WIRELESS SMART MULTISENSOR NETWORKS FOR WINE-MAKING PROCESS CONTROL

Volodymyr Romanov, Igor Galelyuka, Oleksandr Voronenko, Oleksandra Kovyrova, Sergei Dzyadevych, Ludmila Shkotova

***Abstract**: This time industrial wine-making process is based on using complex and expensive analytical equipment such as refractometers, chromatographs, spectrometers, and so on. The equipment is used in large companies, and small manufacturers have not possibility to install it. So, lack of modern equipment for control of parameters of wine-making processes causes decrease of the quality of wine. To improve the quality of wine of small manufacturers it is possible to use developed in the Institute of Molecular Biology and Genetics of National Academy of Sciences of Ukraine smart biosensors and biosensor devises, integrated with wireless sensor networks in Glushkov` Institute of Cybernetics of National Academy of Sciences of Ukraine. The results of developing wireless smart multisensor networks for wine-making process control are considered in the article.*

***Keywords**: wireless smart multisensor networks, wine-making process, quality of wine.*

***ITHEA Keywords**: J.3 Life and Medical Sciences- Biology and Genetics*

Introduction

Smart biosensors, multisensors, and biosensor devises integrated with wireless sensor networks (WSN) permit to improve parameters of control systems for biological and chemical object testing. There are systems of new generation with high sensitivity, selectivity, and operating speed of measurement of substances concentrations. Comparatively with expensive analytical systems

they are low-price, and more usable. Development of smart biosensors, multisensors, and biosensor devices, integrated with WSN is one of the main directions of IoT technologies [Beavers, 2017, 1, 2]. The main idea of the article is results of design and development of smart biosensors, multisensors, and biosensor devises integrated into wireless sensor network for control of wine-making process including the quality of wine.

Work Objectives

Work objectives are design of wireless sensor networks and smart multisensory nodes for quality control of wine-making process, including quality of wine, and intermediate products.

Industrial wine-making process and physicochemical parameters of wine

Industrial wine-making process consists of following main stages:

- Raw preparation;
- Pulp pressing;
- Must fermentation;
- Wine settling;
- Wine management
- Wine filling-up;
- Wine aging;
- Wine treatment.

The main physicochemical parameters of wine according to international standards are presented in the Table 1. Abnormalities of the physicochemical parameters of wine according to the international standards are shown in the Table 2.

Table 1. Physicochemical parameters of wine

Sort of wine	Physicochemical parameters of wine				
	Alcohol, %	Sugar, g/dm^3	Titrated acids, g/dm^3	Light acids, g/dm^3	
Dry					
white	9,0-14,0	>3,0	5-7	1,2	
rose	9,0-14,0	>3,0	5-7	1,3	
red	9,0-14,0	>3,0	5-7	1,5	
Semi dry					
white	9,0-14,0	5,0-25,0	5-7	1,2	
rose	9,0-14,0	5,0-25,0	5-7	1,3	
red	9,0-14,0	5,0-25,0	5-7	1,5	
Semi sweat					
white	9,0-13,0	30,0-80,0	5-7	1,2	
rose	9,0-13,0	30,0-80,0	5-7	1,3	
red	9,0-13,0	30,0-80,0	5-7	1,5	
Fortified wine				ordinary	vintage
white	14,0-20,0	2,0-110,0	3-7	1,2	1,0
rose	14,0-20,0	30,0-10,0	3-7	1,2	1,0
red	14,0-20,0	30,0-10,0	3-7	1,2	1,0

Table 2. Abnormalities of the physicochemical parameters of wine

Parameters	Abnormality
Alcohol, %	± 0,5
Sugar, g/dm3	± 5,0
Titrated acids, g/dm3	± 2,0

Technical requirements to the wireless sensor networks for wine-making processes control

Based on the Table 1, there is large quantity of physicochemical parameters of wine, and for control of the parameters in real time it is needed biochemical laboratory with complex analytical devices, and skillful staff.

Only large wine-making companies with high volume of sales have such laboratories. But there are many small-scale wine-making farms which instead of the biochemical laboratories use special, as a rule, inaccurate devices for control the wine-making processes. It affects adversely on the quality of wine. Improvement of control of wine-making process is possible on the base of developed in National Academy of Sciences of Ukraine smart biosensors and smart WSN. Smart WSN includes smart multisensor nodes with bio- or multisensors, ADC, filters, processors or controllers, transceivers, network interfaces, and so on as shown on Figure 1.

