

WIRELESS SENSOR NETWORK FOR RIVER WATER QUALITY MONITORING

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Abstract – This paper presents wireless sensor network for water quality monitoring, which was developed within the Hungarian – Slovak cross border project supported by EU. The nodes of wireless network are realised as buoys fixed in the river stream and carrying sensors measuring 8 basic water quality parameters and wireless communication system for data transfer to the network control server across wireless gateway. This server controls and reconfigures the measuring nodes, pre-processes and formats data, and sends them to the data processing server. The data processing server store the data to the database shared in Cloud, process them by statistical methods, and presents in the form of public accessing web pages Moreover it enables performing advanced data processing and present results of the analysis for the private advanced user.

Keywords: wireless sensor network, river water quality monitoring

1. INTRODUCTION

The river water quality monitoring is one of the most required and important measurements in environmental monitoring. The quality of river water has direct and indirect impact life in and around the river. Moreover river water is used for many human activities from agriculture, and fish farming through various industrial applications up to creating drinking water sources. Water quality monitoring is often applied also at country border crossing, nearby agrarian and industrial enterprises, big towns and agglomerations and other potential sources of water pollution.

The basic requirements on modern river water monitoring systems are:

- Autonomous functioning
- Remote control and data acquisition
- Limited power sources
- Reliable functioning at difficult environment conditions
- Robust construction of sensing system
- Advanced data processing with alarm generation
- Easy reconfiguration

Water quality monitoring in Europe is intended to control water pollution and enforces water protection

legislation [1]. With a view of unifying Europe, national regulations have to be harmonized and transformed into water policy in compliance with the Water Framework Directive (WFD) [2]. Due to WFD an integrated approach on basin of rivers with respect to water quality management and monitoring will be mandatory in the future. Today local and national authorities utilize a number of laboratories and research facilities which provide the requested water quality data, mostly based on laboratory analysis on a monthly scale for a monitoring purpose.

One crucial issue within water quality management as required by the WFD is to have sufficient and comparable information on water quality, where the traditional approach to monitoring of river water quality consists of manual sampling in remote locations and the transport of samples to the laboratory for chemical analysis. This approach does not allow the continuous collection of data consequently major challenge with respect to the setup of integrated management is data mining and data processing. Thus remote sensing technology is a valuable tool in obtaining continuous information on the processes taking place in the surface waters. As examples, new technology and instrumentation automatic stations are effectively used in a number of networks for monitoring of various pollutants or temporal changes in toxicity [3], [4], [5] and [6].

In Slovakia there are only a few studies discussing water quality monitoring using remote sensing for support of water policy and legislation in compliance with the WFD. In Slovakia, the only automatic station located in Pinkovce on the river Uh was installed in 1993 and is out of order in the present.

The pilot activity in modern remote water quality monitoring system in Slovakia and in Hungary is the Wireless Sensor Network for wATER QaUALity Monitoring (WSN-AQUA) project. The project was initiated in 2013 by the Hungary-Slovakia Cross-border Co-operation Programme between the BME-Infokom Company (BME) and the Technical University of Kosice (TUCE). The goal of this project was to develop the automated system that would monitor several river water parameters and test it in real condition in the chosen river. In this paper we present the developed wireless sensor network for river quality monitoring and some results achieved during pilot application of the system

The paper is organized as follows. An overview of the system architecture of the developed water quality

monitoring network and particular hardware and software components are described in Section 2. Section 3 presents the some results achieved during the pilot implementation of network in May – June 2015.

2. ARCHITECTURE OF DEVELOPED SENSOR NETWORK

The developed wireless sensor network for the water quality monitoring consists of two parts connected into one common complex system across the Internet. The first part performs water parameter sensing and data preprocessing (Fig.1.) The sensor nodes based on multiprobes systems are placed in buoys floating on the water surface and fixed to the river bottom. The sensed data are transferred by wireless buoy transceiver to the gateway. Gateway collects data from all buoys and sends them to the first server across a standard mobile communication network.

The main tasks of the first server are:

- To store data temporally in the first step database
- To detect measured parameters limits overrun and to send alerts by SMS to the group of expert users as well as across the Internet to the second server with bu.
- To test the consistence of data and to identify potentially possible faults in particular sensors functionality. If any fault is identified the alert is send by SMS.
- To offer expert users reconfiguration of sensor network, buoy firmware upgrade, etc.

The pre-processed data are coded and sent across the Internet to the second part of the water quality monitoring system for the final storage, processing and presentation (Fig. 2). The server stores all measured data in main system database, generates dynamic web pages presenting the latest measured data in graphical form including simple statistic processing. The dynamic web pages are accessible for public access to any user on the link <http://husk.fei.tuke.sk>.

