A Local Water Control Architecture based on Internet of Things to Water Supply Crisis

Sérgio F. T. de O. Mendonça, João F. Silva Júnior, Fábio N. Bonifácio, Fernanda M. R. de Alencar
Department of Electronics and Systems
Federal University of Pernambuco
Recife, Brazil
{sergio.mendonca, joao.fsilva2, fabio.bonifacio, fmra}@ufpe.br

***Abstract*—Water is one of the most valuable assets for humanity, it represents life, but its misuse, misapplication and inappropriate distribution can result in considerable losses, escalating to major problems. The objective of this study is to present a solution based on the Internet of Things, for domestic monitoring and control of water distribution, to prevent waste. We adopted an IoT-Ontology approach to ensure semantic (solid representations) between entities and other devices. The results presented in this study have been achieved by initially considering a low cost and low power consumption device. Further implementations of the solution presented will consider improvements of the experimental testing for end users and device development with government funding agencies.**

Keywords—Local Water Control; Embedded Systems; Internet of Things; WLC.

I. INTRODUCTION

Water is the most abundant natural resource on the planet and is present in the daily lives of everyone [1]. In recent years, Brazil started to notice signs of what may be the greatest water crisis in its history. The fundamental resource for the human being survival faces a major supply crisis [2]. The Brazilian water loss average is 40%, between real and apparent losses, its treatment and availability to the public [3].

Water consumptions has tripled worldwide since 1950. Thus, the community has several planning and control initiatives to minimize waste and mismanagement of water resources [2], [3]. The current usual control and individual metering of domestic water consumption presents numerous problems and demands more effective actions: *i)* manage the water applicability; *ii)* minimize water waste: misuse (washing sidewalks, vehicles, etc.); general leaks in distribution pipes (apparent and non-apparent).

This paper proposes a design of a network composed by smart devices capable of monitoring in real-time the domestic water usage or waste. We have adopted the IoT-ontology standards to maintain the integrity of layers and other devices in the Internet of Things approach. A water flow controller, a communication device in the IEEE standard XBee and Arduino (and their libraries) have been used for the proposed design.

This study is structured as follows: Section II discusses related work. Section III describes the Internet of Things/Embedded Systems target architecture. Section IV describes the Local Water Control Architecture proposed. Finally, Section V presents concluding remarks and plans.

II. RELATED WORK

Despite the growing need for better strategies and management of water resources, few studies have addressed the implementation of such modules so far. In [4] the authors have very similar strategies to the previous work, giving more emphasis to the ZigBee architecture and monitoring of power consumption, and how to perform the meter reading in real time, avoiding human labor and consequently errors. In [5] the authors proposed monitoring the water pressure in the distribution network pipes, analyze the operation of the devices and ZigBee network and how they conducted the monitoring via pressure sensors. They conclude with a comparison of the power consumption of various modes transmission of data water pressure in the distribution-piping network and showing the time variation of water pressure. In [4] the authors presents an equipment perception layer, information transmission layer and data application layer. In the equipment perception layer, a network of sensors to monitor water information is constructed. In the information transmission layer, real-time information transmission is achieved. In the data application layer, water information is stored, managed, applied and shared on internet by users. The application shows that our system can provide real time and reliable water resource information for water resource management. These works considerably contributed to this proposal. We use the results of their tests to verify the devices used in the communication layer for our application, considering the best performance in communication and low power consumption and to present evidence of the improvement of the monitoring system of a domestic distribution network.

III. ARCHITECTURAL ASSUMPTIONS

A new line of research called embedded systems, characterized by a processing unit, running specific software, designed to run an application with high availability usage warranty for an extended period, has been used to solve problems in many sectors of industry, with today's computer systems. Depending on the nature of these systems, specific architectures to connect them must use them to ensure data integrity between layers of devices and other applications. And, depending on the nature of these systems, specific architectures to connect them must use them to ensure data.

We identify the entities presented in the construction design of this prototype from the Semantic Smart Gateway Framework, the IoT-ontology [6] and the Technological W3C Stack [7]. The purpose was to create a fully immersed application with the Internet of Things approaches, with semantic, entities and, consistent representations. For this project, we have considered the collection, transmission and, storage of data, such as security issues, privacy, reliability, shipping, and latency and other aspects.

Fig. 1 presents the main concerns of the project, in order to maintain the integrity of the smart entities and control entities, as well as between the physical entities associations and features, software agents, applications and services. The layer of IoT-ontology entities [6] and namespace are listed and described in the page directories, used to organize and prevent conflicts with the pages with the same name.

