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Flexible GPS/GPRS based System for Parameters Monitoring in the District Heating System

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Abstract:
Energy consumption for heating purposes accounts for a significant part of the budgets of individual and collective users. This increases the importance of issues related to the monitoring of heating energy flows, analysis of flow parameters, verification of fees and, in the first place, minimization of energy consumption. The goal of this paper is to develop, by employing Global Positioning System receivers, measurement techniques that are suited to the continuous monitoring of the heating substation parameters. This paper presents the design and implementation of GPS/GPRS (Global Positioning System/General Packet Radio Service) system for low power data acquisition using MSP430 Texas Instruments microcontroller for monitoring of the heating substation parameters. The system is implemented in heating stations for a temperature and pressure monitoring. It contains GPS/GPRS gateway and 8 analog sensor inputs. Acquisition module and the server base station are suitable for industrial applications, home applications and for other appliances. The proposed measurement procedures, which are different from commercially available measurement units, are based on general-purpose acquisition hardware and processing software, thus guaranteeing the possibility of being easily reconfigured and reprogrammed according to the specific requirements of different possible fields of application and to their future developments.
Keywords: Distributed measurement systems, GPS/GPRS, computer data acquisition, low power microcontroller.

1 Introduction

An adequate control of all relevant parameters of the heating process is one of the most significant means of power consumption optimization. District heating substations, as a link between hot-water network and internal heating installations in buildings, are used to adapt high-pressure hot water to temperature and pressure conditions required by space heating systems of buildings as well as by the systems for the preparation of hot service water in buildings. To control the energy transfer in the district heating substation, some kind of control system is needed. The overall efficiency of district heating could clearly be improved by using new strategies for measurement and control. To maximize energy efficiency in the district heating network it is essential to have a large temperature drop across the substation between supplies and return pipes in the distribution network. A larger temperature drop will contribute to more possible customers in available district heating networks without increasing the production power. An efficient system will reduce the amount of wasted energy while maintaining comfort, and indirectly reduce CO2 emissions for heating purposes, which accounts for 30% of the worlds current CO2. Very rough estimates shows savings of more than 1 million year when increasing the temperature drop across the substation between by 5 °C in a 760 GWh district heating system. Today, in most substation control a system focuses on indoor comfort and do not generally consider temperature

drop across the substation, since it is not measured by the control system. The rapid progress in microprocessor and communication technologies over the last ten years or so has provided great potential for innovative applications in the field of protection and substation control [1]. There are a number of applications of different strategies of monitoring and control of district heating system components: a new control and communication architecture based on WSN and SOA for district heating substations are developed in [2], [3]. Reference [4] shows the issue of integrating of intelligent electronic devices (IED) data recording by different IED types and focuses on how to facilitate the use of the integrated data; The water temperature control of a district heating substation using soft computing methods, based on fuzzy logic, is presented in [5]. Fuzzy logic control is implemented and the good performance of the fuzzy control proves that this can be an alternative to the classic control. The control and monitoring system for the heat distribution network with a multi-layer structure, which integrates several state-of-the-art technologies and standards applied in modern industrial automatics, are presented in [6]. The applied control system and supervisory control algorithms have result in power savings. Reference [7] proposes an alternative approach to the problem of district heating monitoring parameters selection. The wireless technology comparing with non-wireless technology has some important benefits, for example the system cost reduces and easier the installation and maintenance. Some of the most popular low power wireless sensors networks are ZigBee, Bluetooth, distance between sensors and the base station is limited to about 1500 m are presented in [8], [9]. This paper presents GPS/GPRS based wireless acquisition system. The Global Positioning System (GPS), which is a satellite based system, is the main synchronizing source that is used to provide a time reference on the communication networks, and its widespread availability makes it possible to obtain, at each point of the tested system, a clock signal that is synchronized with the one generated in other remote places. Currently, GPS is the only satellite system with sufficient availability and accuracy for most distributed monitoring and control applications in distribution systems. Alternatives will eventually become available, with GALILEO being the most promising at this time [10].

2 The remote acquisition system

The basis of hardware part of GPRS - based system for data acquisition (GPRSuC) from remote locations consists of low power MSP430F147 microcontroller and Telit GM-862 GPRS/ GSM/GPS module.

They communicate with each other in the process of collecting and sending data to remote server. The main objective of the microcontroller is to sample data from eight multiplexed analog inputs, and to form data blocks with time stamp from GPS sentences. Telit module is used to send those data blocks to the server base over GPRS system. Besides the standard functions of the devices used in M2M (Machine to Machine) communication, this module has a GPS receiver, as well as the GPS dedicated port on which the data obtained from GPS are shown in NMEA(National Marine Electronics Association) format. System's operating range is from -10 °C to + 55 °C, which can be potential problem if GPRSuC is used in environments with very low temperatures. The GSM modem is made in a way that the RF transmission is not continuous else, it is packed into bursts at a base frequency about 216 Hz. Firmware is written in C, and its structure is shown in Fig. 1. Telit module acts as a slave carrying out the commands that are sent by the microcontroller.