The server can also apply advanced statistical processing on data from the system database. The choice of processing methods and data range is under control of advanced private user with account on the server. The protocol from the advanced data analysis can be also generated and send to the

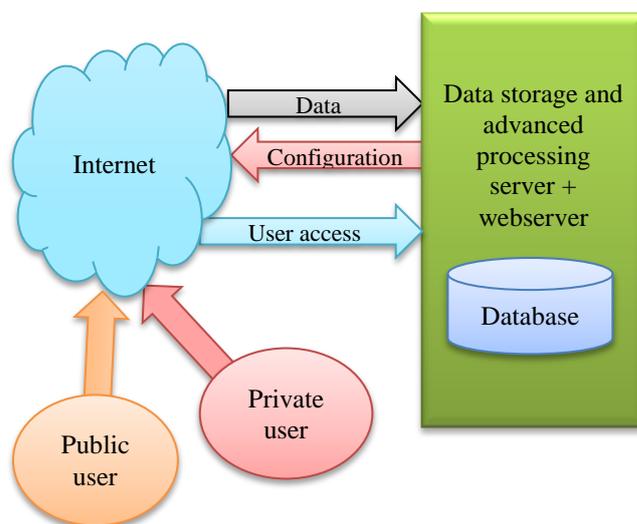


Fig. 2 Data processing and publishing part of sensor network.

advanced user in MS Word format by email to the used predefined or chosen address. This part of server functionality is password protected and accessible only to registered users. Another server functionality is alerting selected group of advanced users by email in the case that a chosen critical monitored parameter overrun s setup limit.

2.1. Probes and measured parameters

To fulfil the requirements on water quality monitoring given by EU and national regulation the following parameters must be monitored at least: temperature, pH, conductivity and dissolved oxygen. As a compromise among costs and quality of the probes by Ponsel have been chosen. Ponsel PHEHT (gel probe) measures pH, redox, and temperature, Ponsel C4E (4-elektrodes probe) measures conductivity and Ponsel OPTOD (luminescent optical technology) measures dissolved oxygen. The overview of the probes is in Tab. 1. All measured parameters are corrected on temperature and atmospheric pressure, which is measured by an additional sensor in gateway. The probes require calibration before the first use. All chosen probes have digital communication interface with Modbus protocol which enables easy connection of the probes to the microcontroller in buoy control unite.

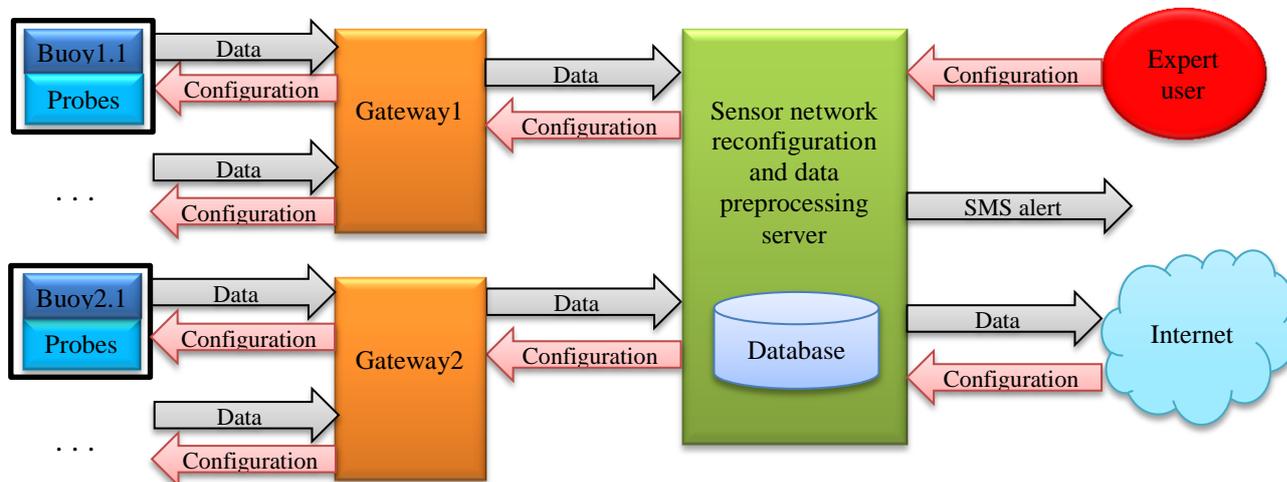


Fig. 1 Architecture of monitoring part of sensor network.

