Water Drain Emergency System

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Need for healthy drinkable water is growing from day to day, but available resources are limited. Accelerated development of information communication technologies opens the path for evolving upgrade of existing systems for production, distribution and consuming clear water on different levels. Internet of Things (IoT) technology is not suitable for real-time control and safety critical applications. Still, it makes possible that using public Internet networks we increase reliability of existing systems or develop application that are tolerant to time delay.

In this article we present a water drain emergency system which is using cheap network embedded system. On first level, it stops unwanted rise of water level in manholes of water network. On second level sends SMS alarm using GSM network. Data of alarm is keeping in database for further analyze.

Keywords: **water level control, manhole, alarm service, Internet of Things, Arduino**

1. INTRODUCTION

Reserve of drinkable water in world and in our country are less by the day. It is expected that by 2025. year, about 2/3 of world's population feels serious missing of water. Water is becoming increasingly important strategic resource. Manufacturing and distributing sufficient amounts of water is becoming increasing technical challenge. Using modern information communication technologies in monitoring, management and maintenance may even a bit contribute in solving problems in this area.

Remarkable price drop for microprocessors and other electronic equipment opens possibility for wider application of network embedded systems (NESs) in different engineers disciplines and also in area of production and distribution of water. Different types of "smart" sensors and actuators are used more and more. They are containing microprocessor with additional processor power and network interfaces for remote communication. In addition to increased local possibilities (filtering, self-tuning, fault diagnostic, linearization, control) communication in real-time enables synchronization and optimal work on system level. Idea is to upgrade existing systems with not expensive NESs and with their synenergy acquire new value. With that, system for distribution of water can easier implement in global system for providing services as distributing electric power, gas, heat, Internet, etc.

Embedded systems (ES) began to use during 70's years of past century. But for users, most visible presence of computers for general purpose are ES – which are having most wider use. For example, it is expected that Electricity Smart Grid Networks become 100 to 1000 times more ES than that is a case on whole Internet [1]. In the beginning, ES were watched only as small general-purpose computers with limited resources. Design of these systems are based to implementation some of optimization techniques. Recently, engineers realized that main challenge in design this kind of systems arises in their interaction with physical processes and not from limited resources [2]. Interaction between ES and real word is changing continuously. It can be viewed from different levels. Depending of technology which is used in mutual communication, there are different names: Cyber-Physical System (CPSs), the Internet of Things (IoT), Industry 4.0, Machine-to-Machine (M2M), the Internet of Everything, etc.

It is often to in realization of one system, different technology are intertwined. For example, in production of pure water, we can use SCADA system for remote reading of consuming of water with use of IoT technology, GSM in maintenance, XML for exchanging of data, etc. Independent from technology which is used, NESs is backbone of networks. During the process of design NESs based system, it should be considered joint dynamics of physical processes, hardware, software and networks [2]. Happenings in real world have continuous character, while in virtual world changes are happening in discrete moments or they are event driven. With software for general purpose software it is important that time for execution of task be as shorter as possible, but it is not critical for functioning of system. With NESs based systems time could be crucial for acceptable functioning of system. "In the physical world, as opposed to the cyber world, the passage of time is inexorable" [2]. Besides, in real world many phenomena are happening parallel, with different speed. On the other hand, software processes in basic have sequential character [3]. Task is up to designer for using sequential semantics to solve parallel problems from the real world.

CPS technology is engaged in integration NESs system and physical processes on low-level layer. During designing question like software interrupts, memory architectures, assembly-level programming, device drivers are considered. They enables hard connections between two world and demand special access during design [2]. With IoT approach we are using Web technology for

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communication. IoT is not suitable for real-time control and safety-critical applications, but it is simple and cheap for implementation. It is based on standard interfaces, open-source software and public communication networks. It is enabled for evolving development of system according to economical possibilities.

Many process in production and distributing of water are not time critical and tolerant to time delays. Those processes contains potential for further spread of IoT technology. In this paper, we will give example of water drain emergency system, who has a goal to prevent rise of water level in water manhole, above allowed value. With this kind of system, we are protecting equipment of damage and preventing unwanted water lost in network. It is used two levels of protection. On first level we have local feedback control loop which include submersible pumps for extracting water from manhole. On second level, if water level in manhole still rise, with public mobile network, SMS is sending to center for monitoring SMS. SMS server is writing arriving SMS to data base and send alarm to operator on duty. With help of saved data in database, we could execute additional reliable fault diagnosis and take various preventive measures.

