpose of measuring climate quantities (temperature, pressure and humidity). The measurement data are collected from the object under test using an EE06 sensor from *EE Elektronik* connected to the DAQ acquisition board from *National Instruments*.

The proposed WDVI configuration is shown on Fig. 3. The presented WDVI consists of three basic parts:

- the module responsible for the measurement part;

- the module allowing for the presentation of data on the mobile phone display;
- the database storing the measurement results, configuration data and the list of users authorised to view and to configure the measurement data.

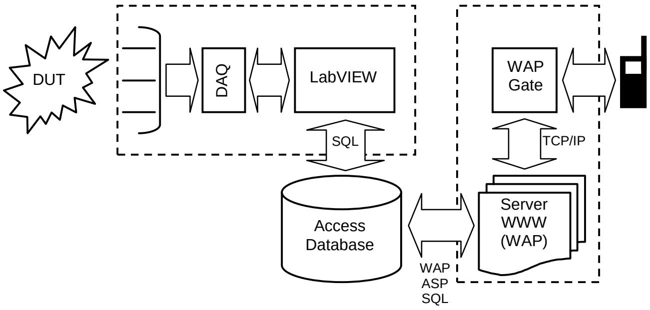


Fig.3. The proposed WDVI configuration

The measurement part of the WDVI consists of the data acquisition board installed inside the PC, and any given set of sensors connected to it. In the conducted experiments it was equipped with the temperature, pressure, humidity and light exposure sensors. The data are read independently from each channel according to the programmed schedule (the measurement frequency depends on the channel). Additionally, independently on the measurement procedure, the system monitors the entries in the database containing the instrument configuration information, which is used for the user interaction. One of the fields is the configuration marker, which informs whether any of the measurement parameters has been changed since the marker was read for the last time. If during the data checkout it is determined that the marker indicates changes in the configuration, the measurement procedure is aborted, the configuration information is read again, and the measurement procedure is restarted using the new parameters.

The measurement system server has been created using the *National Instruments LabVIEW 6i* integrated programming environment. It consists of:

- **the data acquisition part** – responsible for receiving and processing the results from the temperature, pressure and humidity sensors.
- **the communication part** – responsible for reading the configuration data and sending the read and processed measurement results.
- **the configuration part** – controlling the system configuration information.

The system provides two modes of operation: continuous operation and immediate measurements. In the continuous mode, the system measures selected parameters in programmed intervals, in accordance to the configuration parameters, and stores them in the database together with the measurement date and time stamp. The access to the measurement results stored in the database is independent on the measurement process. Similarly, altering the configuration data for one of the measured quantities does not affect the parameters for the other ones, and the changes are executed only after confirmation.

In the immediate mode it is possible to select the measured quantity (sensor selection), immediately execute and retrieve the results of the measurement. The two operation modes work independently and do not affect each other. It is also possible to disable one of the modes without interfering the operation in the other mode.

The access to the data is conducted using the WAP terminal; it is split into several groups. Two modes of operation are available: the control mode and the configuration mode. The user chooses the desired operation mode after registering in the system. If the desired mode is not accessible by the user or the user is not on the list of the persons authorised to use the system, a proper message is displayed and the terminal goes back to the user identification card. The task of authorising the user is executed after establishing the connection to the database. An instance of the ADODB.Connection object is created and the link to the data source *pomiary* is established. The data source needs to be created earlier by pointing to the *pomiary.mdb* database, as hereafter described in the data source creation procedure. Subsequently, appropriate variables are assigned the values originating from the data identification section. The verification whether the user identified by the specified data exists in the database and has access to the requested operation mode is performed using SQL commands. The access to the data themselves is performed using "queries". "Queries" can by executed by:

- providing the time stamp of the measurement (date and time), the entered value is rounded up to the nearest one stored in the database.
- providing the number of the measurements to display; the subsequent values stored in the database (max. 5 positions) are shown, beginning at the specified time stamp. If the available measurements are less numerous than required, only the available results are presented.

In the configuration mode it is possible to alter the measurement schedule. One is able to change the following:

- enabled or disabled state for given sensor (channel)
- the interval between the samples on the given channel
- starting and aborting the measurement process

It is also possible to execute previously declared measurement macros, such as daytime or overnight measurements. The configuration data are stored in a separate database, containing the following information:

- the character of the measured quantity,
- whether to perform measurements of this quantity,
- how often to perform measurements of this quantity.

The example of reading the temperature measurement result is shown on fig. 4.

