Improved Data Transfer for Wireless Meteorological Stations

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Abstract – **In this paper the preferred wireless data transfer technologies are described and analysed. A meteorological data organization and management is proposed. An improved data processing algorithm is given. An implementation in microprocessor system is proposed and experiment with GPRS data transfer and FTP protocol is accomplished.**

Keywords – **Meteorological Station, Wireless Data Transfer, GPRS.**

I. INTRODUCTION

The modern technologies represent variety of possibilities for research in the area of communications. This progress also affects the technical resources for handling meteorological data. A major problem for transferring such a data is the available communication options, especially for more distant and inaccessible meteorological stations. Therefore the wireless data transfer methods are preferred as they are offer a number of advantages when used in a meteorological data acquisition system. But these methods have their own specifics and factors that have to be taken in account when choosing the most appropriate one. These problems and their improved solutions are introduced and analyzed in this paper. The main focus is on the computer based data processing and the network based communication methods that are convenient for post processing and complicated meteorological analysis. The meteorological system could be organized in different way when the information is used for synoptic meteorology, warnings for dangerous weather conditions, climatology, past analysis etc. [1].

II. PREFERRED WIRELESS DATA TRANSFER TECHNOLOGIES

A. Requirements and Criteria

The preferred wireless data transfer technologies have to fulfill several requirements and criteria which matter is determined by the exact application of the meteorological station and the organization of the whole data acquisition system [2].

The first criterion is the *data transmission interval*. It depends on the purpose of the measurement data. If a real time monitoring is accomplished, the data transmission should be initialized on relatively small intervals of time, depending on the speed of change of the measurement values. On other hand the station could be used for data logging for the purpose of climatological researches and in that case a data transmission on relatively long interval of time i.e. one or few days with proper processing and compression, is enough. An emergency situation could occur when a rapid change of measurement value occurs or a predefined limit is approached and this situation could be reported with immediate unplanned transmission session.

The second criterion combines *speed and reliability of transmission*. In real time monitoring the measurement data has to be transferred with proper speed that can be achieved with the wireless technology. The transfer has to be reliable enough so that the measurement data stays unchanged. This is provided by the high and low level protocols.

Another criterion is the *price*. The price of the communication could be a crucial factor and it has two main aspects. The first one is the initial price of the communication equipment and the second aspect is the data transfer price. A meteorological measurement system that comprises of more than few stations, working with several sensors at short sampling period generates lots of traffic that could be very expensive if improper wireless technology is chosen.

The last reviewed determining criterion is the *accessibility*. The wireless technology has to be accessible to all meteorological stations during the scheduled and possible unscheduled transmission sessions. This is more difficult to implement when measurement stations are situated on a wide area and/or are significant number.

The preferred wireless technologies are introduced in the following sections.

B. UHF Radio Technology

The Ultra-High Frequency (UHF) radio technology works in the frequency range between 300 MHz and 3 GHz. The exact communication frequency has to be selected according to the free and allowed by laws range which is specific for most of the countries. The UHF Radio Technology gives lots of freedom of design due to the specifics of the measurement systems, although it requires more time and expenses for design. A factory radio transmitter or transceiver modules are more appropriate to be used, giving a physical range up to few hundred meters, which could be easily embedded into the meteorological station hardware. Also a custom transmission protocols have to be designed and special care has to be taken for low-power consumption. The physical range could be

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expanded on relatively short distances, using retranslators or on unlimited distances, changing the communication media i.e. using Internet. Major disadvantages of these approaches are the additional complicity and the additional expenses of the measurement system.

The custom UHF radio technology in the common case is suitable for data acquisition systems with more than few meteorological stations that are situated on limited area.

C. ZigBee Technology

The ZigBee technology is a suite of high level communication protocols that use low-power digital radios, all unified into single housing. It is based on the UHF standard and normally uses the legalized 2.4 GHz transmission frequency [4]. ZigBee technology has a low data rate but low-power consumption and secure networking. The physical range is up to 1000 m. The ZigBee modules are capable of rerouting signal from other devices and expand the physical range. They could be used for building wireless personal area networks (WPAN) for the needs of meteorological data acquisition systems and give flexibility.

The ZigBee technology is cost effective solution which is appropriate for meteorological system with one or more meteorological stations, situated on limited area.

D. GSM Technology

The Global System for Mobile communications (GSM) is widely used, constantly developed and adapted for the needs of small size, low-consumption mobile devises such as mobile phones. There are factory application specific transceiver radio modules with different characteristics, working with the GSM standard.

The coverage and the service itself are provided by GSM operators. In Bulgaria they are available in the inhabited territories and in most of the agricultural and forest territories. The same situation exists in most of the European countries. This is major advantage for big meteorological data acquisition systems, situated on large territory i.e. for creating wind solar map or researching agricultural conditions.

The GSM technology includes several communication services that differ from audio (voice) transfer.

The Short Message Service (SMS) transfers digital messages with fixed size of 1120 bits. They are sent to SMS center which provides store and forward mechanism. The time of delivery and the delivery itself are not guaranteed, but in the common case it is almost immediate. SMS are charged per unit and are not cost effective for transfer of meteorological data. In meteorological stations they could be used for activating the other GSM services when they are switched off or in some kind of emergency situations i.e. system fault.

