Smart Water Management System using the Microcontroller ZR16S08 as IoT Solution

Michel R. Machado, Tiago Ribas Júnior, Michele R. Silva and João B. Martins

***Abstract*—This paper presents a smart water management system using the microcontroller ZR16S08 as IoT solution, for water distribution support and losses prevention. The system operates through the smart monitoring of the water flow in pipes of the water distribution network, aiming to ensure quality of the water supply, knowing that water losses characterize one of the great problems in the world, as pipe holes may be open doors to water contaminants. As an alternative to circumvent this issue, a series of experiments were taken to create a network of sensors capable of monitoring water pipes in real time. Adopting criteria such as low consumption and low cost, the use the ZR16S08 microcontroller in the design of wireless sensor nodes that will be coupled in the water pipes was adopted. Complementing the system, a central processing unit, composed of a Raspberry Pi microcomputer, manages the traffic of the information collected by the sensor nodes and routes it to a web server. All data addressed by the central unit are available on-line by means of a supervisory platform. Considering the size of the sensor nodes, their power consumption, and regulatory issues, a link between the sensor nodes, operating at a frequency of 433 MHz, was defined. Preliminary results show the effectiveness of the proposed architecture for sensor nodes, allowing application for the monitoring of water and controlling losses.**

***Index Terms*—Water losses control, Water management using IoT concepts, Wireless sensor nodes, ZR16S08 microcontroller**

I. Introduction

THE water supply management in the world has always brought challenges. Water is an essential resource to human survival; however, for an adequate water distribution, some important factors must be considered to guarantee the supplying. Among them, the losses in pipes characterize a point of greater fragility in the whole process of water distribution.

According to the International Benchmarking Network for Water and Sanitation Services - IBNET, and based on studies conducted in developing countries, 35% of water is lost on average. Considering the causes for water losses, the main ones are technical failures in the distribution process and leaks caused by regular use everyday. In addition, there are some tradeoffs regarding water loss control. An important one is illustrated in Fig. 1, that shows the associated cost to decrease water losses in relation to the cost of potable water supply. As it is not practical to fully remove all water leaks, often a leaking level is accepted for a given water production so to keep the total water cost at a minimal level.

Underdeveloped countries have in general a much worse situation when compared to developed countries. There are no reliable statistics in these countries and most water supply industries lack water pipeline monitoring technology, making it even harder to predict the cost to detect and repair water losses.

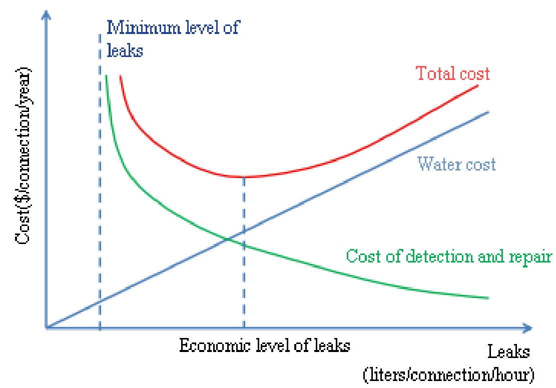


Fig. 1. Total cost due to water losses. [1]

Under this situation, the use of smart solutions, sensor networks and IoT solutions may represent a great alternative for the monitoring of the water distribution network. Perhaps not a coincidence, this type of solution has already been adopted in several other services.

II. IoT Application

This work aims to develop an IoT (Internet of Things) system for water management, especially in water losses occurring in city pipelines. For this purpose, sensors, RF processing and communication modules, communication software between sensor nodes thus forming a wireless sensor network (WSN) and preferably open source platforms for cloud access will be used. Compared to other technical solutions, this work intends to move significantly towards a more flexible solution using dedicated integrated devices for the multi-parameter acquisition of data in the water conduits to map areas with potential for losses, failures due to misuse of plumbing and other relevant information. The ZR16S08 microcontroller will be used in this system.

This system also aims to stimulate the rational water use and while providing means to improve the Quality of Service (QoS) regarding water services, contributing to consumer satisfaction. Figure 2 shows the architecture of the system to be developed.

M. R. Machado, T. Ribas Júnior and M. R. Silva are students of Electrical Engineering the Federal University of Santa Maria, Rio Grande do Sul, Brazil (emails: michel.r.machado@gmail.com, tiago.trj@gmail.com, mihrdgs@gmail.com).