In the event of any execution error, an e-mail message is immediately sent to the operator; the e-mail contains information on the character of the error and the time of occurrence, as well as the means to forward the information to a mobile phone as a short message. If any of the fields is changed, a marker indicating the change to the configuration parameters is saved in the control file. Fig. 5 shows a complete diagram picturing the operation of the GSM terminal application.

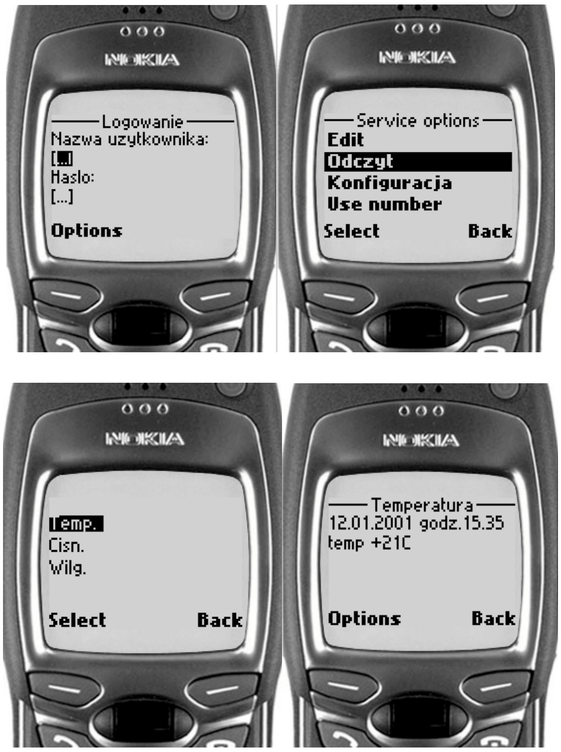


Fig. 4. Subsequent steps to access the measurement results

Most of the code implementing the presentation part has been written as ASP files containing elements of WML, VBScript and SQL languages. Owing to the usage of ASP files and databases, it is possible to access the measurement results with a standard web browser just after minor amendments to the code. The WML cards and the ASP files have been designed using the *Nokia WAP Toolkit 2.0*. The software controlling the National Instruments DAQ acquisition board, the measurement process and database storage process has been developed using the *LabVIEW* environment. The databases have been created using the *Microsoft Access* application, being a part of the *Microsoft Office 2000* suite. The *LabVIEW* application communicates with the DAQ acquisition board using an internal driver. The received measurement results are transferred to the *Access* database using SQL commands. Similarly, the WWW server uses SQL commands included in the ASP files to read and write data to the database. For the WDVI to work properly, a WWW server with ASP technology support is required, as well as a WAP gateway. The communication between the WWW server and the WAP gateway is performed using the TCP/IP protocol. The mentioned elements enable any user registered in the database to access the measurement results from any mobile phone.

4. RESEARCH

Before commencing the research, the complete route of the signal has been identified, from the moment of selecting the service, to the moment of displaying the welcome screen on the GSM terminal, as well as the total time of signal transmission during a single measurement.