Smart multisensor nodes transmit necessary data extracted from the data stream to the transport layer or cloudy server for preparing management decision only. So, they include such functions as filtering, decimation, data extracting, data processing and data interpretation. It is provided management of frequency range, data access speed, and dynamic range in the smart node. The main requirements to the smart multisensor nodes are following: low power consumption, input/output signal filtering, data acquisition, data preprocessing, and data communication.

There are many analog components in the smart multisensor node. So analog filtering is very important for such unit. But analog filtering led to information losses. So instead of analog filters or further to it smart multisensor nodes use digital filters on the ADC output. As a rule there are two types of ADC in smart sensor nodes such as successive approximation and sigma-delta ADC. Modern sensor nodes as a rule are based on the ARM processor with Cortex core.

WSN integrates to the cluster many smart multisensor nodes, as shown on Figure 2.

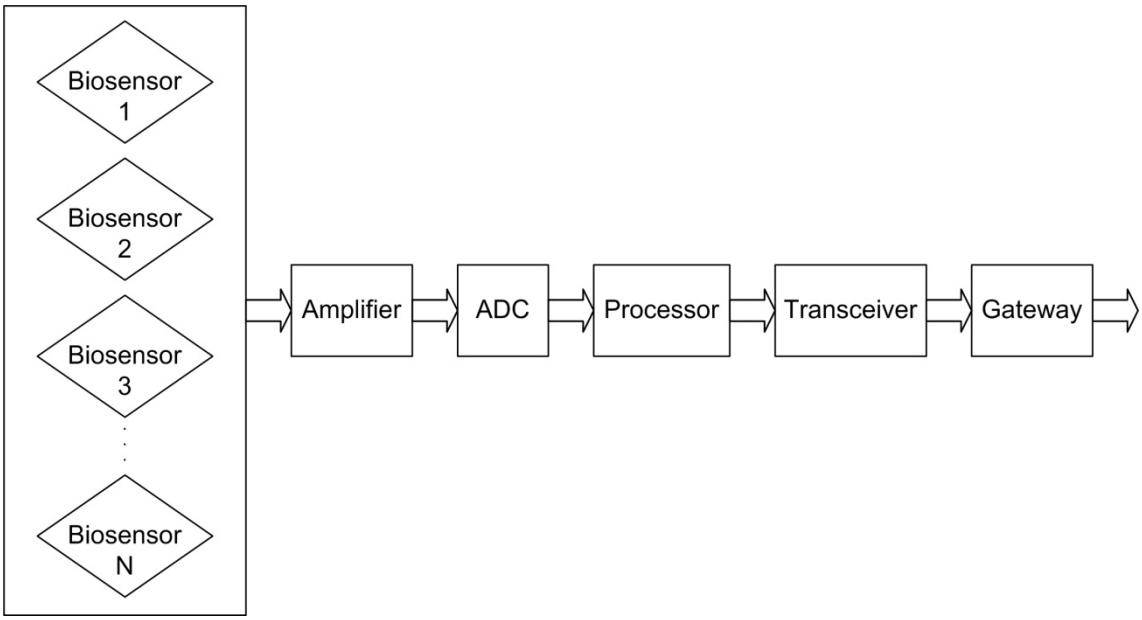