Tab. 1 Specification of used Ponsel probes.

Probe	Values	Ranges, Units	Power consumption
PHEH T(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
OPTO D (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

2.2. Network sensor node

The sensor node system consisting from probes, control and communication electronics and its power is placed in robust buoy made from composite material as it is shown in Fig. 3, Fig. 4, and Fig.5. The buoy is fixed in the river (Fig. 3). The power of sensor node is realised from build-in accumulator (Fig. 5) rechargeable from photovoltaic panel as it is seen in Fig. 3. Small antenna for wireless data link the sensor node with gateway has been fixed near the photovoltaic panel.



Fig. 3. Buoy carrying sensor systems.



Fig. 4. Internal construction of the buoy.

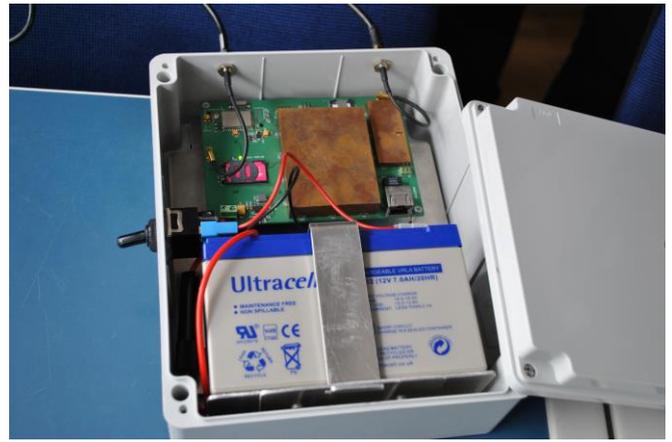


Fig. 5. Sensor electronics and wireless buoy transceiver

2.3. Sensor node electronics and RF communication subsystem

To ensure the smart behaviour of sensor node and secure and robust data transfer in developed sensor network the control electronic system of node was developed and implemented in buoy. The block diagram of the smart node electronics and gateway is shown in Fig. 6.

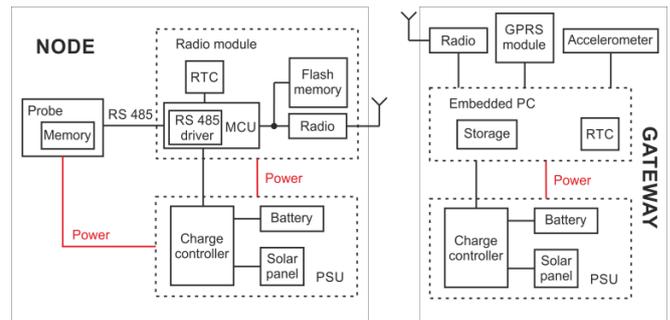


Fig. 6. Block diagram of sensor nodes (buoy) and gateway

The 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. The smart system in node enables remote upgrade of firmware and changing operation modes according to remote configuration commands.

3. EXPERIMENTAL RESULTS

The developed system was tested in pilot operation in the period May – June 2015. Ten buoys together with gateway were placed around Slovak – Hungarian border in the river Ipel as it is shown in Fig. 7 and Fig. 8. The implementation consisted from two sensor networks, each with 5 buoys and one gateway. The distance among neighbouring buoys was 500m and the distance of buoys from gateway was about 1000m. The duration of pilot operation was about one month and during the period a few extreme variations of weather

such as relatively high air temperature and flash flood appeared.



Fig. 7. Buoys in the river Ipel during the pilot operation.



Fig. 8. Gateway near the river IPEL during the pilot operation.

During the pilot operation the monitored parameters were also compared with the limits specified by Slovak WQM legislation for the river Ipel (Tab. 2). In the case when a monitored parameter crossed its limit the alert in the form of SMS and email was generated.

Tab. 2 Limit values, determining the good status of the Ipel River part in the Slovak territory close to Hungary border (K2S type) [7].

Parameter	Limits of the good status	Parameter	Limits of the good status
Temperature [°C]	< 24	pH [-]	(6; 7> or <8.5;9)
Conductivity [μS/cm]	< 700	Dissolved oxygen [mg/l]	>6.5

To document of achieved results from pilot operation, the course of temperature, dissolved oxygen (oxygen concentration), conductivity, and pH measured in positions of buoy 1, 2 and 3 are presented in Fig. 9.