Fig. 1. IoT_Entity definition in Protégé 4.2 notation, showning the assert and inherited axioms (as classes) in separate panes. Source: [6].

In order to build a solution to improve the water distribution, allowing better planning and regional strategies, and enhance the domestic consumption of treated water, by applying the IoT concepts, we proposed the use of smart devices to perform, autonomously (or with lower power consumption). For this, we searched for commercial solutions, performing research with systematic methods related to the control of the demands and offers and the supply of water.

The proposed architecture was built considering four layers: The perception layer, the middleware layer, the communication layer and the perception layer. The perception layer is responsible for data collection of flow sensors and, it sends data by Wireless Sensor Network (WSN) nodes. This study focus on the Communication layer. Within the perception layer, the data collected from the sensors is read. For the scenario considered in the study, these sensors are responsible for measuring the water flow, which data will therefore be transmitted by the WSN network nodes (Wireless Sensor network) in the following layer. The communication layer receive the data from the sensors and, transmit them through a network of WSN Nodes, using the ZigBee modules, to the concentrators, that will send the data further to a Data Collector. In the Middleware layer, these data received from the Communication layer are then validated and, stored data into a database, observed in Fig. 2.

The forerunner prototype Local Water Control (LWC) has two layers: *i)* the perception layer, responsible for the data collection concerning the consumption of water, performed by a water flow sensor; *ii)* the communication layer, which specifies the network access control topologies: point-to-point, star, tree, cluster and mesh, observed in Fig. 3.

The application was developed and tested with the Arduino Mega 2560, responsible for the communication between the water flow sensor and data communication.

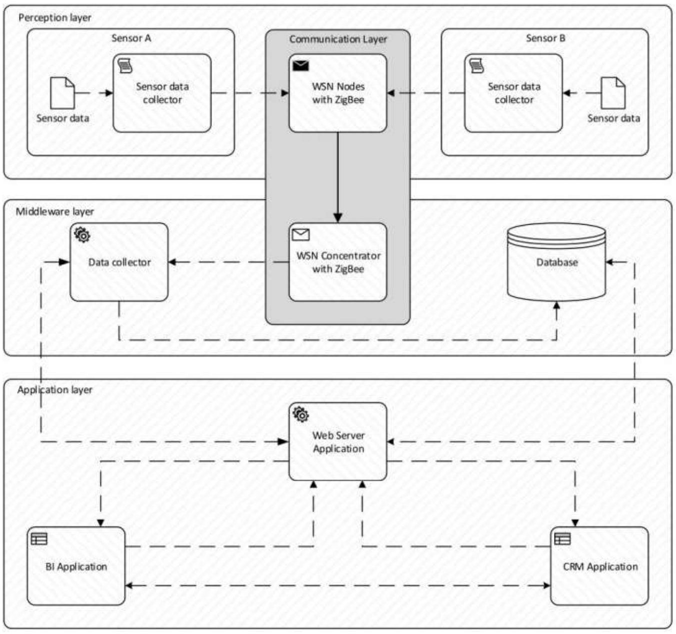


Fig. 2. Local Water Control Architecture has four layers. They are a) Perception; b) Communication; c) Middleware; and, d) Application Layers.

A. Perception Layer

The perception layer is responsible for collecting data related to the consumption of water by a water flow sensor. The water flow sensor is a plastic body, a rotor, and a half-effect sensor. The water flows through the rotor that rotates and generates frequency pulses detected by the half-effect sensor (flow rate range: 1~30L/min), with this structure it is possible to know the flow rate and, therefore, the average of the domestic water consumption (real time) in each residence. This layer captures data by flow sensors. The proposed study do aim to consider the flow rate analytics.

B. Communication Layer

In [4] the authors presents some advantages of the IoT wireless sensor network, where data is collected by various sensors. The data collected is then transferred to a server by GPRS-DTU using a GPRS communication network and stored on a remote terminal unit (RTU). The ZigBee is a low cost, two-way, wireless communication standard. Its operating rate varies from normal 75m to even a few kilometers, presents low power consumption requirements. The ZigBee communication module, in miniaturization and low power consumption, provides the basis for the Internet of Things, with an open communication protocol IEEE 802.15.4 built for industrial, scientific and medical environments. It meet all required features for this design, as excellent immunity to interference, high reliability (packet delivery guarantee, even in the event of data corruption), low power consumption, good range (even without sight), native encryption of 128-bit, up to 65,536 nodes in the network, and cost/benefit. The ZigBee module allows the availability of network topologies in a tree, star or mesh topologies, as seen in Fig. 3. Note that the choice of topology can suit the operation and architecture requirements.