2. SYSTEM DESCRIPTION

To secure sufficient water flow to all consumers/costumers, geographic distributive pumping stations are used in water network. Their assignment is to compensate energy losses which are show in some part of water pipelines. Pumps with measuring equipment and pumping equipment are placed into manholes which secure ambient conditions for their work. At a Figure 1, we have shown interior of manhole from water network of Kraljevo city.

Figure 1: Interior of one water network manhole from city of Kraljevo

Because of possibility of breaking pipes, entering outside atmospheric water or some other reason, there is possibility of rising water level above acceptable value. With this scenario, expensive equipment will be damaged (electric motors with invertors) and that will lead to disruption in supply of water. In example of breaking pipe (Ø100) water will come to critical level in few minutes. Unfortunately, designer overlooked this possibility, so this system is needed to upgrade with system for protection of flood.

Water drain emergency (WDE) system which we are presenting in this paper uses NES with two levels of protection. Both levels of protection are based on Arduino microcontroller (Figure 2).

Figure 2: Single-board microcontroller Arduino

Arduino is a open program of several hardware and software companies surrounded around production of single-board microcontrollers and equipment for embedded system which are distributed as open source hardware and software (*https://www.arduino.cc/*). Products are licensed under GNU Lesser General Public License (LGPL) or GNU General Public License (GPL) which permitting the manufacture of Arduino boards and software distribution by anyone. Basic idea of project is building simple, low-cost development platform for embedded systems. First platform consisted of printed circuit board with ATmega168 microcontroller. We are using IDE (integrated development environment) for programming, based on Processing language project (*https://processing.org/*). Programs are written on one of C language dialects. Thanks to wealthy library of built-in functions, programming is simplified for users without a background in electronics and programming. Big popularity Arduino owe to different expansions boards (shields) which extends functionality of main board.

3. WDE - FIRST LEVEL

On first level for protection of flood we are using local feedback control loop with block diagram shown on Figure 3.

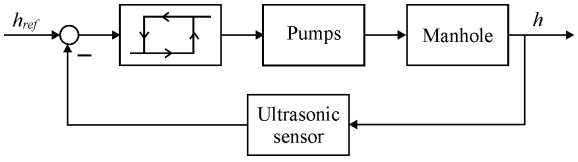


Figure 3: Local feedback control loop

For measuring water level in manhole, we are using ultrasonic module which is directly connected with Arduino board digital pins. Signal time chart for measuring is shown on Figure 4.

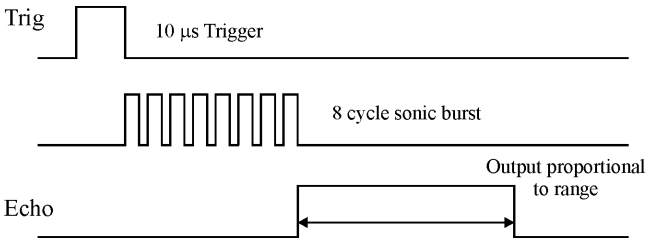


Figure 4: Ultrasonic sensor time chart

Arduino recipient is activated by setting on *High* digital port *Trig* in time span of 10µs. After that, transmitter sends 8 pulses to obstacle by speed of sound, and returns to recipient. Echo port is going to state *High* by the time needed for ultrasound to go to obstacle and returns to sensor. Picture of ultrasonic module and mentioned pins are shown on Figure 5.

Figure 5: Ultrasonic sensor with pins

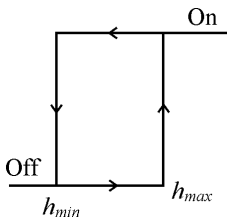
Example of program code for reading water level is shown on Figure 6.

```
// Sets the trigPort on HIGH state for 10 micro seconds
digitalWrite(trigPort, HIGH);
delayMicroseconds(10);
digitalWrite(trigPort, LOW);
// Reads the echoPort, returns the sound wave travel time in
//microseconds
T1 = pulseIn(echoPort, HIGH);
// Calculating the distance
WaterLevel= T1*0.034/2;
```

Figure 6: Reading water level by ultrasonic sensor

For turning on and off pumps, relay regulator is used with hysteresis, showed on Figure 7a. Size of hysteresis is adjusted by the noise gathered during measuring of water level. Software realization for Arduino is showed on Figure 7b.