Since the platform is designed to be suitable for the monitoring of the mobile location, GPS accuracy is very important. After the initialization, moving system variable need to be set. Complete algorithm depends on the value of this variable. After checking the network status system is trying to catch GPS signal (see Fig. 1). When there is no GPS signal Telit module

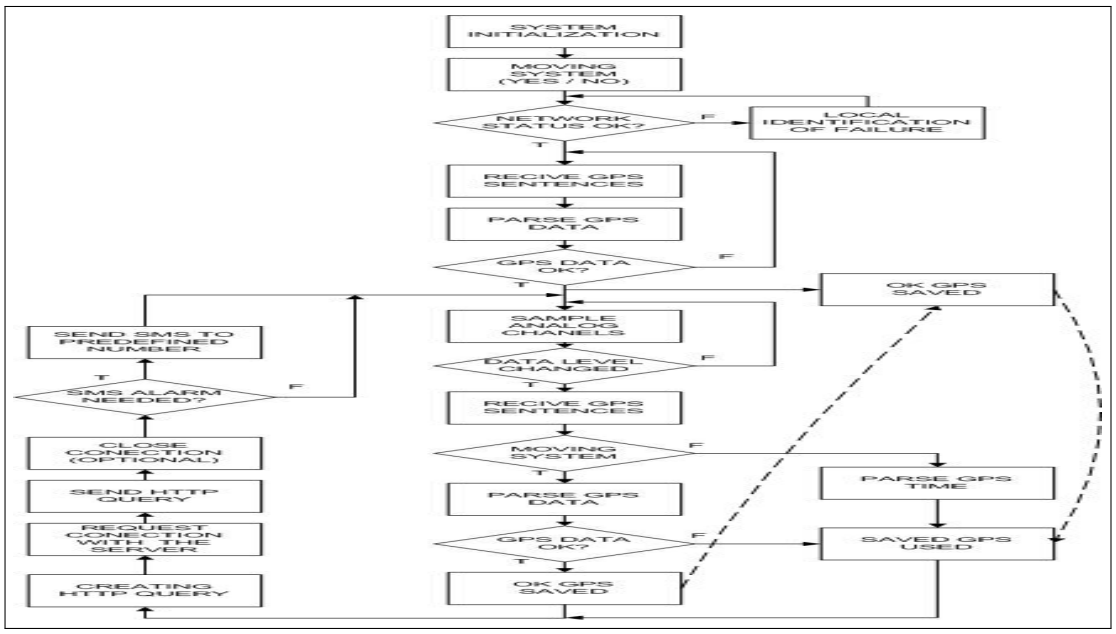

Figure 1: Flow chart of the firmware

returns NULL in latitude and longitude fields. This routine repeats until it is established that the GPS signal is captured. Last good GPS position is saved and used in case that GPS signal is lost due the impact of various barriers, which is especially important when system is moving. If the system is not moving then saved GPS position is used. Time is extracted from GPS sentence in short routine and it is used even though the system is not moving.

3 Communication resources used for remote aquisition

General Packet Radio Services standard allows data transfer in a completely different way from the Circuit Switch Data (CSD) type of transmission. In CSD, data is transmitted by establishing connection with other, remote modem, directly, so all devices in between are used to provide simulation of the physical connection between the final points (point-to-point connection). Besides the obvious disadvantage in terms of low utilization of network resources, there are also problems of long delays in establishing a connection and high fees for using network resources, based on time period of established link, not amount of data like in GPRS [11]. One message from remote acquisition system consists of eight measured parameters, time stamp and identification field, and has near 110 bytes, so it is appropriate to use GPRS system. Mobile operators provide fixed IP address service, and it is possible to achieve communication in both directions with changes in overall software of the system. In realization of GPRSuC prototype this service is not used in order to make remote acquisition platform as cheap as possible. As practical part of this project is regarded, its main goal is to presents the data collected in a way, which was explained in the previous chapter. The entire software solution has been realized using the open source J2EE technology. One of the reasons why the J2EE technology is selected is the possibility of extension to mention the system used on mobile phones in a J2ME applications. Completed software solution can be roughly divided into two parts, which exchange data with hardware and presents results to the client The part of the software used to exchange data with hardware, is the interface with the hardware support. This part of the software has no visual interpretation and is executed only when the http request is passed to the Servlet by a device