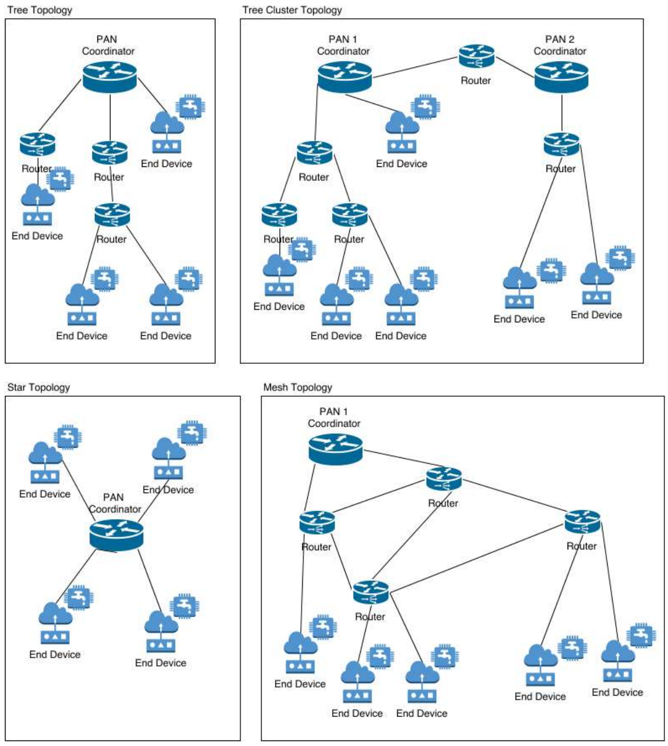
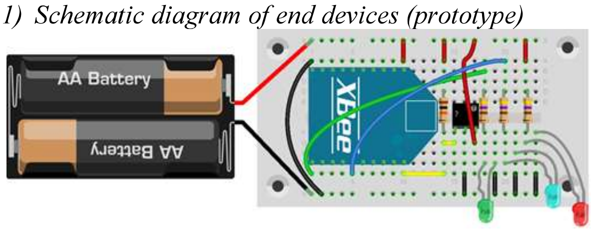


Fig. 3. XBee network topology.

1) Schematic diagram of end devices (prototype)



2) Pseudo source of end devices

```
Algorithm "ASensor"
var
   signalSensor, pinSensor, RX, TX: integer
   waterFlow: real

begin
      // Pin setup
      pinSensor <- 2 // sensor reading Pin
      RX <- 2 // XBee Pin RX
      TX <- 3 // XBee Pin TX
      // Starting variables
      waterFlow <- 0 // Storage the water flow
      // Randon value for simulation
      signalSensor <- 55
      // Receives the sensor signal calculates the flow
      waterFlow <- signalSensor * 60 / 5.5
      // Print the output of the XBee gross
      print ("ASensor: ", waterFlow)
      // Print the output of the XBee cubic footage

end
```

The Coordinator is responsible to initiate and maintain the network connections, and also to act as a bridge between different networks. The Router works as a node and as a bridge between other network nodes. Finally, the device hosts receives data from the sensors and send the data for processing and transmitting directly to the actuators. Fig. 4 presents design of this architecture. The water will flow from left to right and, passes through the water flow controller in WLC, causing the rotor to rotate and, it generates half-effect sensor pulses.

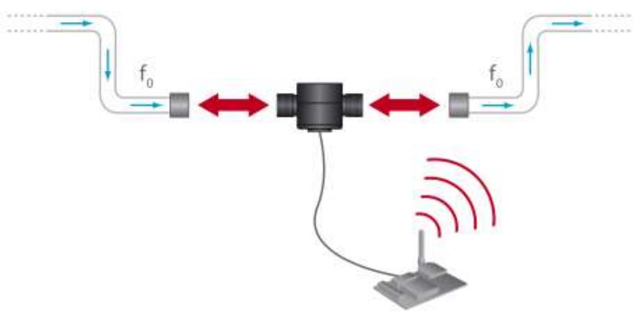
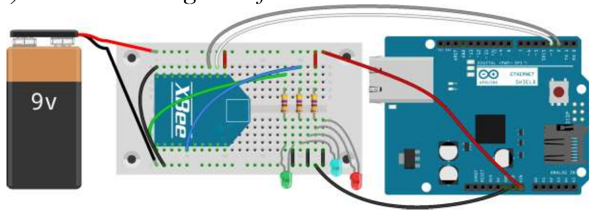


Fig. 4. Device (prototype) installed in domestic pipe.

