Sensor Node for the Remote River Water Quality Monitoring

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Abstract. *The paper describes digital sensors and front-end electronics of a wireless sensor network node developed for water quality monitoring. The nodes are realized as buoys fixed in a river stream, carrying the water quality sensors, power supply and communication system for wireless data transfer. The buoy monitors four basic water quality parameters (pH, conductivity, dissolved oxygen, temperature) and transmits acquired data via gateway to the network control server for further advanced processing, visualization and archiving.*

Keywords: Water Quality, ph, Conductivity, Dissolved Oxygen, Modbus 485, Monitoring Buoy

1. Introduction to water quality monitoring

The river Water Quality Monitoring (WQM) belongs to the most required and important measurements in environmental monitoring. The basic requirements for modern river WQM systems can be summarized as follows: 1) sustained and autonomous observations, 2) remote control and data acquisition, 3) limited power sources, 4) reliable functionality at difficult environment conditions, 5) robust and reliable construction of sensing system, 6) advanced data processing with the alarm generation, 7) easy reconfiguration. WQM in Europe is intended to monitor water pollution. With a view of unifying Europe, national regulations have to be harmonized with water policy in compliance with the Water Framework Directive (WFD) [1]. Due to WFD an integrated approach on basin of rivers with respect to water quality management and monitoring is pursued in the individual European countries [2] and will be mandatory in the future. One crucial issue within WQM as required by the WFD is to have sufficient and comparable information on water quality. Thus remote sensing technology for water quality monitoring is a valuable tool how to obtain continuous information on the processes taking place in the surface waters. For example, new technology and instrumentation automatic stations are effectively used in quite a number of networks not only in Europe [3], [4], [5] but also worldwide [6]. Currently, in Slovakia there are no studies about WQM using remote sensing in compliance with that of the WFD. However, the Wireless Sensor Network for wAter QaUAlity Monitoring project (WSN-AQUA) for an early warning system of surface water pollution was initiated in 2013 within the Hungary- Slovakia Cross- border Co-operation Programme established between the BME- Infokom Company (BME) and the Technical University of Kosice (TUKE). The goal of this project is to develop automated station that will monitor several water parameters on a selected river. In this paper we present digital sensors and front-end electronics of the developed sensor node (buoy) for remote WQM.

2. Architecture of developed sensor node

The developed sensor node diagram (buoy station) for WQM as well as the remote gateway used for wireless data collection by the sensor network is shown in Fig.1. We use compact

Ponsel digital sensors [7] for monitoring pH, conductivity (EC), dissolved oxygen (DO) and temperature as well as embedded microcontroller (MCU) for sensors configuration, data packing and RF channel transmission. We connected these robust waterproof (with IP68) digital sensors to the MCU electronics by using standard Modbus RS485 bus. This approach allows us to extend easily the functionality of the node by adding new digital sensors in the future. We used following Ponsel digital sensor's features: 1) low power consumption with auto-shutdown capability, 2) internal sensor temperature compensation, 3) conformity with international water quality monitoring standards [8], [9] and [10], 4) operation configurable by external MCU master, 5) storage of calibration constants in the sensor embedded flash memory. Our implemented control software fully supports low power node operation. We cross-developed control software in C by using PC platform with Modbus RS485 adapter. Our software was than ported to the custom MCU hardware in cooperation with BME partner. In order to increase reliability of node operation our control software writes to sensor configuration FLASH memories only during cold system start and during normal sensors operation we use only sensor RAM only. Our control software configures modes of sensors operation, periodically acquires measured compensated data from digital Ponsel sensors, parses acquired data and forms data packet for transmission acquired data through RF channel in 433 MHz frequency band. Encrypted RF channel communication was implemented by our BME partner. Proposed protocol uses standard 128-bit AES symmetric encryption algorithm and protects network communication against typical attacks including repetition one.

