Multi-parametric Sensor Network for Water Quality Monitoring

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***Abstract* –Water quality in the sea especially around the mouths of rivers is greatly affected by the quality of river water bringing polluting agents. The paper presents a possible solution of wireless sensor network for river water quality monitoring. The network has been developed with support of EU as a pilot project. It consists of 10 buoys carrying sensors, short and long distance communication systems and two central control nodes processing sensed data and perform their visualization and storage. Moreover, the central nodes perform SMS and email alerting and administration of whole network. The developed system was tested in river at the Slovak Hungarian border.**

I. INTRODUCTION

Water quality (WQ) in the sea, especially around the river mouths and deltas is greatly affected by the quality of river water. The river water may be polluted by many chemical, physical and other agents originated in man-made activities such as industry, agriculture and everyday living. To protect the sea ensuring acceptable quality of water in rivers plays very important role. In other words, the responsibility of sea water quality is not only task for countries with direct access to the sea but for all countries around the world.

With a view of unifying Europe, WQ 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. 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], but also worldwide [5].

Because of missing any study about WQ remote sensing in Slovakia, the project “Wireless Sensor Network for wAter QaUAlity Monitoring” (WSN-AQUA) for an early warning system of river water pollution was initiated 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 was to develop automated station that will monitor several water parameters on a selected river.

In this paper we present the concept of the network, digital sensors and front-end electronics of the developed sensor node (buoy) as well as results achieved during pilot run.

II. CONCEPT OF THE NETWORK

The main requirements on the network were: 1) multisensor and multimode system, 2) sensor nodes with minimal energy consumption, 3) reconfiguration 4) real time processing of acquired data with alerting option, 5) optional data processing with automatic protocol generation, and 6) data storage and accessing in cloud.

A. Sensor nodes

The developed network consists of 10 buoys carrying multi-parameter Ponsel sensors. The sensor system integrates Ponsel PHEHT (gel probe) sensor, which measures pH, redox, and temperature, Ponsel C4E (4-elektrodes probe), which measures conductivity and Ponsel OPTOD (luminescent optical technology), which measures dissolved oxygen [6]. The buoys contain also the supporting electronics, controller, power source using photovoltaic cell and communication subsystem. The block diagram of buoy node electronics is shown in Fig. 1, the realized buoy in Fig. 2 and its interior in Fig. 3.

The robust waterproof (with IP68) digital sensors are connected to the MCU electronics by standard Modbus RS485 bus. This approach allows us to extend easily the functionality of the node by adding new digital sensors in the future. The following Ponsel digital sensor’s features were preferred: 1) low power consumption with auto-shutdown capability, 2) internal sensor temperature compensation, 3) conformity with international water quality monitoring standards [7], [8] and [9], 4) operation configurable by external MCU master, 5) storage of calibration constants in the sensor embedded flash memory.

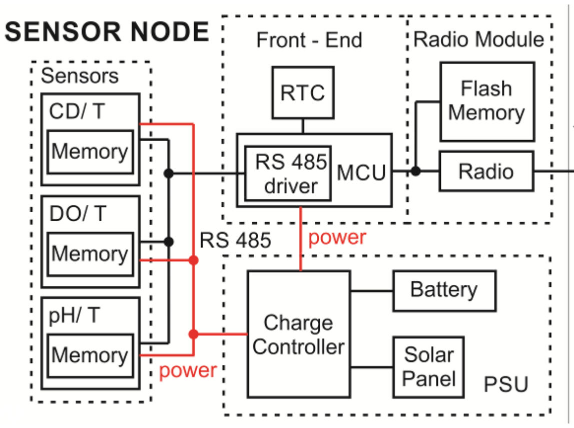

Fig. 1. Block diagram of the sensor node in buoys.

Fig. 2. Buoy with sensors on the river Ipel.

