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IoT based system for real-time monitoring the hydrogen-ion activity in water bodies

To cite this article: M S Yuzhakov *et al* 2021 *J. Phys.: Conf. Ser.* **1989** 012021

IoT based system for real-time monitoring the hydrogen-ion activity in water bodies

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Abstract. The paper presents design and principle of operation of a mobile combined pH meter. Sensor's network underlying the IoT system for monitoring water bodies hydrogen ions activity in real time was demonstrated. The measuring device was tested on liquids with different pH levels. The obtained measurement results were compared using a stationary pH meter OHAUS Starter 3100.

1. Introduction

Water is essential for human survival. Human life activity (drinking water, industrial, etc.) depends on its quality, as well as aquatic environment suitability for fish, algae and other living organisms [1, 2]. Therefore, water pollution continuous monitoring is an important environmental task. One of critical parameters for assessing water quality, along with temperature value, is the pH level **-** hydrogen ions activity in liquids [3]. The pH value is a mandatory parameter for monitoring environment state, indicates water suitability living organisms and indicates water biological compliance with norm [4]. This parameter determines acid-base balance level in range from 0 to 14. There are acidic (pH <7), neutral (pH = 7) and alkaline (pH> 7) environments. This necessitates automated technical measuring instruments use in vast water bodies areas throughout the year [5]. Energy efficient network data collection technologies, built on IoT principle [6], can help solve this problem. This will allow data to be collected around clock on water pollution indicators status, and end users will be able to access collected data through a web interface. Thus, the paper presents system implementation variant for hydrogen ions monitoring activity based on probes network for registering water pH. It is proposed to organize data transfer from probes to the Internet using LoRaWAN technology through an intermediate station connected via Wi-Fi.

2. Theory

2.1. Measuring principal pH water sensor

The pH sensor is a combination electrode (measuring and reference) in a glass tube with a blown ball at the end. The measuring electrode is made of tube form borosilicate glass with a thin-walled ball at the end, filled with a suspension of AgCl in HCl solution and immersed in a silver wire. The central glass layer is selective for H + ions. When measuring pH, this glass interacts with water using only H + ions due to the external helium layer, which is a barrier to others.

The reference electrode is the second important component, its task is to provide a measurement with a constant reference potential. The electrode contains a mercury-calomel paste in a saturated potassium chloride solution. The reference electrode body does not allow positive hydrogen ions to pass through. Potassium chloride is a conductor between the mercury-calomel half-cell and the solution in which it is measured (Figure 1).

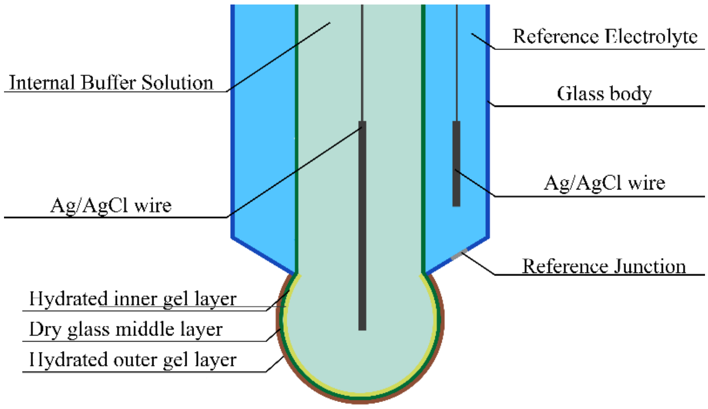

Figure 1. Combination pH electrode design.

Figure 2. pH meter "SKU SEN0161"

pH meter operation principle is based on a potential difference. When a pH meter is immersed in a solution, an electrical circuit is closed. The galvanic circuit consists of a silver chloride electrode and a reference electrode. Under measured potential difference action, electrons are transferred from silver chloride electrode to reference electrode and equivalent protons transfer from glass electrode inner part to test solution occurs. Considering H + ions concentration inside glass electrode does not change, EMF is proportional to hydrogen ions activity in the solution, i.e. pH.

To implement an IoT system for monitoring water bodies hydrogen ions activity in real time, a probe has been created to measure the pH level. The pH measurement will be performed by an analogue pH meter "SKU SEN0161 v.1.0" (Figure 2). This pH meter works in conjunction with other sensors suite that combine to form a water source climate data collection device-probe (Figure 3).

The control board is responsible for reading the potential difference between the measuring and reference electrodes, signal stabilization, signal amplification using operational amplifiers and filtering. When measured, resistance appears between the electrodes, which is proportional to solution conductivity.