J. B. S Martins is full professor the Department of Electronics and Computer Science (DELC), Federal University of Santa Maria, Rio Grande do Sul, Brazil (e-mail: batista@inf.ufsm.br).

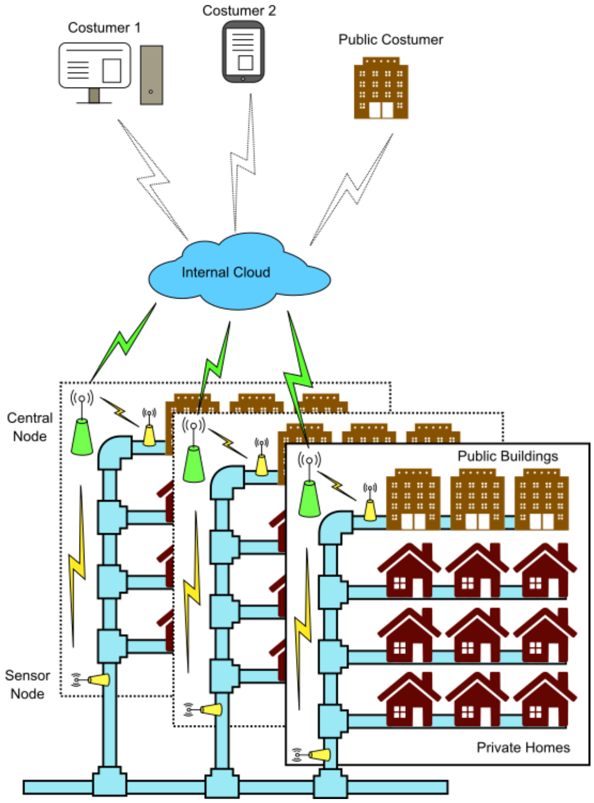


Fig. 2. Structure for the IoT system under development.

III. System Description

The system as presented allows the water monitoring in pipes through a network of sensors where each one is connected to a microcontroller capable of interpreting the measurements of the sensor, storing this data and sending it further wirelessly, thus defining several sensor nodes of a network where the management is performed by a central system consisting of a more powerful microcontroller capable of establishing communication with the internet and send data to a cloud storage.

A. Water Flow Sensor

The measurement of water flow can be done invasively by using a water flow sensors model YF-S201. This sensor consists of a plastic body, a rotor with a turbine made of magnetic blades and a Hall effects sensor. If you have a water flow in the rotor, the turbine blades will rotate and, each time one passes through the Hall effects sensor, allocated at a fixed point above the rotor, there is an interaction between the magnetic fields. In every interaction, the Hall effects sensor generates a pulse, so the more water flows through the rotor, the greater the frequency of pulses. Therefore, the relation between those is made, resulting in a value of flow water in liters per minute.

B. Network Topology and Modulation

The sensor network designed utilizes a single hop star type topology, as shown in Figure 3. This type of topology is characterized by sending data unidirectionally to a central unit, which in addition to requesting information, also acts as an intermediary for communication with the cloud.

The advantages of using this model of communication structure are the low consumption of the sensor nodes when compared to a multi hop topology [2], since the same ones, after sending data, go into "Standby" mode, deactivating most of their logical functions.

It is intended that this system operate at a high frequency and regulated long range, but for reasons of compatibility with the microcontroller, the initial tests used communication modules of 433 Mhz with maximum transmission rate of 4 Kb/s. These types of modules, although not used in long-range networks, facilitate the laboratory tests, allowing exploring other factors, such as processing and consumption of the microcontroller.

The communication between the sensor nodes and the gateway is done through an On-off Keying (OOK) modulation. Setting the microcontroller to an IDLE state during the "zero" logic transmission, in fact, in the logic zero state there is no transmission, conserving battery power.