The unlimited communication service that is the most suitable for meteorological stations is the General Packet Radio Service (GPRS). It communicates though Internet and the GPRS device has unique Internet Protocol (IP) address. It is extremely flexible and cost effective as only the used traffic is charged and it is not affected by the destination or the active connection time. GSM GPRS communication is suitable for all kinds of meteorological stations that could be easily centralized though Internet into single database server and/or mobile devices.

III. METEOROLOGICAL DATA ORGANIZATION

The meteorological data acquisition system consists of single or numerous measurement stations that constantly send data. The data has to be properly managed so that it is properly stored and could be rapidly accessible and used. The best approach to satisfy these conditions is to use a centralized server (a dedicated computer, a web based application or a portable device) where the meteorological station/s periodically synchronize data (not only send meteorological data but also receive new settings and necessary operational information). The server provides long-term data storing into database that supports the necessary queries. The server also has to be on-line for scheduled synchronizations and be able to communicate with multiple stations at the same time.

A sample meteorological data organization is given on Figure 1.

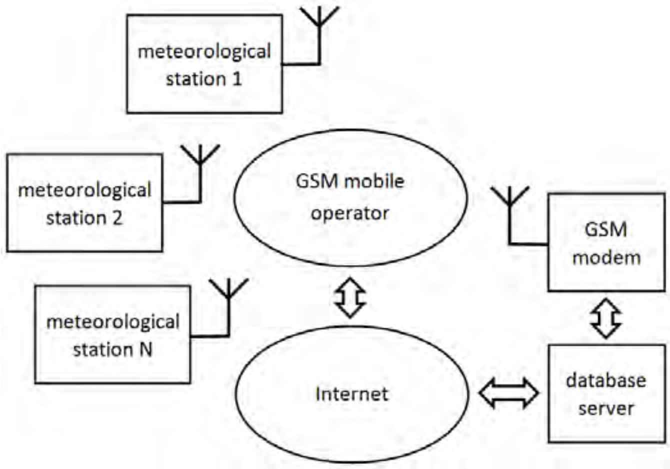

Fig. 1. Meteorological data organization using GSM technology

A major advantage of such a system is the usage of an improved data processing algorithm that obtains processes data in advance so that the communication line is unloaded and server storage place is reduced.

IV. IMPROVED DATA PROCESSING ALGORITHM

The data processing algorithm manages the data from the digital sensors outputs to the report file that is ready to be sent by the preferred wireless data transfer technology. It consists of two major stages. The first stage is adapted due to measurement value specifics of each sensor. It implements digital filtering and decimation of the sensor output [7]. The digital filter is low pass filter with finite impulse response (FIR) which band stop frequency depends on the typical signal frequency range. Decimation is accomplished, gaining efficiency to the digital filter. It is combined with averaging so that samples are reduced with interval of seconds or minutes, depending on the needed meteorological value minimal resolution that is determined due to speed of change of the measured value i.e. samples reduction for wind velocity is completely different, compared to ambient temperature.

The FIR filter performs the following convolution equation:

$$y_n = h(k) * x(n) = \sum_{k=0}^{N-1} h(k) \cdot x(n-k) \qquad (1)$$

The second data processing algorithm stage implements different kind of data sample reduction. It is similar to data compression as the total data size is reduced. Its purpose is to decrease sampling rate in the signal sections where the signal speed of change is lower and to keep the sampling rate high or unchanged where the signal speed of change is high so that the substantial information of the signal remains, local and global maximal, and minimal values are available. It is one directional data signal compression with quality reduction in the less important sections of the signal. This approach is appropriate for meteorological data management as the necessary information for analysis can be obtained from the compressed signal and the data size and server storage place are optimized without using decompression when the signal is analysed. A sample wind velocity data is given on Figure 2. The data are taken from DAVIS weather station Vantage Pro2 installed on the territory of Technical University of Varna.

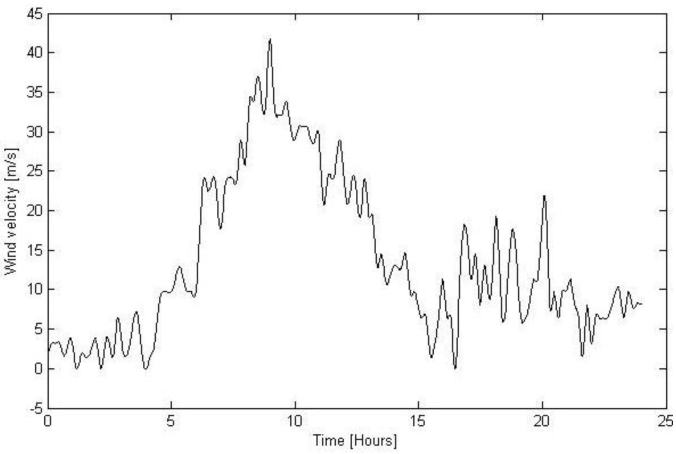

Fig. 2. Wind velocity data per day

The proposed approach for implementing the second part of the data processing algorithm is wavelet transformations [8]. The wavelet transformations provide information for the signal in both frequency and time domain so that rapid changes in the signal could be localized in time. Higher the resolution in time, lower the resolution in frequency so a proper balance has to be maintained.