that forwards data. It has been develop as a Java Servlet, which call by hardware is using the HTTP GET request. To the appropriate data Servlet that performs the same processing and saves them in the MySQL database. The server confirms a successful reception of data and it is able to send the parameters which correct the way that device work. Since the Servlet can be accessed with the use of HTTP requests from anywhere in the world, this way of communication gives this project one global level. There is the ability of usage in different cities, countries and even continents. The preference listed in the realization of communication in addition to the great advantages is also a defect that opens a project to the attacks and simulation of some other persons who would like to emulate values of the passed parameters. As the container, Apache Tomcat version, 6.0.16 is used. The project is implemented as a Web application, which is located on the server in Laboratory. It provides current monitoring of more parameters from one station and displays their values in real time. Since this system has a role in monitoring, the value of parameters for easier viewing, the marker may be green, yellow or red depending on the values of parameters, i.e. whether they allow or do not allow critical range, respectively. In addition to transferring data, hardware has a role that does the processing of data, and as a parameter sends its status. Processing is not on the server from the simple reason that for n stations which monitoring m parameters would representing an (m x n) processing every few seconds. It is very important that every measured value is stored in a MySql database and thanks to that it could be seen whenever it is needed. This is important because the further analysis of data is possible in a very easy way. Since a system sends GPS coordinates, GIS support is used for better data presentation. This is especially important with moving systems. It is also interesting using GIS presentation when there is more then one system for tracking and their positions are easy to monitor. As a geographical support in the project, the Google Maps API is used. It provides great opportunities thanks to the entire globe coverage with satellite and aero-photo shots of high resolution. The principle of working with Google Maps API is that a complete GIS system is on Google's server. The user passes the coordinates and parameters for the display, to the corresponding server that replies by sending the required graphic content. Google Maps usage is free of charge and only Google key is needed. The Google supplies the key and a Gmail account (mail) is required. In order to get the key, it is needed to enter the URL of the Web server on which Google Maps will be used. Mouse click on the marker surface displays current parameter values for wanted system (see Fig. 2).

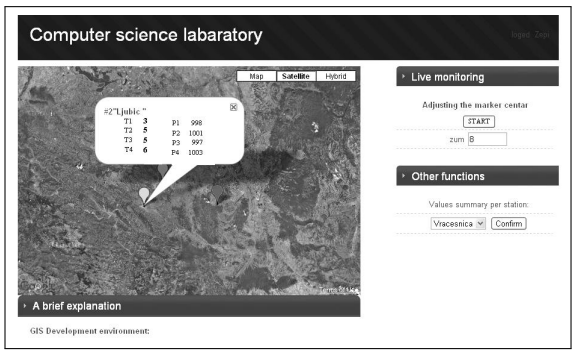

Figure 2: Multiple systems monitoring with wanted system data presentation

If live monitoring for one system is needed, web application offers functionality (see Fig. 3) where user activity is not needed since AJAX is refreshing a web page after any data value change. Alarm values are shown with red background color. There is also a possibility for history observation of measured parameters values with table or chart view.

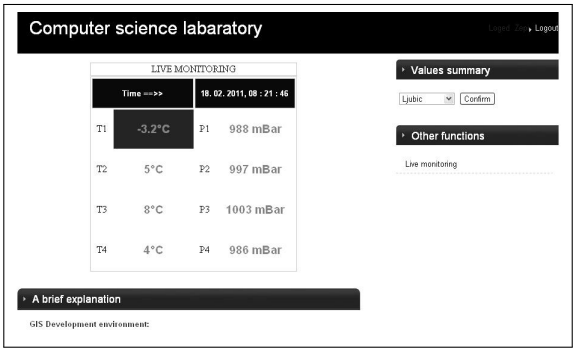

Figure 3: Live temperature and pressure monitoring in laboratory area

4 Conclusions and Future Works

In this paper, a flexible measurement system for parameters monitoring in district heating system is proposed. This system is able to react rapidly to any incidental parameters changes and alarm responsible server in base station. GSM network is widespread, reliable and cheap. GPRSuC system describes an attempt of integration low power microcontroller, Telit module and server applications into a distributed system for data acquisition and monitoring remote measurement sites. The flexibility of system arises from the use of general-purpose acquisition hardware, which allows the system to be easily upgraded and/or reconfigured according to the specific measurement needs existing and evolving in modern District Heating systems. Communication of the system is complete wireless, easily operable and low power. To maximize the energy efficiency in the district heating network, it is essential to have a large temperature drop across the substation between supplies and return pipes in the distribution network and the proposed system has and economic reasons for implementation. The proposed measurement systems could be further improved simply by using more sophisticated acquisition hardware.

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