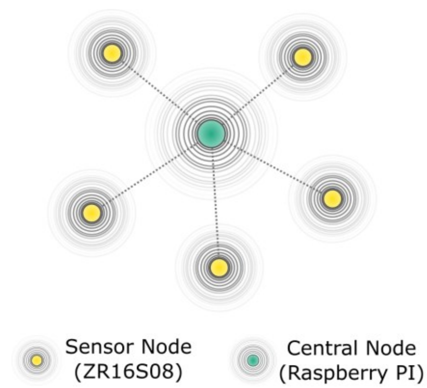


Fig. 3. Star-shaped network topology

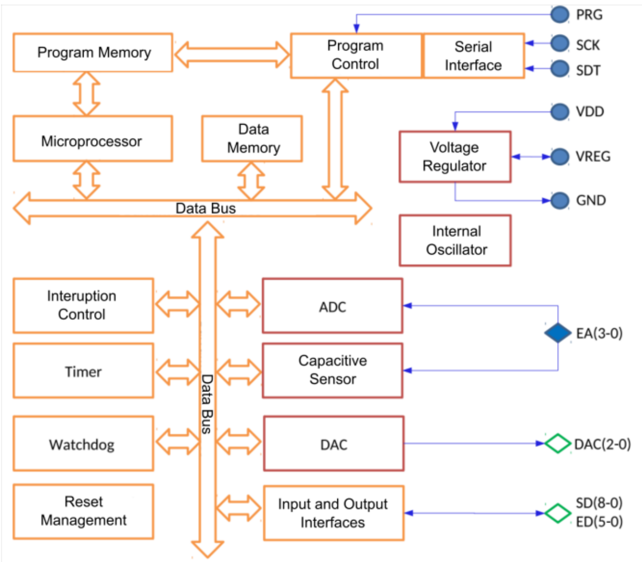
When in operation mode, if a new measurement is requested by the central unit, all values collected by the ADC microcontroller are encoded into 8-bit strings by setting different high and low pulse times.

The implemented modulation uses a period of 50 milliseconds to represent each bit. In the transmission where the bit "1" is represented by a time of HIGH equal to a time of LOW, in this case 25 milliseconds, whereas the value 0 is represented by a short time of HIGH of 10 milliseconds and a longer time of LOW of 40 milliseconds. Every 8-bit string of the information has a 50 milliseconds interval between another, so that the central unit by using a timeout function can make the proper comparisons and processing of the data.

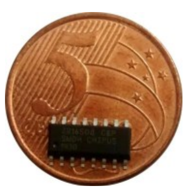
The choice of a period of 50 milliseconds for each pulse was made based on the lowest frequency that was able to be generate an output signal wave without noise with the used RF modules.

C. Sensor Node

The microcontroller used for the sensor nodes is the ZR16S08, a Brazilian microcontroller developed at the Santa Maria Design House (SMDH) and Chipus Microelectronic S.A, shown in Figure 4 (a) and (b). This chip was recognized by the Ministry of Science and Technology (MCTIC) through Ordinance 939, as an electronic component developed in Brazil. A low budget 8 bits microcontroller that emphasizes on analog and digital integration offering a great cost to performance ratio. For this project, 10-bit ADC, 256x8 SRAM memory and 16-bit timer are intensively used for a reliable interpretation of the measurement made by the sensor, storage of the data converted and creation of a communication protocol between node and the central. The ZR16S08 microcontroller internally has an internal voltage regulator, with variable input from 5 to 30V and output to 3.3V. This feature differentiates the ZR16S08 from other microcontrollers on the market.



(a)



(b)

Fig. 4. ZR16S08 Microcontroller: (a) Microcontroller Architecture (b) Pilot Lote – Package SOIC16

D. Central Node

For the central, a Raspberry PI microcomputer is used to request and receive the data stored in the ZR16S08 using radiofrequency communication. The request is made by broadcasting the desired node ID then each node reads the ID and checks if its own ID matches the requested by the central. If the requested node is ready to send it will verify and match the requested ID and then send the desired information. If the node is not ready to send after a specific time, the central will stop requesting the specific node.

After receiving data, the central will analyze this data and then look for common value so it can process the data and send it to a cloud storage where it can be visualized and manipulated using an interface from any computer with internet connection.

E. Cloud Storage

The concept of cloud is the main point in an IoT system. This type of application has the characteristic of access from any point and be stored in different servers, which guarantees the integrity of the information to be manipulated. From the cloud, system's users should be able to access the data and manipulate using a website or another desired interface. Another main part is that the cloud storage may be designed for public or private access, depending on the type of data collected.

In this application, the Google Drive platform was used due to its facility of access and popularity that makes easier to find material about how to use it and for being a free service that can be used for tests.