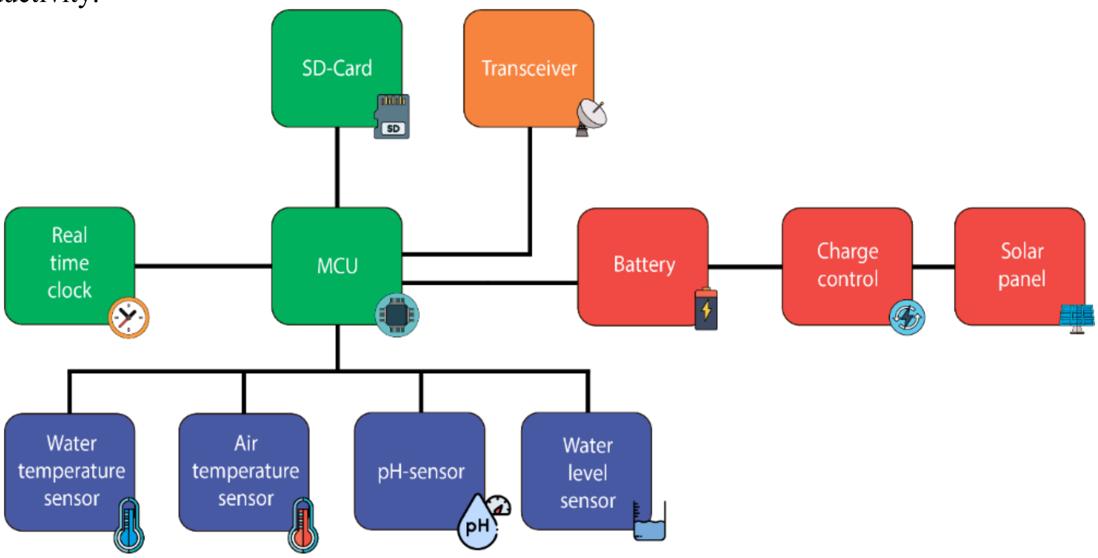

Figure 3. Probe block diagram.

2.1.1. Sensor's network

The probe structure can be divided into components groups. The first group consists of measuring sensors: air and soil temperature sensors (DS18B20); pH sensor (Article SEN0161 v.1.0); water depth sensor (ultrasonic rangefinder HC-SR04), which will determine pH meter immersion depth in liquid. The second group is responsible for processing and recording data: MCU ATmega328P; real time clock (DS3231) and memory card for recording measurement results. The third group includes the E19-868M20S transceiver based on the Semtech SX1276 chip for transmitting sensor's data to base station. Base station will transmit data to server and web interface. After which every user can view measurement results (Figure 4). The last group is responsible for powering and recharging the device: battery; battery charging module and solar panel for autonomous recharging.

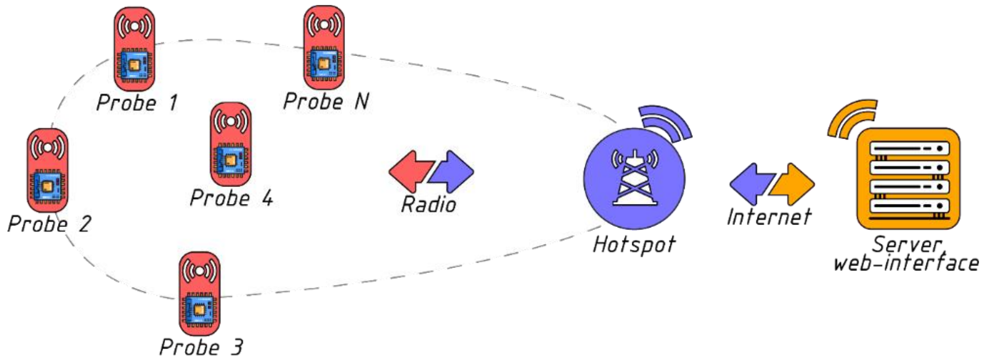

Figure 4. Sensor's network structure.

2.1.2. Network element interaction protocol

When base station is turned on, configuration is performed: initial connection to server, receiving configuration data from server, and setting up base station. After all manipulations, the base station is ready to work (Figure 5).