Figure 1. Block diagram of typical smart multisensor node

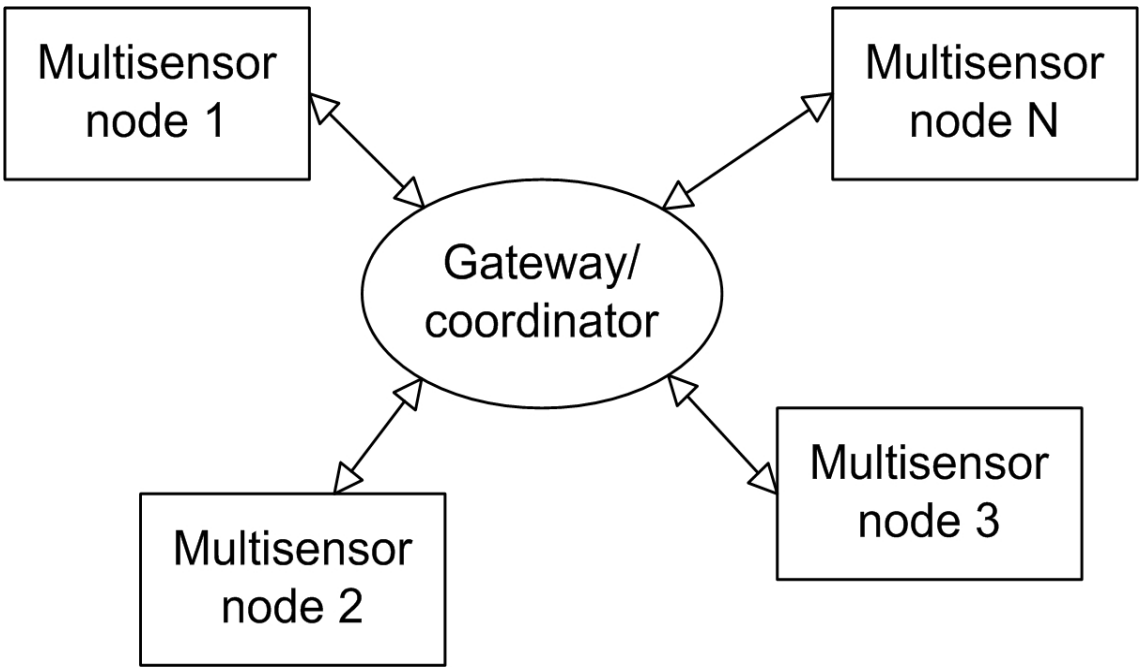

Figure 2. Smart multisensor nodes integrated to the cluster

Multisensor node functional diagram

Developed smart multisensor as a part of multisensor node is intended for WSN for wine-making processes control. It includes biosensing elements: Biosensor 1, Biosensor 2, … Biosensor N, as shown on Figure 3, based on amperometric enzyme biosensor for determination of concentrations of main substances of wine during some minutes. The output signal of the amperometric enzyme biosensor is variable current [Shkotova et al, 2004, Shkotova et al, 2005]. So analog front-end interface includes current/voltage converter and ADC.

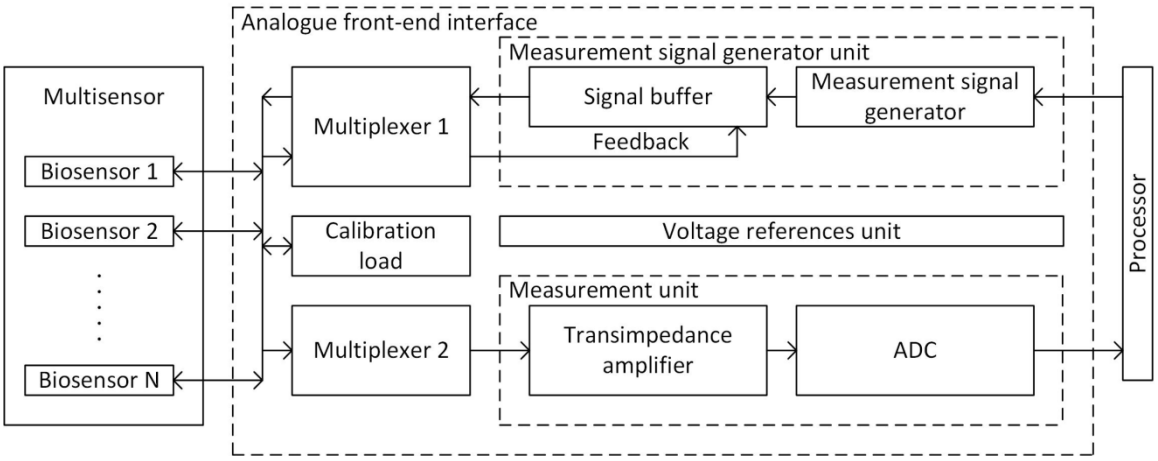

Figure 3. Analog front-end interface of smart multisensor node

In addition, smart multisensor node includes data processing, and data communication units. All electronic units are designed on VLSI. For example, system-on-chip ADuCM350 of Analog Devices is intended for amperometric, conductometric, and potentiometric transducer and includes 16 MHz ARM® Cortex M3 processor with 16-bit ADC, sampling rate 160 kHz.