So the second part of the improved data processing algorithm implements a wavelet analysis of a time window of the signal from a sensor that is already decimated and averaged. Afterwards the signal is variably compressed due to wavelet analysis results.

V. Implementation in Microprocessor System

The proposed data processing algorithm is designed to be implemented into a microprocessor system that will satisfy application specific requirements. The microprocessor has to be capable of performing the algorithm calculations in parallel while reading the sensors and managing the station periphery, combined with low-power consumption as distant meteorological stations run on limited power supplies. The 32bit ARM Reduced Instruction Set Computer (RISC) microprocessor fulfills the requirements and it is widely used in high performance portable devices [5].

Experiments are accomplished using the combined communication module GE863-PRO^3 of Telit Wireless Solutions [6]. It combines an independent ARM9 microprocessor, driving a four band GSM/GPRS modem, memory and periphery, giving a major part of the necessary hardware for an embedded microprocessor communication system. The module has major advantages that make it very suitable for these experiments. The ARM core has operating frequency of 180 MHz, enough for algorithm calculations. The module has built in TCP/IP protocol stack, FTP and SMTP protocols. It operates in wide temperature range from −30 °C to +80 °C so it can withstand real operating conditions of a meteorological station.

The GE863-PRO^3 combined module is embedded into a development kit so that all resources are easily accessible. The kit provides fours standard COM ports and USB port for direct connection with personal computer and monitoring the inner state. The ARM core is programed via JTAG interface and the GSM/GPRS modem is controlled by AT commands through a serial interface [4]. The sensors board is plugged in the connector, placed on the top side of the board that provides direct access to the ports of the ARM microprocessor.

The development board is given in Figure 3.

The communication experiment is accomplished with the GSM/GPRS part of the combined module. The GPRS service

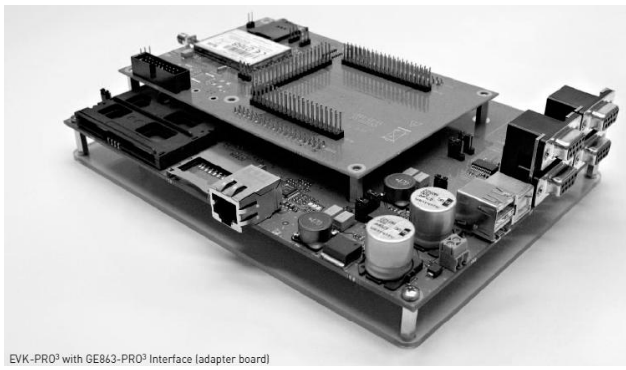

Fig. 3. EVK-PRO^3 Development board

is activated using a SIM card with mobile internet, provided by a mobile operator. A measurement data file is sent to a specially configured ftp server that is connected to the Internet.

The AT command sequence is given in Table I.

TABLE I
AT COMMANDS SEQUENCE FOR GPRS COMMUNICATION

Terminal window	Comment
AT OK	Available communication with GSM/GPRS module
AT#QSS=1 OK	SIM card is available
AT+CPIN? +CPIN: READY OK	PIN code check
AT#MONI #MONI: GLOBUL BSIC:66 RxQual:0 LAC:1392 Id:9C6A ARFCN:91 PWR:-60dbm TA:0 OK	Mobile operator cell is available with the stated signal power
AT+CGDCONT=1,IP,globul OK	Defining Packet Data Protocol (PDP) - Access Point (AP) "globul", data protocol is Internet Protocol (IP)
AT#GPRS=1 +IP: 10.8.215.135 OK	The GPRS service is activated and an IP address is assigned
AT#FTPOPEN=87.126.32.18:21, AMStation, 123456,0 OK	Opening a FTP connection to server with username and password
AT#FTPPWD #FTPPWD: 257 "/" is current directory. OK	Checking the working directory
AT#FTPCWD=station_1000023 OK	The working directory is changed
AT#FTPPWD #FTPPWD: 257 "/station_1000023" is current directory. OK	Checking the working directory
AT#FTPPUT=20121103_183045.XML CONNECT	Opening a data transmission line and transferring data into a specific file
AT#FTPCLOSE OK	Closing the FTP connection

VI. CONCLUSION

In this paper the different wireless data transfer technologies are given and analyzed. It is proposed which method for what type of meteorological station and for what distances is more appropriate.

A methodology for data processing in advance is proposed. The measured signal is processed with digital filter and wavelet transformations. As a result the significant meteorological information from the meteorological sensor signal is retained and the total data size is reduced.

An implementation in ARM based microprocessor system and experiential communication module are proposed.

An experimental data transmission is accomplished over Internet using the GPRS service of GSM communication technology and the embedded FTP client protocols.

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