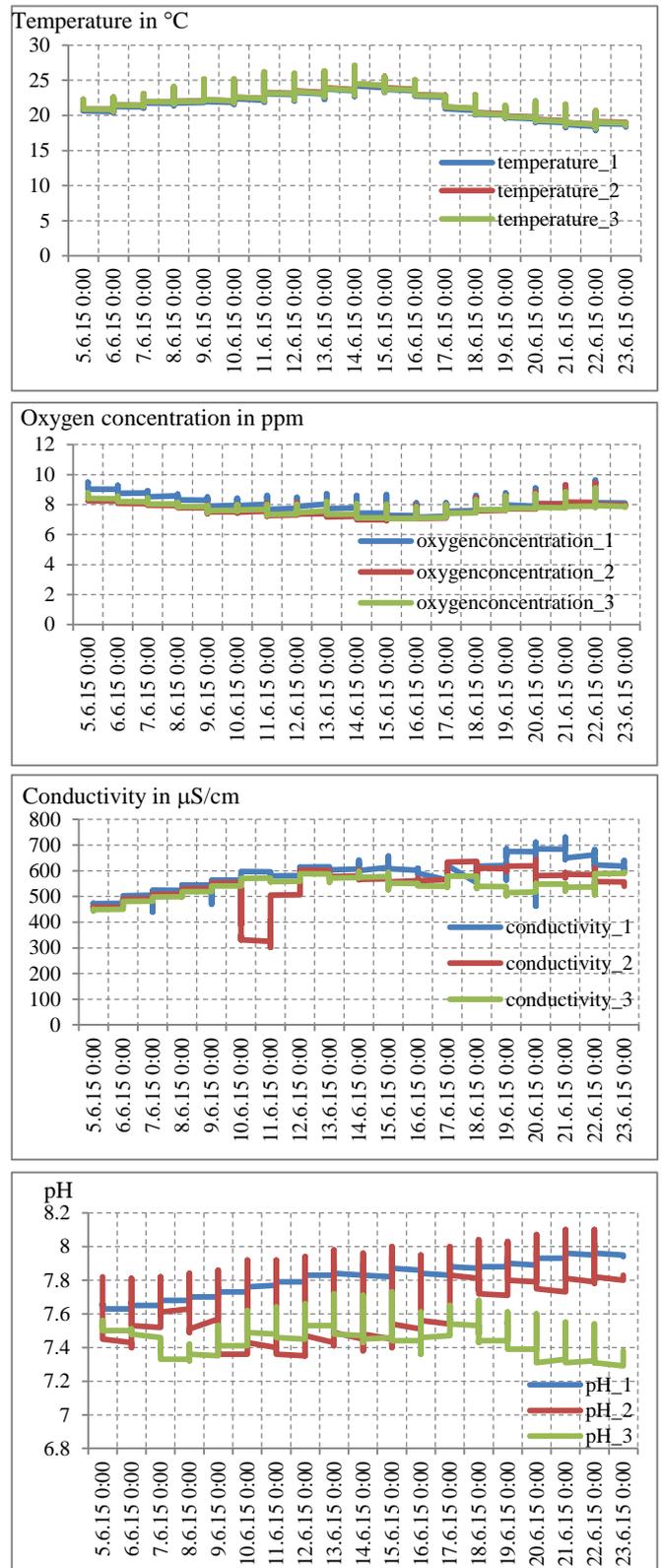


Fig. 9. Example of some acquired water quality parameters in the river IPEL during the pilot operation with daily step.

Acquired values of temperature and oxygen concentration are very similar in all position, what is in accordance with assumption because the distance among the neighbouring position is only 500m. Acquired values of conductivity are also in consonance except a few values measured around June 10 when sensor node 3 indicated lower conductivity than other sensor nodes. Measured values

of pH differ a little among particular sensor nodes but the differences are not big and they can be caused by different distances of sensor nodes from river bank resulting in different properties of water. Some statistical characteristics of quantities from Fig. 9 are summarised in Tab. 3.

Tab. 3. Statistical characteristics of quantities shown in Fig. 9

Parameter	Node 1	Node 2	Node 3
Min. temperature [°C]	17.87	17.79	18.14
Max temperature [°C]	26.87	27.06	27.09
Temperature 90th percentile [°C]	24.81	25.00	25.06
Min. dissolved oxygen [ppm]	7.15	6.930	7.08
Max. dissolved oxygen [ppm]	9.63	10.11	9.11
Dissolved oxygen 90th percentile [ppm]	8.97	8.71	8.50
Min. conductivity [µS/cm]	439.37	302.52	449.91
Max. conductivity [µS/cm]	730.42	642.69	596.76
Conductivity 90th percentile [µS/cm]	679.26	605.22	585.11
Min. pH	7.62	6.68	7.29
Max pH	8.02	8.47	7.73
pH 90th percentile	7.96	8.00	7.63

Fig. 10 shows the course of measured quantities temperature, pH, dissolved oxygen concentration, and conductivity by sensor node 2 with hourly step together with measured air pressure. Variation of temperature, pH, and concentration of dissolved oxygen concentration are strongly correlated and also clearly depend on alternating day and night.