It was developed debugging environment or working place, as shown on Figure 4, for smart multisensor node adjustment, and configuration of WSN for the definite application. It includes measuring devices (5), PC, two monitors (8, 9) with some programming windows, and network coordinator (3) with sensor

monitor (4), radio transceiver (1), and Li-Ion accumulator (2), analog-to-digital signal analyzer (7), and programmer (6).

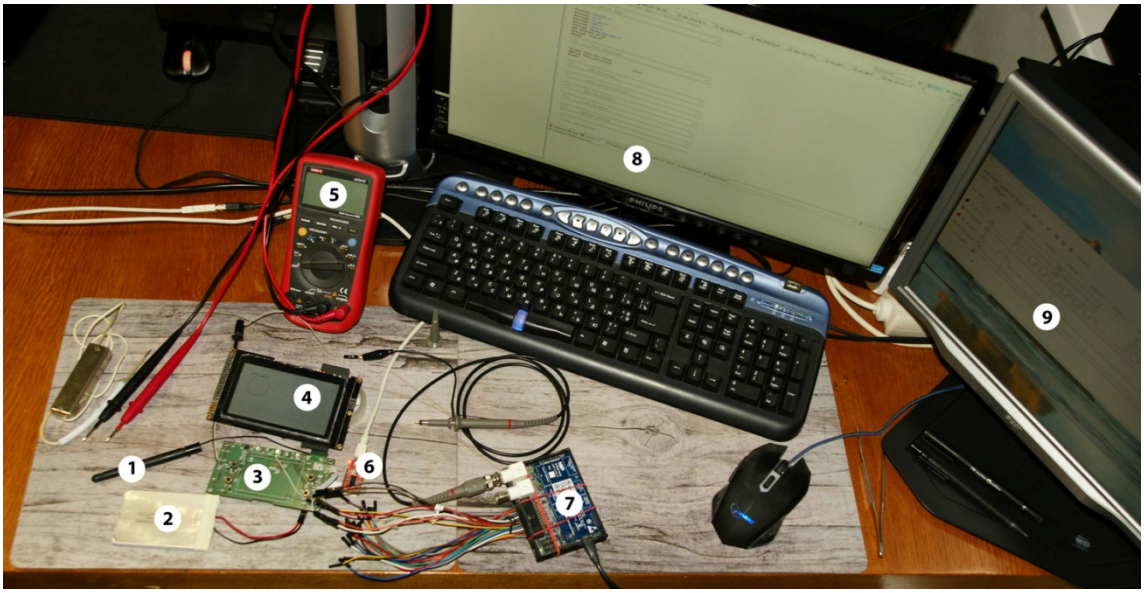

Figure 4. Working place with debugging environment for smart multisensor node programming

Architecture of smart WSN

Practically industrial WSN is based on star or woody network. Developed WSN consists of wireless smart multisensor nodes, network coordinator, and work station for technology staff, figure 5.

The main control unit of the WSN is network coordinator. It supports the structure of WSN, and error-free performance of the smart multisensor nodes. If some of them fail the network coordinator informs the operator, and reformates the network according to new conditions to support functional stability of the WSN. The next function of network coordinator is data acquisition, and data processing, data visualization, and data communication to work station or

working place of technology staff. In addition network coordinator support communication with cloud environment, Internet, and so on.

Smart multisensor nodes are situated in technology equipment of wine-making manufacture for measuring physicochemical parameters of wine, as shown on Figure 6.