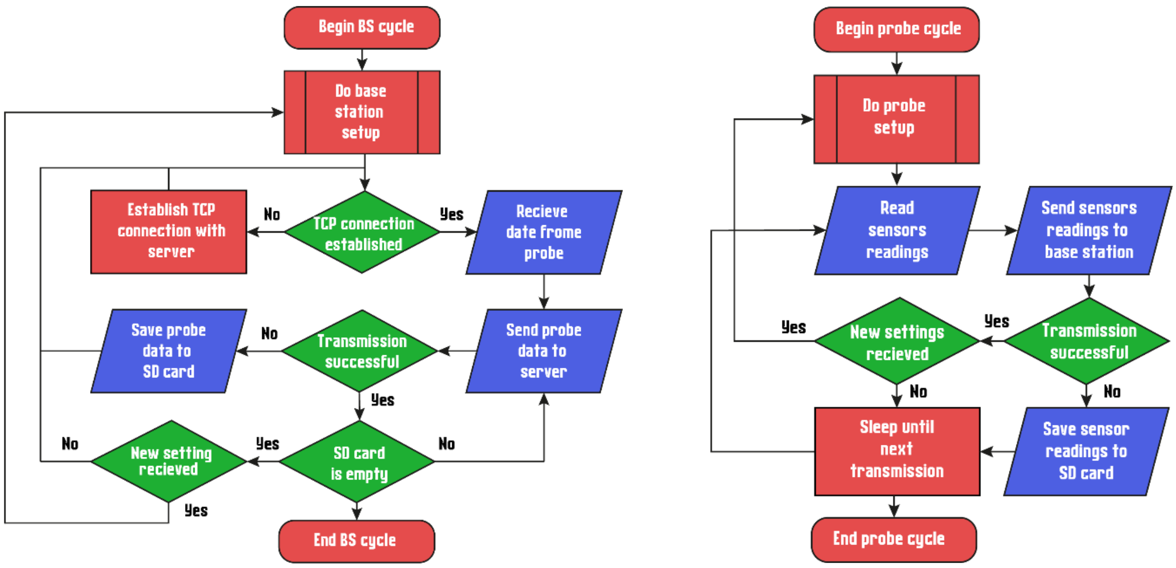

Figure 5. Base station to server (left) and probe to base station (right) interaction protocols.

Base station working cycle consists of check whether a TCP connection to server is established. If it is established, base station receives probes data and sends it to server. Otherwise, base station tries to establish a connection to the server.

After transmitting probes data to server, base station waits for data reception confirmation from server; if answer is negative, all data is written to memory card. If answer is yes, base station checks whether memory card is empty, if there is data on it, then it transmits to server. If there is no data on memory card, then configurations presence received from the server is checked and setting up is performed again, or the cycle is repeated without changing the settings.

When probe is turned on, automatic transmission power adjustment is started first. After, probe receives configuration data from base station, performs tuning and goes into operation mode.

After entering operating mode, probe periodically reads and transmits sensor readings. After transmission, probe waits for confirmation from the base station, if confirmation is received, probe checks if there is a new configuration for it. In new configuration absence, probe goes into sleep mode. In case when confirmation from base station is not received, probe writes data to memory card and goes into "sleep" mode.

2.1.3. Load testing TCP server and HTTP API
Nowadays TCP server is guaranteed processing a model load equivalent to connecting 75 base stations, each of which is interfaced with 60 probes, and each probe transmits once every 15 minutes. HTTP API testing was conducted using the k6 load testing tool. Simultaneous connection was simulated for 100 users. Every user updated probe reading on average once per minute. Server successfully coped with the load, maximum delay in responding to a request to server did not exceed 200 milliseconds.

3. Experimental work
To check measurement results reliability, a stationary pH meter Starter 3100 from OHAUS company was used, which has an accuracy high level and efficiency, it has a ±0.01 pH measurement error. Calibration is carried out at 3 points for maximum accuracy, has ability to automatically and manually determine establishing readings moment.

3.1 *Calibrating pH sensor (SKU SEN0161 v. 1.0) against reference liquids*
To calibrate developed measuring device, liquids with a given pH level were used: 4.01, 7.00, 10.01 at 25 ° C. They were obtained by diluting special buffer powders set in distilled water. Based on measurement solutions data with a given pH level, a calibration curve was constructed (Figure 6), its approximation by a linear equation $y = a + bx$ and correction factors were determined a=-7.17652 ± 0.13704, b = 7.89417 ± 0.07516, which were included in measuring system program code for accurate conversion of measured voltages into pH values.