Behaviour of conductivity is different. It seems that the conductivity varies independently on other monitored quantities but in deeper analysis we can notice some less visible relations with other measured quantities.

4. CONCLUSIONS

The papers presents monitoring system based on wireless sensor network for water quality monitoring, which was developed within Hungarian – Slovak cross border cooperation and the project Wireless Sensor Network for wAter QaUality Monitoring (WSN-AQUA), registration number: HUSK/1101/1.2.1/0091 supported by EU. The developed monitoring system is results of cooperation between nonprofit organization of technology Research and Development – BME Infokom (www.bme-infokom.hu) and the Technical university of Kosice (www.tuke.sk), department of electronics and multimedia telecommunications (kemt.fe.i.tuke.sk). The system has been

successfully tested in pilot operation and it is prepared for modification and application according to the request of future users.

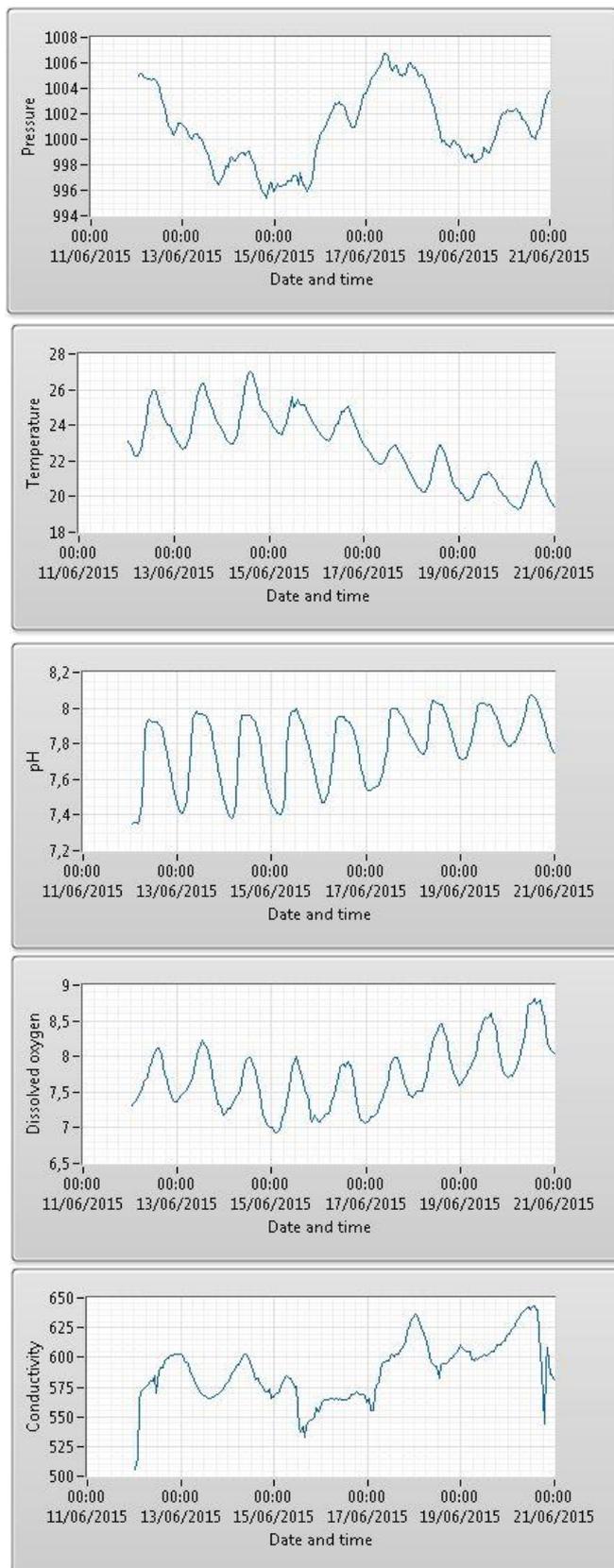


Fig. 10. Air pressure in hPa, temperature in deg. C, pH, dissolved oxygen concentration in ppm, and conductivity in µS/cm measured by sensor node 2 in the period June 12 – 20 with hourly step.

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