3) Schematic diagram of coordinator/router



4) Pseudo source of coordinator/router

```
Algorithm "Coordinator/Router"
var
   mac, IPAddress: character
   analogInPin, analogOutPin, sensorValue, EthernetServer,
i: integer

begin
   // Network setup
   mac <- "0xDE, 0xAD, 0xBE, 0xEF, 0xFE, 0xED"
   IPAddress <- "192.168.25.201"
   EthernetServer <- 80
   // Pin setup
   analogInPin <- 0
   analogOutPin <- 9
   // Starting variables
   sensorValue <- 55
   i <- 0
   // Print data
   while sensorValue <> 0 do
      clear
      // Starting Ethernet service
      print ("Server running on IP: ", IPAddress)
      print ("")
      timer 500
      repeat
         // Print data received by XBee
         print ("ASensor: ", sensorValue, " m^3/hour" )
         i <- i + 1
      until i = 10
   endwhile
  end
```

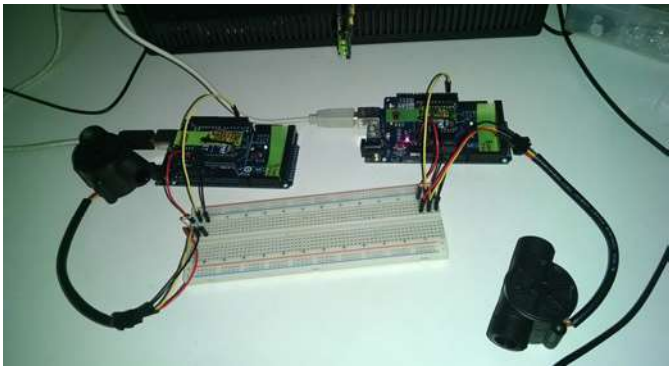


Fig. 5. Simulations at laboratory.

CONCLUDING REMARKS AND PLANS

This work detailed the LWC architecture to help control and manage domestic water consumption, with parameters and processed data by the IoT devices. The experimental results suggest that the proposed architecture has high stability and integrity between entities (adoption of IoT-Ontology) and is robust to variations in water pressure, making the correct measurement of water flow and transmitting the integrity data between nodes of the network. This prototype presents low power consumption design can be operated by solar battery module, reducing energy costs and promoting the device autonomy.

Consumption telemetry uses state changes at end users (residences). A big costumer (e.g. a shopping center) knows its flow rate consumption and, any change in the water distribution network can compromise water pressure, with loss or leakage problems. Initial results showed that the use of telemetry (focus of this study) has a consumption curve, for both residential customers (end users) and industrial water administrator in real time during the day and thus, better sizing the pressure and water availability in the network.

We plan to make an architecture based on the four layers, despite the two layers already proposed in this study, including, in our proposal, a Middleware Layer and, an Application Layer. A small board device, to carry out tests to the end users, water distribution centers, and support government agencies. The Altera-Intel Quartus II will be considered in order to help the development of the apparatus and, to improve the experimental testing for end users and device development with government funding agencies.

REFERENCES

[1] RFF, “Water,” *Resources for the Future*, 2015. [Online]. Available: http://www.rff.org/research/topics/water. [Accessed: 10-Jul-2015].

[2] E. Union, *EU Reference document Good Practices on Leakage Management WFD CIS WG PoM: Case Study document*. 2015.

[3] ABES, “Controle e redução de perdas nos sistemas públicos de abastecimento de água” 2015.

[4] G. Zheng and Z. Zhang, “Intelligent wireless electric power management and control system based on ZigBee technology,” in *Transportation, Mechanical, and Electrical Engineering (TMEE), 2011 International Conference on*, 2011, pp. 1120–1124.

[5] R. Aminzadeh, F. Kashefi, and H. Alee, “Hydraulic pressure distribution for pipeline networks by wireless sensor networks,” in *Applied Electromagnetics (APACE), 2010 IEEE Asia-Pacific Conference on*, 2010, pp. 1–5.

[6] K. Kotis and A. Katasonov, “An ontology for the automated deployment of applications in heterogeneous IoT environments,” *Semant. Web - Interoperability, Usability, Appl. an IOS Press J.*, 2012.

[7] E. R. C. on the I. of Things, “Internet of Things - IoT Semantic Interoperability: research challeges, best practices, recommendations and next steps,” vol. 1, p. 48, 2015.