Other than turning on drainage pump and turning off pump for supply when water level raise over acceptable value (*WaterLevel>LevelHigh*) microcontroller sends SMS text message to Monitoring Centre. Goal is to turn attention of operator (dispatcher) to the point where he see thata system is gone into emergency regime. More on using SMS text messages will be in next section.



a) Characteristic

```
if (WaterLevel>LevelHigh){
   digitalWrite(relayPort, HIGH);
   sms.beginSMS(remoteNumber);
   sms.print("Alarm1 - Pump On");
   sms.endSMS();
    }
else if (WaterLevel<LevelLow){
   digitalWrite(relayPort, LOW);
   }
```

b) Implementation by Arduino

Figure 7: Relay with hysteresis

Digital output of Arduino (*relayPort*) is connected to solid-state relays with normal open and normal closed contacts.

For securing independent work of microcontroller on longer time interval, we are using watchdog timer (WT). If it comes to failure of some kind in executing software, WT resets processor so microcontroller will continue with work (Figure 8).

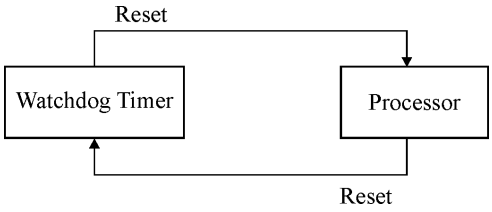


Figure 8: Watchdog mechanism

Essence is that processor must have periodical call to WT, so he will confirm work state. If after certain time WT don't have confirmation, WT assumes that software in processor is for some reason blocked, so WT restart processor. System starts startup procedure form the beginning. WT and processor are in same chip at Arduino microcontroller. Thanks to built-in library function WT can be implemented very easily. In Figure 9, it is shown procedure for processing WT mechanism by Arduino.

Inside of *setup()* function of main program, it is needed to make set up of WT. For example, it is needed to set time which WT counts down till reset of processor (*Treset*). By each parse through main loop, it is needed to answer to call of built-in function of WT – *wdt_reset()*. If time between two calls of this function is greater than (*Treset*) it is assumed that there is mistake in process, so it restarts processor and calls bootloader again.

In main program we can write and procedure that can act upon WT interrupt. In previous example, function

ISR(WDT_vect) can be used for sending alarm that will signal the creation of reset signal.

```
void setup() {
      //...
      watchdogSetup();
}
void loop() {
      //...
      wdt_reset();
      //...
}
ISR(WDT_vect) {  // Watchdog timer interrupt.
      // Send alarm
}
```

Figure 9: Watchdog mechanism for Arduino

4. WDE - SECOND LEVEL

On first layer of protection, we are trying to prevent raising level of unwanted water with local feedback control loop. However, if drainage pump don’t have enough capacity or stops with work, amount of water will still raising. When water level goes over certain maximum permitted value, it will generate Alarm. Alarm signal on second level is formed by Arduino, with help of independent sensor of level (“red zone” alarm). Second level sensor is used to upgrade reliability of the system. Alarm is sent to center for monitoring (Figure 10).

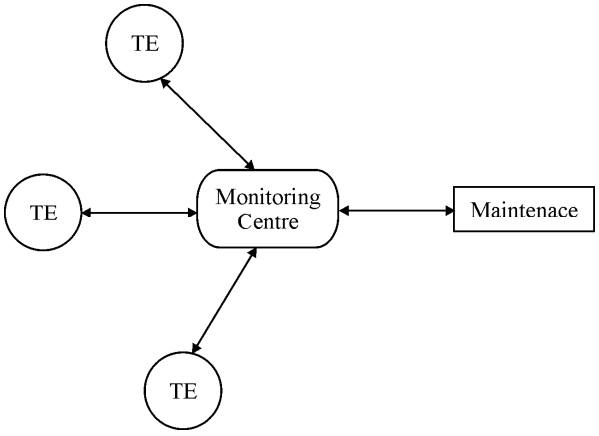


Figure 10: WDE Second level schematic View

As a terminal equipment (TE) we are using Arduino with GSM Shield (Figure 11). Arduino with GSM Shield (GSMS) is communicating over serial port using AT commands. From angle of Arduino, GSM shield is acting as modem, and from monitoring center angle is acting as mobile phone. GSMS enables to make phone calls, send and receive SMS messages and connect over Internet (over GPRS).