Combining this platform with a script designed to manipulate the data sent by the central node to the cloud allowed the storage and visualization of the data acquired in a way that the user can easily notice any leakage problem on the pipes.

IV. Measurement and Communication Tests

In order to validate the water management system and its IoT architecture, a prototype comprising most of the system hierarchy layers was implemented, from the very bottom 1.5m-long polyvinyl chloride (PVC) pipe with attached to the highest level of the system, characterized by cloud storage and management.

The water measurements were performed using the premises of a fluid-mechanics laboratory where two water flow sensors were attached to the pipe, one meter apart from each other, allowing thus 2-point water flow measurements, as shown in Figure 5. Both sensors were running the same water flow measurement algorithm, implemented in the ZR16S08 microcontroller.

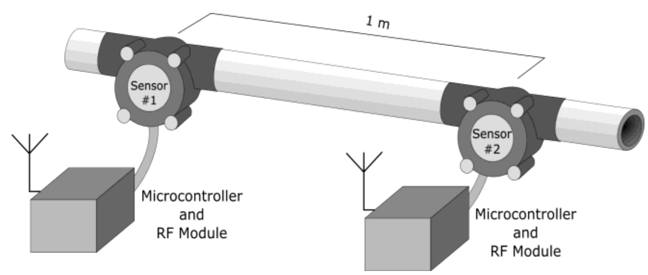


Fig. 5. Water flow measurement system

For comparison purposes, each sensor was connected to an Arduino UNO board, allowing visualizing the direct measured data on the node through the Integrated Development Environment (IDE) Serial Monitor of the board and comparing it with the data received by the supervisory platform. The choice of the Arduino board in conjunction with its IDE was made as it has an 8-bit Atmega 328 microcontroller architecture, similar to the ZR16S08. This allowed the analysis of the real behavior of the sensors in the water pipes improving the monitoring of the water flow.

Figure 6, generated online by Google Drive, shows water flow measurements in the presence of water leaking in between the two sensors, sustained through a pipe hole, introduced at t=17s when the water flow measurement difference indicates a leaking issue, that eventually may trigger an alarm given water leakage thresholds levels.

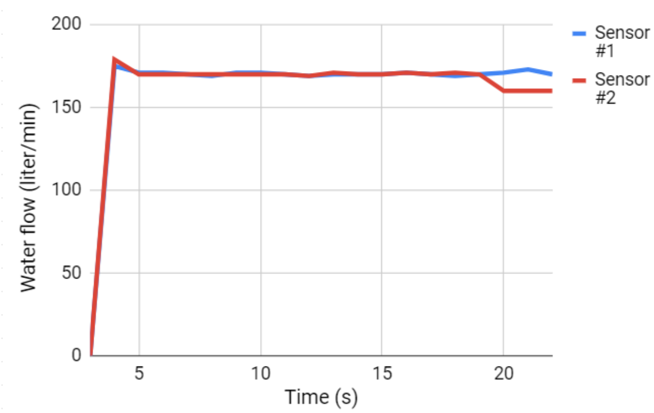


Fig. 6. Comparison between two flow sensors

While analyzing the data transmission between sensor nodes and central node, an experiment was made attaching a potentiometer to the input of the sensor node ADC so different known values of voltage could be applied, measured and transmitted to the cloud allowing the comparison between the received data by the central node and the original measure made by the sensor node ADC. Fig. 7 shows the first 3 bytes received by the central node when adjusting the potentiometer, so the voltage applied to the sensor node would be 1.000V. It's important to mention that this data is extracted from the Raspberry PI thus including a post processing implemented in the central node that optimizes and filter the data received. The first 8-bit string received by the central, when reversed represents the sensor node ID that was requested by the central, being in this case the binary 00101010. While the other 8-bit strings when reversed are the measurements made by the sensor, being in this case 01001110 that must be complemented with two zeroes to match the 10bit ADC measurement. Therefore, 0100111000 would be the closest value acquired by the ADC, which represents the decimal number 312 that can be read as 1.006V when using the 3.3V reference of the sensor node ADC.

With this values its noticeable that the difference between the data acquired by the sensor node and the data sent by the central node to the cloud has a difference of approximately 0.59% which has almost none impact in the implemented system.