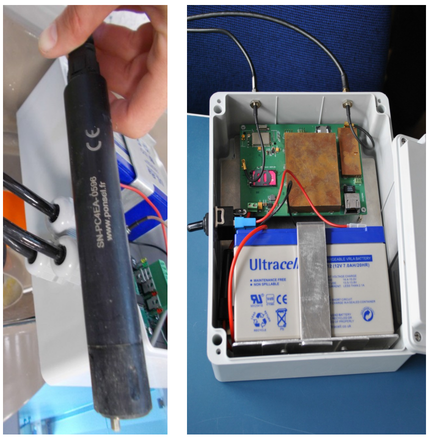

Fig. 3. Sensor and the interior of a realised buoy.

The implemented control software fully supports low power node operation. We developed control software in C 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.

The compensated DO measurement also requires known air pressure value to provide correct results. We measure the air pressure (and compute compensated results) in the remote gateway. The measurement of pressure out of buoys with limited power sources simplifies the whole monitoring buoy construction significantly without influence on the accuracy of achieved results.

B. Short distance communication

The buoys transfer data to onshore gateways using wireless short distance communication system. The great emphasis was put on the communication protocol and messages. It is essential that the communication protocol operates as efficiently as possible, thus reducing the energy consumption of network nodes. We developed multi-hop communication system with automatic node discovery mechanism. Each buoy creates a table of adjacent nodes automatically and the table is updated after each message transfer fault.

The structure of message consists of two parts: header fields carrying communication control bits such as addresses, commands and queries and the useful content part carrying measurement data. The communication protocol is based on the fact that the buoys are in energy saving sleep mode until awaked by the message from gateway. Each correctly delivered message is confirmed by acknowledge. The multi-hop network also tries to find the shortest and this way the most energy efficient way to transfer message from gateway to the addressed way on basis of the actual table of adjacent nodes and the history of message transfers.

The wireless communication technology for acquired data transfer employs RF channel in 433 MHz frequency band. Encrypted RF channel communication was implemented by our BME partner. Proposed protocol uses the standard 128-bit AES symmetric encryption algorithm and protects network communication against typical attacks including the repetition one.

C. Long distance communication

The gateway collects data from the nearest buoys, stores them and transfers via the Internet (GSM) to the first central node located at Infokom in Budapest (Fig.4). Here the data are qualified by comparing with critical set limits, and temporarily stored. If a measured value crosses the limits, the first central node generates SMS alert sent to phone numbers stored in the node internal reconfigurable table.

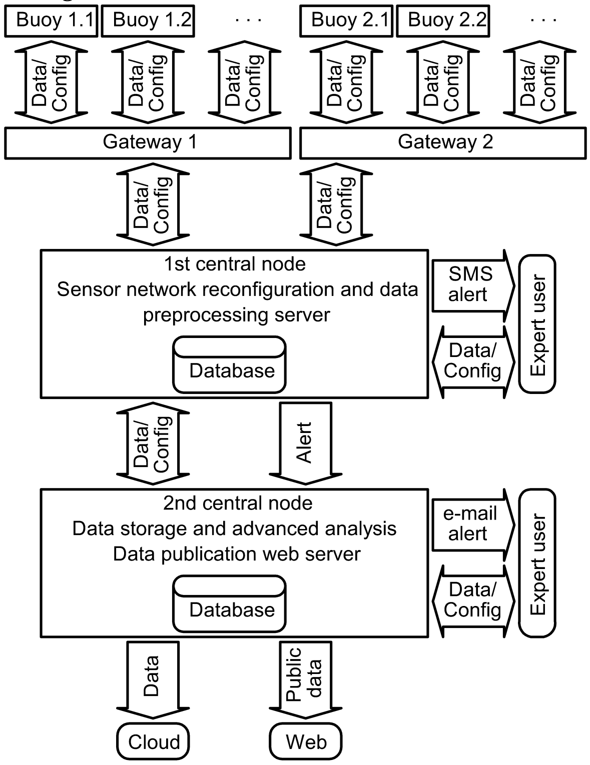

Fig. 4. Concept of measuring system.

Along with SMS alert the node sends alert together with data to the second central node at TU in Kosice via the Internet using web services technology. In the case that no alert has been generated within 24 hours the first node transfers all data collected during the last 24 hours at midnight to the second central node in Kosice via the Internet and using webservices.