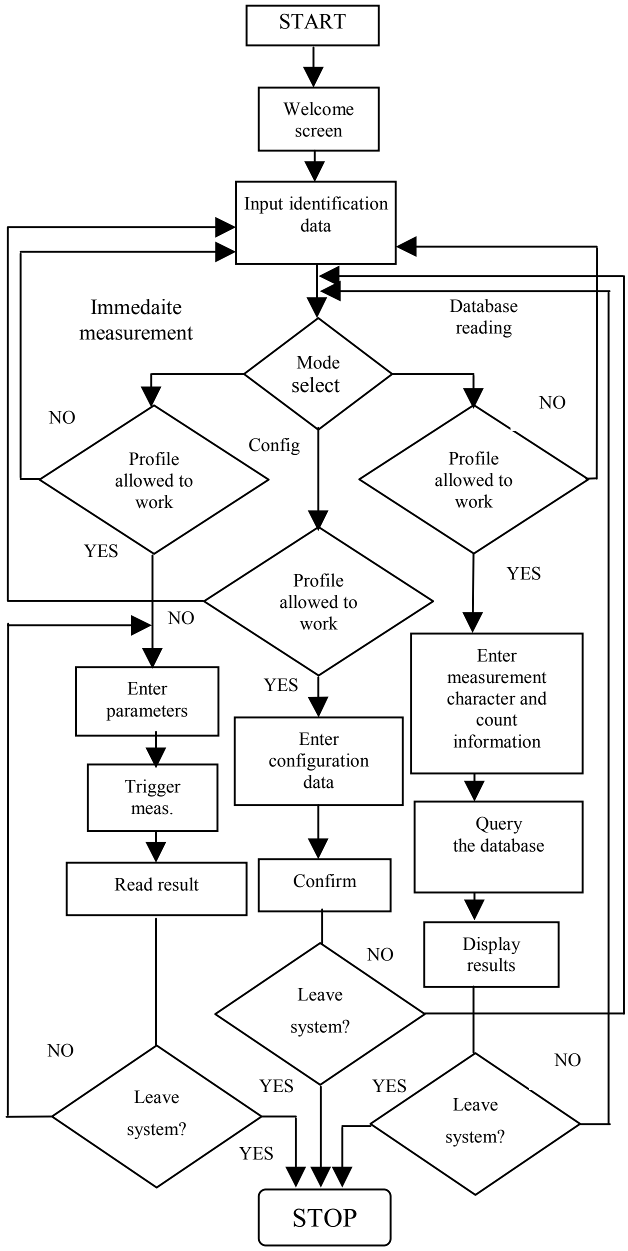


Fig. 5. An operation diagram of the GSM terminal application.

The total time of waiting for the welcome screen to appear (T_k) can be described as:

$$T_k = t_w + t_u + t_{tb} + t_{bs} + t_s + t_{sb} + t_{bt} + t_o$$

where:

t_w – time of dialling in to the WAP service (or connecting to the GPRS bearer);

t_u – time required for WAP user authorisation;

t_{tb} – time required to transmit a request for the chosen service between the GSM terminal and the WAP gateway;

t_{bs} – time required to transmit the request from the WAP gateway to the web server which hosts the requested service;

t_s – time required to process the request on the server (ASP);

t_{sb} – time required to send the processing result between the server and the WAP gateway;

t_{bt} – time required to transmit the result from the gateway to the GSM terminal;

t_o – time between receiving the information by the terminal and showing it on the phone display.

The total time of signal transmission during a single measurement is by far more complicated. It results from the fact that during the process the connection to the measurement server needs to be established. The total measurement time (T_p) consists of:

$$T_p = t_{tb} + t_{bs} + t_{zd} + t_{od} + t_k + t_p + t_{op} + t_{zw} + t_s + t_{sb} + t_{bt} + t_o$$

where:

t_{tb} – time required to transmit the configuration data from the GSM terminal to the WAP gateway

t_{bs} – time required to transmit the configuration data from the WAP gateway to the WWW server

t_{zd} – time required to store the configuration in the database (either locally or over the Internet)

t_{od} – time require for the measurement server to read the configuration

t_k – time required to configure the DAQ card

t_p – measurement time

t_{op} – time required to receive the results from the DAQ board

t_{zw} – time required for the measurement server to store the results in the database

t_s – time required for the web server program (ASP) to read the results from the database

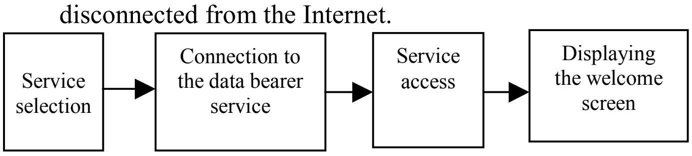
t_{sb} – time required to send the processing result between the server and the WAP gateway

t_{bt} – time required to transmit the result from the gateway to the GSM terminal

t_o – time between receiving the information by the terminal and showing it on the phone display.

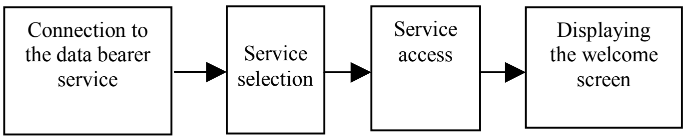
Due to the lack of possibility to measure all of the mentioned times, it has been decided to simplify the described schemes and, for the time analysis, to split the connections into:

- direct connection to the service – consisting of selecting the service, establishing the connection (either circuit – switched or GPRS – based), accessing the measurement service and displaying the welcome screen. It stands for accessing the service from the state of being completely disconnected from the Internet.



t_p t_d

Connection to the service after prior connection to the Internet. It stands for the actual time of accessing the service.



t_p t_d

where:

t_p – time of the connection establishment;

for the circuit – switched data transfer, it consists of:
- dialling-in time
- connection establishing time
- network log-in time

for the GPRS packet transfer, it consists of:
- time of opening the transmission channel
- time of authorising the users in the network

t_d – time of accessing the "Climate" system. It is the time required for the welcome page to appear on the display elapsed since the moment of selecting the address and it depends heavily on the Internet speed. It consists of:

t_1 – time required to send the request for the page. It consists of:
- time required to send the data from the terminal to the WAP gateway,
- time required to transmit the request from the WAP gateway to the web server which hosts the requested service

t_2 – time required for the WWW server to process the page

t_3 – time required to transmit the WWW server response to the terminal. It consists of:
- time required to transfer the data from the server to the WAP gateway
- time required to send the response from the gateway to the terminal
- time required to display the result

The research was conducted using several terminals, both with circuit-switched data and the packet transfer. The times required to establish a connection with the WAP service spanned from 15 to 30 seconds in the case of circuit-switched data (dependent on the network load), and from 4 to 5 seconds in the case of the packet transfer.