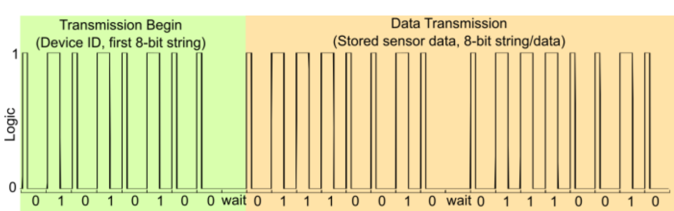


Fig. 7. Data received by the central node from the sensor node.

V. Conclusions

In this paper, a complete IoT solution for water management was presented including the measurement system and data communication between sensor nodes and central node. Preliminary results have shown a fully operational prototype system capable of measuring the water flow, comparing the data and reproduce it with a minimal error.

The experiments performed showed results with discrete and reliable values, which allow measurements of other parameters besides the water flow.

The use of the microcontroller ZR16S08 in this application was a great technological advance, because it is an integrated circuit with 100% Brazilian design. This means a paradigm shift.

Research and tests in progress are focused on minimizing energy consumption and optimizing communication, mainly operating on a better frequency channel, with a higher rate of data transmission, thus increasing network reliability and distance between the sensor nodes.

VI. Acknowledgment

The authors thank the Brazilian National Council of Technological and Scientific Development (CNPq), Research Support Foundation of the State of Rio Grande do Sul (FAPERGS/RS) and PRONEX for their financial support. Thanks also to the direction and staff of the Microcontroller Group (gMicro), of the Federal University of Santa Maria, for all support and incentive.

VII. References

[1] ABES - ASSOCIAÇÃO BRASILEIRA DE ENGENHARIA SANITÁRIA E AMBIENTAL. Perdas em Sistemas de Abastecimento de Água: Diagnóstico, Potencial de Ganhos com sua Redução e Propostas de Medidas para o Efetivo Combate, 2013

[2] M. Neugebauer, J. Ploennigs and K. Kabitzsch, "Evaluation of Energy Costs for Single Hop vs. Multi Hop with Respect to Topology Parameters," 2006 IEEE International Workshop on Factory Communication Systems, Torino, Italy, 2006, pp. 175-182. doi: 10.1109/WFCS.2006.1704148 Avaible: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=1704148&isnumber=35963.

[3] PFISTER, C. Getting Started with the Internet of Things: Connecting Sensors and Microcontrollers to the Cloud. Maker Media, Inc, 2011.

[4] BASAGNI, S.; CHLAMTAC, I.; FARAGO, A. A generalized clustering algorithm for peer-to-peer networks. 1997.

[5] BULUSU, N.; HEIDEMANN, J.; ESTRIN, D. Gps-less low cost outdoor localization for very small devices. IEEE Personal Communications Magazine, 2000.

[6] CHEN, H.; SEZAKI, K.; DENG, P.; SO, H. C. An improved dv-hop localization algorithm for wireless sensor networks. 3rd IEEE Conference on Industrial Electronics and Applications - ICIEA 2008, p. 1557–1561, 2008.

[7] CHUAN, X. Research on improved dv-hop localization algorithm based on weighted least square method. 2008 IEEE International Symposium on Knowledge Acquisition and Modeling Workshop - KAM, p. 773–776, 2008.

[8] CAPKUN, C.; HAMDI, M.; HUBAUX, J.-P. Gps-free positioning in mobile ad-hoc networks. 34th Hawaii International Conference on System Sciences, 2001.

[9] CHATTERJEE,M.; DAS, S.; TURGUT, D. An on-demand weighted clustering algorithm (WCA) for ad hoc networks. In: IEEE GLOBECOM, 2000. Proceedings. . [S.l.: s.n.], 2000.

[10] DIL, B.; DULMAN, S.; HAVINGA, P. Range-based localization in mobile sensor networks. Third European Workshop on Wireless Sensor Networks, Lecture Notes in Computer Science, n. 3868, p. 164–179, 2006.

[11] GERLA, M.; TSAI, J. Multicluster, mobile, multimedia radio network. Journal ofWireless Networks, [S.l.], v.1, n.3, p.255–265, 1995.

[12] LI, T.; EKPENYONG, A.; HUANG, Y.-F. A location system using asynchronous distributed sensors. Twenty-third AnnualJoint Conference of the IEEE Computer and Communications Societies INFOCOM 2004, v. 1, p. 628, 2004.