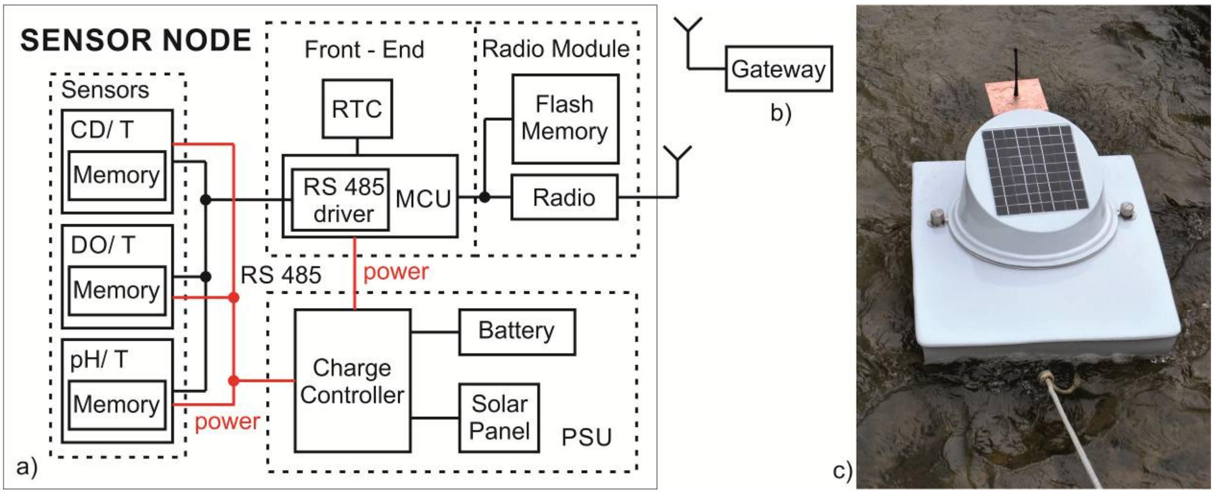

Fig. 1 Water quality monitoring sensor node: a) block scheme of the node including digital sensors, embedded electronics and power supply unit (PSU) b) remote gateway, c) photo of complete monitoring station showing buoy platform, solar panel of PSU and RF antenna for 433 MHz frequency band

3. Digital sensors and settings of alarm threshold indicators for WQM

Since measured values of pH, EC and DO are strongly temperature dependent, we selected Ponsel sensors (probes) that are internally temperature compensated (Table 1 for specific features or [7]). Ponsel sensors recalculate measured data to the reference temperature defined in WQM standards (typically 25°C). We have to calibrate used sensors before the use in the measurement campaign, and then they can work autonomously during relatively longer time period (several weeks or months) without recalibration. These sensors are able to store the calibration constants. The compensated DO measurement requires also air pressure value to provide correct results. We measure the air pressure (and compute compensated results) in the remote gateway. Remote air pressure simplifies whole monitoring buoy construction significantly.

Table 1. Digital physico- chemical Ponsel sensor specifications.

Sensor	Values	Ranges, Units	Power consumption
PHEHT (gel base)	pH/ REDOX/ Temperature	0-14 [-] / -1000 to +1000mV/ 0 to 50°C	Standby: 25µA, Average RS485: 39 mA, Current pulse: 500 mA
C4E (4 electrodes)	Conductivity Salinity	0µS/cm-200.0mS/cm 5-60g/kg	Standby: 25 µA, Average RS485:6.3 mA, Current pulse : 500 mA
OPTOD (luminescent optical)	Dissolved oxygen	0.00 to 20.00 mg/L 0.00 to 20.00 ppm 0-200%	Standby 25 µA, Average RS485: 4.4 mA, Current pulse : 100 mA

We evaluate physico-chemical indicators for WQM by 90th percentile of measured values [2]. The government and WQM legislatives specify limits of all these indicators for the 'high' (the best), 'good' and 'moderate' (or I., II., and III.) status classes of ecological and chemical states of the surface water quality (see e.g. Table 2 specified for Ipel River). Our system automatically activates alarm for responsible persons and institutions if at least one of monitored indicators achieves the predefined limits between good and moderate states. We provide also protocol reporting measured results in accordance with ISO standards [8], [9], [10]. Generated protocols include main monitored values, but also actual temperature, pressure and additional relevant information about WQM measurement conditions.

Table 2. Limit values, determining the good status of the Ipel River part in the Slovak territory close to Hungary border (K2S type) [2].

Parameter	Limits of the good status	Parameter	Limits of the good status
Temperature [°C]	< 24	pH [-]	(6; 7> or <8.5;9)
Conductivity [mS/m]	< 70	Dissolved oxygen [mg/l]	>6.5

4. Conclusions and pilot measurement campaign

We introduced main facts about developed sensor node for the remote river water quality monitoring, designed in the frame of HUSK WSN-AQUA project. We integrate the presented sensor nodes in pilot implementation of our complex river WQM system developed as a main outcome of our project [12]. We will install the whole WQM system in the river Ipel near Slovak-Hungarian border during the period May– June 2015. Our complete WQM system will transfer data from 10 sensor nodes described in this paper by using the gateway and Internet connection to the data server placed in Budapest, Hungary. The data server collects data from our sensor nodes, checks data integrity, errors and temporally stores the data before the transfer to the second server placed in Kosice, Slovakia [12]. The data server in Budapest also allows advanced user interactions with the sensor nodes such as firmware upgrade, calibration, etc. The server also can send alarms on system failure or breaking set-up limits of monitored parameters of river water quality. Our server in Kosice collects data sent by data server in Budapest, stores data in the central cloud-based database, and performs calculations related to advanced data analysis. We can present acquired data and monitor them by using implemented web interface. Our web presentation interface has two levels: the basic one for general public access and the advanced one, which is accessible only to private users and protected by password. The private user can also set-up limits for monitored parameters, generate protocols from acquired and monitored data as well as to be informed about exceeding predefined limits of monitored parameters by email.

Acknowledgement

This work is the result of the Wireless Sensor Network for wAter QaUAlity Monitoring (WSN-AQUA) project of Hungary-Slovakia Cross-border Co-operation Programme, project No. HUSK/1101/1.2.1/0091.

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