The times of connection establishment (t_p) for different network load states and for the Nokia 6310 terminal are shown in Tab. 1, for Siemens MT50 terminal –in Tab. 2.

Table 1: Observed times of establishing the Internet connection using Nokia 6310 terminal.

	Connection establishment time (t_p) [s] (Nokia 6310)			
	Circuit-switched data		GPRS	
	Light network traffic	Heavy network traffic	Light network traffic	Heavy network traffic
Min	14,8	30,8	3,3	3,0
Max	20,1	38,7	7,1	5,0
Avg.	18,3	35,3	4,8	5,4

Table 2: Observed measurement times for Siemens MT50 .

	Measurement execution time, from the measurement triggering on the GSM phone, until displaying the result (T_p) [s] (Siemens MT50)			
	Circuit-switched data		GPRS	
	Light network traffic	Heavy network traffic	Light network traffic	Heavy network traffic
Min	2,8	10,9	2,7	11,3
Max	3,2	14,1	3,1	14,5
Avg.	3,0	12,75	2,87	13,2

The times elapsed from the moment of triggering the measurement in the mobile phone to the moment of displaying the result spanned from 2 to 12 seconds for circuit-switched data (dependent on the network load) and between 2.5 to 13 seconds for packet transfer.

It has also been examined how the GSM phone itself influences the process of controlling and reading the measurement results. The research was conducted using several GSM phones. It had been assumed that the different display layout of the service on different phones would influence the time of accessing and displaying the results. Measurement results prove the thesis is correct. For instance it has been stated that the Nokia 6310 terminal usually reacts quicker than the Siemens MT50 terminal, and therefore the result pages were displayed quicker on the Nokia terminal. The difference could be assessed as 1 to 2 seconds.

From the time measurement results it may be inferred that during the periods of light network load, the measurements using the GPRS transmission are conducted slightly faster than under heavy network load. It stems from the fact that despite narrower transmission bandwidth, the circuit-switched data connections are treated in the same way as voice calls, and as such have higher priority that the GPRS connections. The GPRS transmission mode has the advantage of being charged for on the actual data volume basis. It allows to keep the connection open for a longer time, which eliminates the service connection establishment times while not causing the cost of these connections to rise.

5. CONCLUSIONS

The aim of the presented research was assessing the usability of GSM telephony and WAP protocol to control a measurement system in real time. The methods of transmitting and publishing measurement results on the Internet were explored and the solution using an intermediary database was chosen. A design procedure for the mobile phone-operated measurement systems was elaborated.

It has been proven that there are no obstacles to create applications allowing for controlling the measurement systems from a GSM terminal. The advantages of the mobile measurement control systems are their functionality and independence on the wired Internet access (LAN, WAN or a telephone line). Furthermore, the evolution of the GSM terminals towards combining them with palm devices promises a potential development of methods of managing measurements this way. The additional advantage is the possibility to use the WAP services over the GPRS packet-switched data transfer, which significantly reduces the cost of endorsing the system and will contribute to making this kind of control methods more popular.

The disadvantage of the proposed WDVI structure are longer operation times when compared to ones observed in computer-controlled systems. They stem from the slower operation of mobile terminals, caused by smaller volumes of available memory, as well as from the delays introduced by the GSM transmission path.

It has been observed that the execution times in the system heavily depend on the mobile network operator and the GSM terminal manufacturer and type. It is bound with different implementations of the WAP protocol and data transmission methods in different mobile networks. Furthermore, the terminal manufacturers implement different WAP versions in their devices and assign different bandwidths for the data transmission, both in circuit-switched and the packet-switched mode. It causes significant application execution time differences, depending on the selection of mobile operator, transmission mode and the time of day. On holidays, under a light GSM and Internet network load, the application cycle times of about 2 seconds were observed, while on working days they reached 12 seconds. It seems that the major limitation in the speed of receiving the results is the Internet. It could be inferred by the comparison of the realised system with the one described in [5], which does not employ the Internet transmission.

It is expected that the introduction of the fast Internet II the times of measurement and transmission can be significantly reduced. The expected development and the integration of the UMTS and the Internet justify taking the described course of research.

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