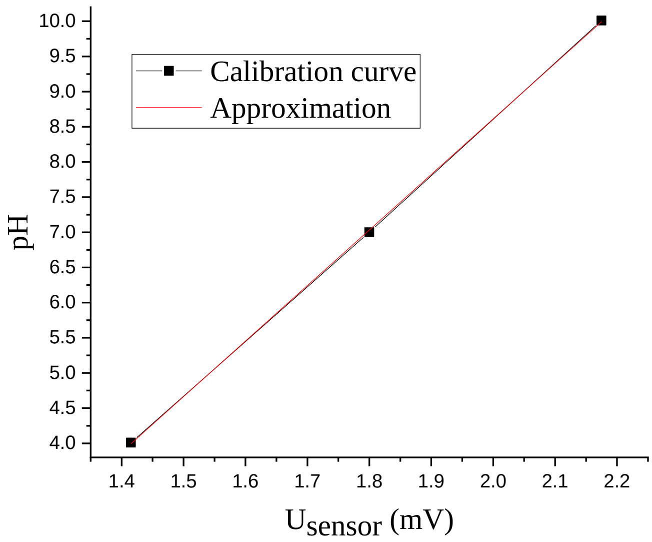

Figure 6. Calibration curve and correction factors.

3.2 *Water sources climate data collection probe measurement results comparison and OHAUS Starter 3100*

We checked the correctness of pH level measurements with a probe. Prepared buffer solutions and a liquid samples set measurements were carried out (Table 1). Measured values were compared with the values measured on an OHAUS Starter 3100 stationary pH meter (Figure 7).

Table 1. Buffer solutions and liquid sample kit.

Sample No	Fluid type	Additive type
1	Distilled water	Buffer solution, pH = 4.01
2	Distilled water	Buffer solution, pH = 7.00
3	Distilled water	Buffer solution, pH = 10.01
4	Artesian water brand "Lel"	Apple cider vinegar (6%) – 5 ml
5	Artesian water brand "Lel"	–
6	Artesian water brand "Lel"	Soda 5 g

"Lel" brand artesian water is used from wells No 7C, No 9C. Water intakes in the area with Krasnoyarsk Selivanikha territory. Total mineralization is from 0.10 to 0.50 (g/dm^3), hardness – from 1.0 to 4.5 ° H. Treatment method is ozonation.

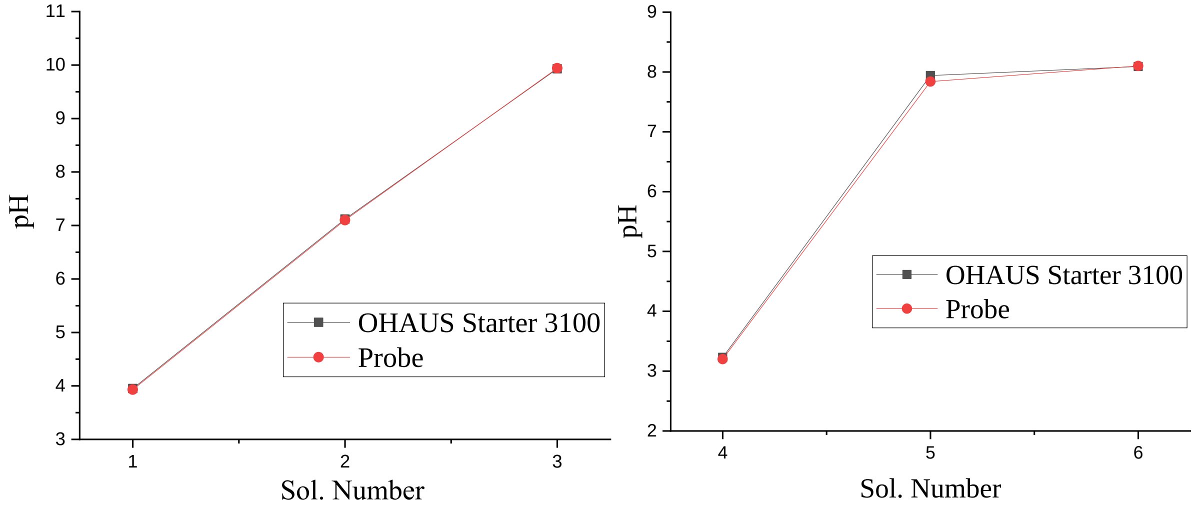

Figure 7. Buffer solutions and specially made liquids pH measurement.

Presented graphs and Table 1 show that measurements obtained by probe are similar to stationary pH meter OHAUS Starter 3100 readings. The largest difference in pH level is observed at the 5th measurement number (Lel brand artesian water), but such a fluctuation is acceptable, since pH sensor (SKU SEN0161 v.1.0) measurement error is ± 0.1 pH.

4. Conclusions

IoT system was developed for monitoring water bodies hydrogen ions activity in real time: probe for water bodies collecting and monitoring pH parameters based on the ATmega328P microcontroller was developed and tested; pH meter was calibrated on buffer solutions with given pH; measuring device testing was carried out on liquids with different pH levels; measurements on the stationary pH meter OHAUS Starter 3100 comparison were made.

Acknowledgment

The reported study was funded by the UMNIK program.

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