D. Data processing and system control

The first central node allows also expert control and reconfiguration of whole measuring system including such tasks as checking status of all network components, performing self-test, upgrading firmware in buoys and gateways, changing constants in calculations in buoys, time synchronization in systems, etc. The software of node was developed in C language.

The main tasks of the second central node in Košice are to collect and store data in local database as well as in Cloud, perform analysis of data for public project web page as well as to perform advanced analysis accessible only to private user, which is protected by login and password. Except the statistical analysis (histogram of chosen buoy number and measured quantity with its analysis - mean, standard deviation, percentile, etc.), also correlation analysis among quantities measured by different buoys. The advanced analysis offers also option to generate complex protocol from chosen analysis in docx format including tables and graphs in the standardized form and mail it as attachment of email to a indicated email address.

The second central node also processes alerts from the first central nodes, generates and sends alert emails according to a list of specified email addresses in internal reconfigurable table.

Software in the second central nodes is based on combination of LabVIEW, MySQL and php.

III. EXPERIMENTAL RESULTS

The developed system was tested in pilot operation. Ten buoys together with gateway were placed around Slovak – Hungarian border in the river Ipel The implementation consisted from two sensor networks, each with 5 buoys and one gateway as it is shown in Fig. 5. The distance among neighboring buoys was 500m and the distance of buoys from gateway was about 1000m.

Fig. 5. Geographical arrangement of buoys and gateways with pilot test

The duration of pilot operation was a few months covering periods with a few extreme variations of weather when relatively high air temperatures and heavy rains flash floods appeared.

Fig 6 shows a few examples of acquired values from database as they are shown to users including case when a measured value overruns the set up limit.

Fig. 6. Examples of measured data from database as they are shown to the user. Measured conductivity exceeded the upper limit.

IV. CONCLUSIONS

The paper presents multi-parametrical sensor network for water quality monitoring, which was developed within Slovak – Hungarian project supported by EU. The sensor network uses modern multi-hope communication technology saving energy required for full functionality of the network. The applied Ponsel sensor system allowes multiparametric sensing. The acquired data are processed and stored in Cloud database for later deeper analysis including automatic protocol generation. The network was tested in real environment and proved well functionality and reliability also during rather extreme weather conditions. The experience from the network development may be used for development of other sensor networks for water quality monitoring. The experience was also used in education process at the Faculty of Electrical Engineering and Informatics of the Technical University of Kosice for direct teaching as well as for building the Laboratory of sensor systems.

V. AKNOWLEGEMENT

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REFERENCES

[1] Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy" Official Journal of the European Communities, vol. 22, 2000.

[2] Directive No. 269 of Slovak republic government with requirements for good state of water bodies. 2010.

[3] Q. Chen, Y. Zhang, and M. Hallikainen, "Water quality monitoring using remote sensing in support of the EU Water Framework Directive (WFD): a case study in the Gulf of Finland," Environmental Monitoring and Assessment, vol. 124, no. 1-3, pp. 157–166, 2007.

[4] S. Mijovic and B. Palmar, "Water quality monitoring automation of rivers in Serbia," Facta universitatis, Series: Working and Living Environmental Protection, vol. 9, no. 1, pp. 1–10, 2012.

[5] R. D. Woodsmith, P. K. Wilkins, and A. Bookter, Water Quality Trends in the Entiat River Watershed: 2007–2010, 2013

[6] Digital sensors (SDI-12 or Modbus RS485 protocol (pH-Redox-Conductivity-Turbidity-Dissolved Oxygen)) http://www.ponsel-web.com/cbx/s747_cat15034.htm

[7] International Standard ISO 7888-1985: Water quality–Determination of electrical conductivity, first edition 1985-05-15.

[8] International Standard ISO 17289-2014: Water Quality–Determination of dissolved oxygen–Optical sensor method, first edition 2014-07-01.

[9] International Standard ISO 10523- 2008: Water quality–Determination of pH, second edition 2008-12-15.