In this work, for communicating we are using SMS service with build-in GSM Library. Program code which sends SMS message about Alarms is shown on Figure 12 (*https://www.arduino.cc/*).

Figure 11: Arduino GSM Shield

```
// Include the GSM library
#include <GSM.h>

#define PinNum="..."  // Number of SMS Server"
#define ServerNum="..."  // Number of SMS Server"
void setup() {
      //...
      // Start GSM shield
       while (notConnected) {
            if (gsmAccess.begin(PinNum) == GSM_READY)
          {
                notConnected = false;
            } else {
              //...
            }
       }
}
void loop() {
      //...
      // send the message
      if (RedSensor) {
            sms.beginSMS(ServerNum);
            sms.print("Alarm 2 - Red Sensor On");
            sms.endSMS();
      }
      //...
}
```

Figure 12: Sending alarm SMS

After we import GSM library we insert PIN code of SIM card and number of SMS server. In *setup()* procedure Arduino makes connection with modem. In main loop, we constantly check state of *Red* sensor. If water level have raised to maximum value, it sends SMS text message to SMS server.

As before, SMS alarm could be send and by interrupt procedure of WT, which will be activated on the moment when signal comes from *Red* sensor.

As we could see from Figure 10, Monitoring Centre gets information’s from terminal equipment located in different manholes. With that we can get reliable information of happening, because happenings from one manhole will reflect on other nearby. From internal database, by time table, SMS text sends to on call worker about need of his intervention on certain manhole.

All SMS messages are kept in database. In this case we are getting complete picture of happening in certain manholes in longer time period. With help of certain

software, we could make analysis and implement certain preventive measures.

In order to test system, we built experimental system (Figure13). Goal was to test functionality of system in laboratory condition before implement on real system.

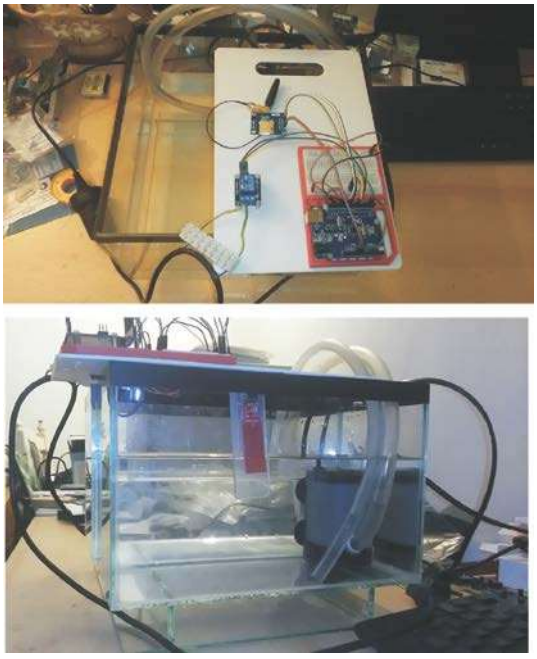


Figure 13: Experimental test rig

5. CONCLUSION

Reduced price of hardware and software open’s door for wide application of NESs systems and certain Internet technologies on places where until now was unthinkable. Thanks to standard interfaces, it isn’t obligatory large knowledge on software architecture. Even thou those technologies are still not in everyday use for strong real-time control and safety critical applications, there is still enough place to find their own spot. Managing production and distributing of water can reduce water loss, optimize spending, and enlarge energetic efficiency, synchronies production with changeable demands and so on. We used pretty low cost equipment and public (GSM) service to prevent damage that can be even larger. Application of this technology is at a beginning. There is still a large number of questions that must be solve , like reliability of this kind of systems.

RFERENCES

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