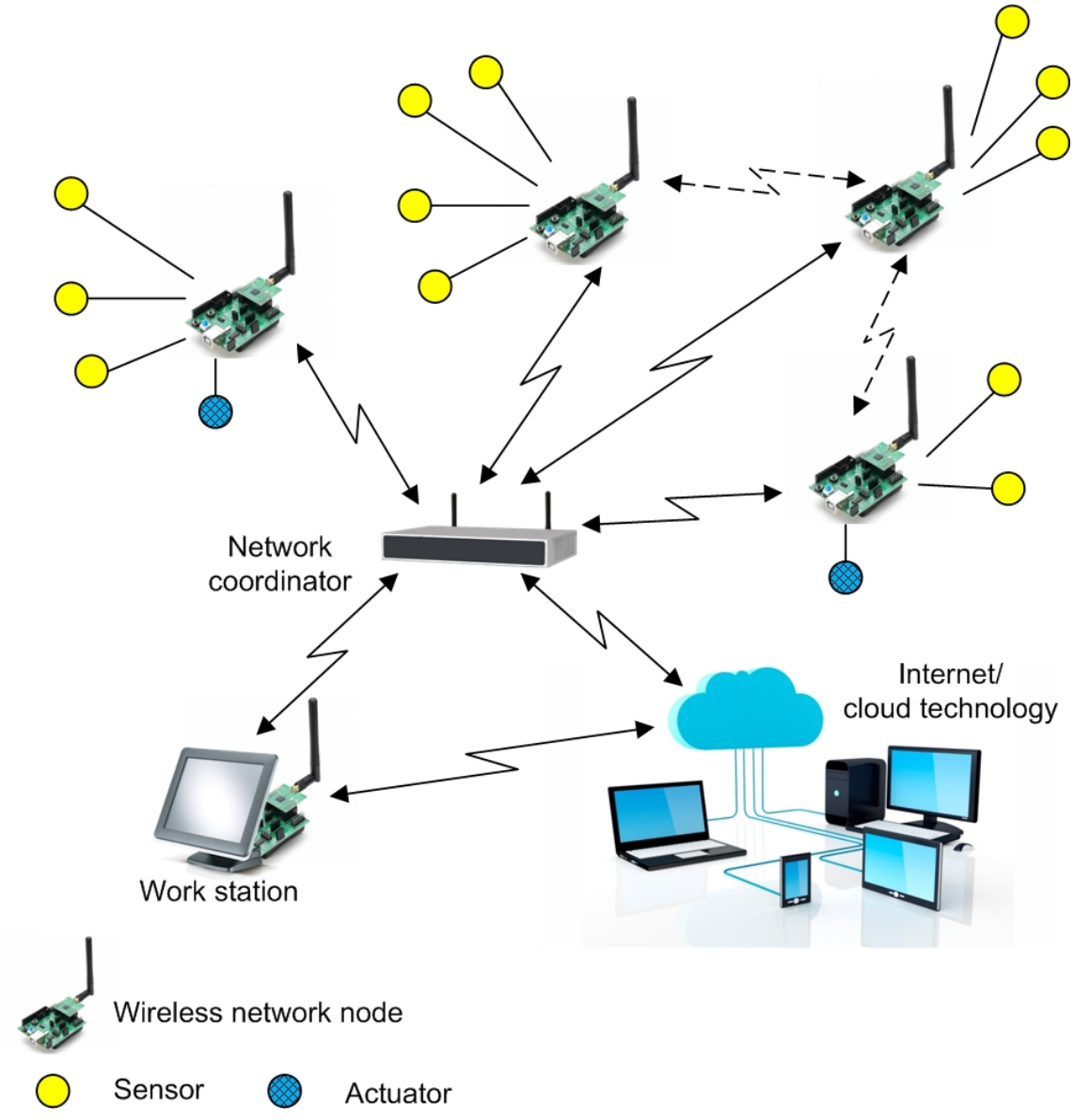

Figure 5. Architecture of type industrial WSN

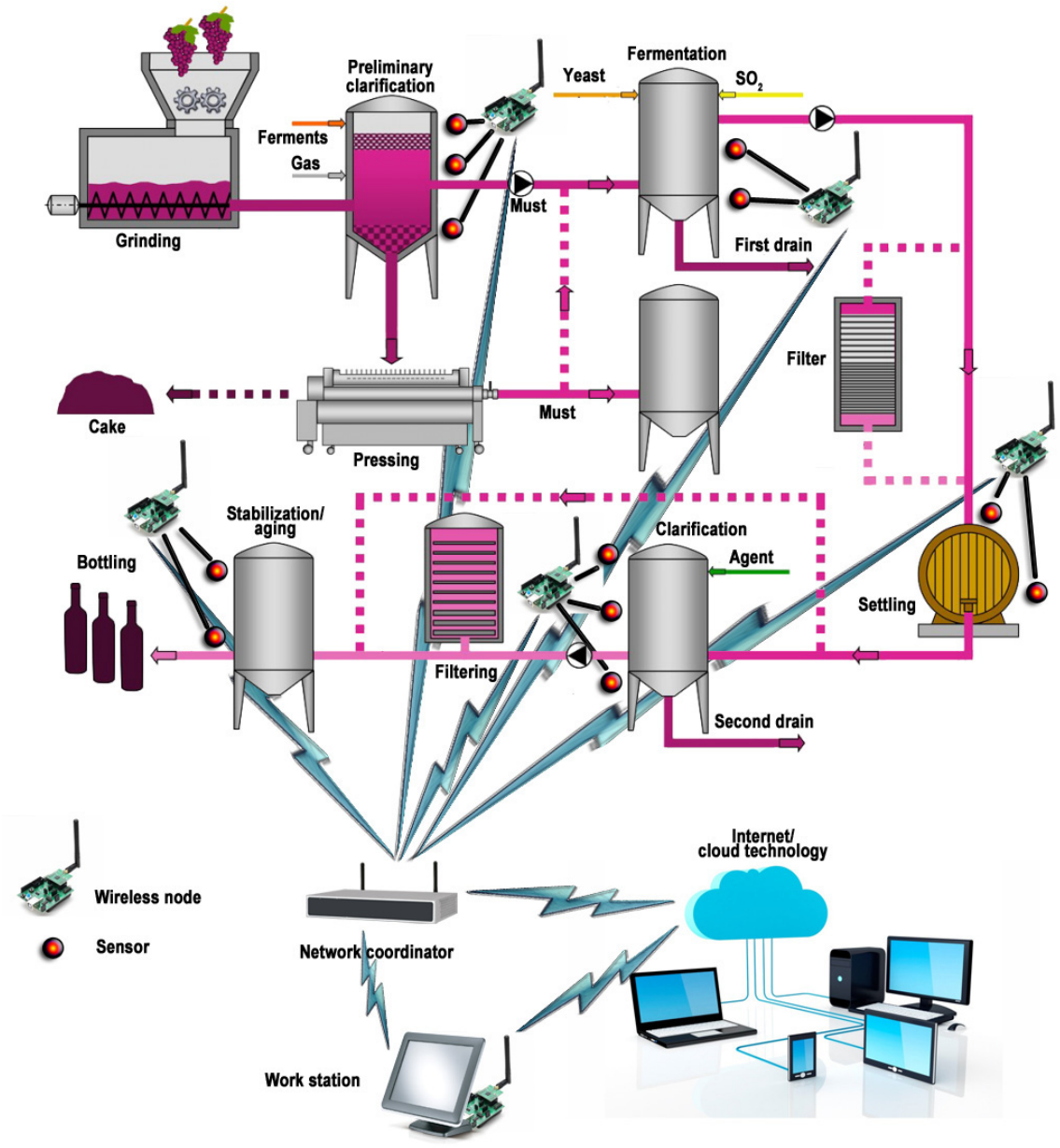

Figure 6. Architecture of WSN for application in industrial wine-making manufacture

Network coordinator

Coordinator block diagram is shown on Figure 7.

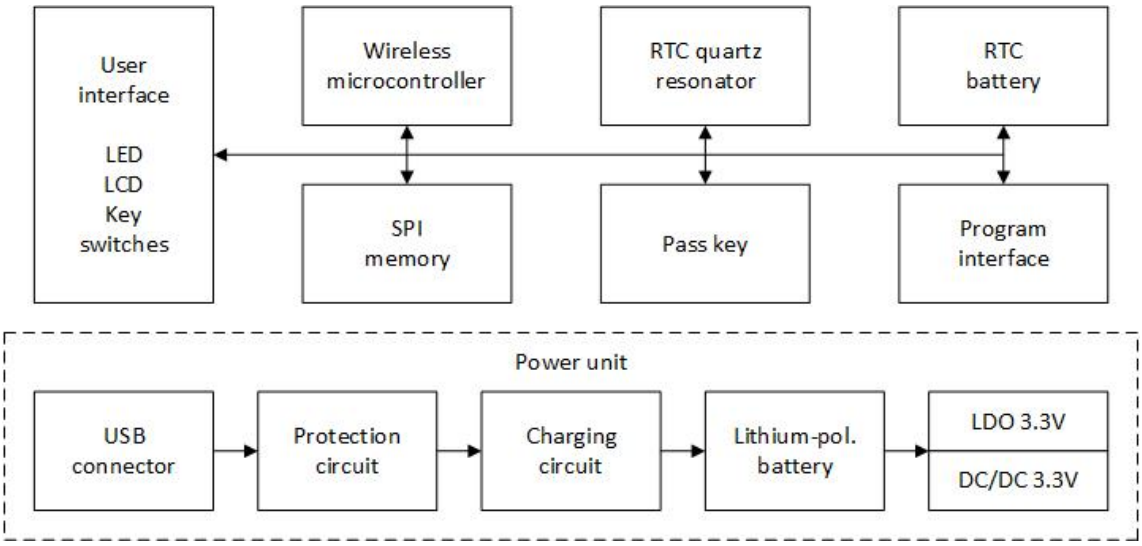

Figure 7. Block diagram of network coordinator

The main WSN coordinator functions are following: network configuration, network initialization, network status management, memory management, measurement management, communication management, and visualization management [Palagin et al, 2017]. According to the functions algorithms and application software of network coordinator were developed. Prototype unit of network coordinator is shown on Figure 8.

Conclusion

Features of wireless sensor network for wine-making process monitoring and control, based on new smart multisensor nodes are considered. Block diagrams of smart multisensor nodes, and coordinator are developed. Requirements to the main network units are determined.

Figure 8. Prototype unit of WSN coordinator

Acknowledgement

The work is supported by Special-purpose program of scientific researches of National Academy of Sciences of Ukraine "Smart sensor devices of new generation based on modern materials and technologies".

Bibliography

[Beavers, 2017, 1] Beavers I. Intelligence at the Edge Part 1: The Edge Node. 2017. [https://www.analog.com/en/technical-articles/intelligence-at-the-edge-part-1-the-edge-node.html].

[Beavers, 2017, 2] Beavers I. Intelligence at the Edge Part 2: Reduced Time to Insight. 2017. [https://www.analog.com/en/technical-articles/intelligence-at-the-edge-part-2-reduced-time-to-insight.html].

[Shkotova et al, 2004] Shkotova L.V., Soldatkin A.P., Dzyadevych S.V. Adaptation of amperometric enzyme biosensor for analysis of glucose in wines // The Ukrainian Biochemical Journal. 2004, volume 76, № 3. pp. 114–121. (in Ukrainian)

[Shkotova et al, 2005] Shkotova L.V., Slastya Ye.A., Zhylyakova T.A., Soldatkin O.P., Dzyadevych S.V. Amperometric biosensor for analysis of ethanol in wine and grape must during fermentation // The Ukrainian Biochemical Journal. 2005 volume 77, № 1. pp. 96–103.

[Palagin et al, 2017] Palagin O., Romanov V., Galelyuka I., Hrusha V., Voronenko O. Wireless Smart Biosensor for Sensor Networks in Ecological Monitoring. In: Proceeding of the 9th IEEE International conference on "Intelligent Data Acquisition and Advanced Computing Systems: Technology and Applications", IDAACS'2017. Bucharest, Romania. 2017, September 21–23. pp. 679–683.

Authors' Information

Volodymyr Romanov – *Head of department of V.M.Glushkov Institute of Cybernetics of National Academy of Sciences of Ukraine, Doctor of engineering sciences, professor; Prospect Akademika Glushkova 40, Kyiv, 03187, Ukraine;*

e-mail: *VRomanov@i.ua; website: http://www.dasd.com.ua*

Igor Galelyuka – *Leading research fellow of V.M.Glushkov Institute of Cybernetics of National Academy of Sciences of Ukraine; Candidate of engineering sciences; Prospect Akademika Glushkova 40, Kyiv, 03187, Ukraine;*

e-mail: *galelyuka@gmail.com; website: http://www.dasd.com.ua*

Oleksandr Voronenko – *Research fellow of V.M.Glushkov Institute of Cybernetics of National Academy of Sciences of Ukraine; Prospect Akademika Glushkova 40, Kyiv, 03187, Ukraine;*

e-mail: *alexander.voronenko@dci.kiev.ua;*

website: http://www.dasd.com.ua

Kovyrova Oleksandra – *Research fellow of V.M.Glushkov Institute of Cybernetics of National Academy of Sciences of Ukraine; Prospect Akademika Glushkova 40, Kyiv, 03187, Ukraine;*

e-mail: *kovyrova.oleksandra@gmail.com;*

website: http://www.dasd.com.ua

Dzyadevych Sergei – *Chief scientist of Institute of Molecular Biology and Genetics of National Academy of Sciences of Ukraine; Zabolotnogo Str., 150, Kyiv, 03143, Ukraine, website: http://www.imbg.org.ua/en/*

Shkotova Ludmila – *Senior scientist of Institute of Molecular Biology and Genetics of National Academy of Sciences of Ukraine; Zabolotnogo Str., 150, Kyiv, 03143, Ukraine, website: http://www.imbg.org.ua/en/*