A Proposal of Communication Protocols in Ubiquitous Computation Environment in the Residential Automation

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ABSTRACT

An ubiquitous computation environment has as presupposed that the computation is in all equipment and devices, and these are interacting between itself and with the people. The connection between objects and human beings is instantaneous, when these enter in the ubiquitous environment. A communication protocol to make the linking between many devices, of many manufacturers, in this environment, will be the key so that this connectivity happens. In the industrial automation, the protocol RS 485, is very used. Although some similarities in the intentions, the residential automation has different concepts from the industrial. The protocol I2C, of the wire technology, developed by Philips, appears as option for the residential automation. Protocols of wireless technology, as bluetooth and zigbee, because of its characteristic of covering, are presented as complement for this automation. This article aims to present a vision about the necessary characteristics of the communication protocols for a ubiquitous computation environment in the residential automation. In it will be described the studies, development and implantation of devices of residential automation that occurs in the QualiHouse Residential Automation, incubated company in the Trilha, pre-incubator of the Faculdade Integrada do Recife - FIR.

Keywords: ubiquitous Computing, Communication Protocols, Automation, I2C.

1. INTRODUCTION

The environment where behaviors alter automatically, without needing the users to express their desires, are called smart environments. When all interaction with the environment happens through automatic behavior, characterize invisible computation. With the physics mobility of equipments, logic mobility of applications with addition to the smart environment results in the ubiquitous computation.

Mark Weiser in 1988 was the first author to use the term ubiquitous computation. He used it to describe his idea of turn the computers omnipresent and invisible. The idea was that it wasn't necessary to exist a computer visually so the user could interact, in other words, work or have fun. It wasn't enough have a friendly interface, it should go beyond. More improved than what exists in virtual reality. No keyboard, mouse, screen or wires plugged in the user. "It's to do your job with the help of the computers without worrying with working in the computers" [1].

The residential automation is growing strong in the last two decades, affirming its own concepts, and not the ones from the industrial automation. It's considered by many integrators, people specialized in making adverse technologies working, as a difficult task, because in residential automation each client has one different context, different equipments, different applications. Analyzing what each client wants from the automation and drawing a solution for the situation offered is needed. There will be clients prioritizing the security of their residence, with sensors and video camera all over the backyard, and others prioritizing the entertainment, installing screens and distributing audio and video in the house rooms.

The communication of many equipments and devices inside the environment of ubiquitous computation is the problem to be solved. The manufacturers of the many electric and electronic equipment that equip a residence, yet not converged to a unique technology, whence the integrators of the residential automation can utilize this facility.

The proposal of this research project is to implement the concepts and principles of ubiquitous computation for applying in the Smart House. For this, the technologies of many devices inside the house will be studied and implemented. The

QualiHouse Residential Automation Company, pre-incubated in the Trilha Incubator of Faculdade Integrada do Recife, is responsible for the development of the control system that will be used as a module of tests and showroom of the involved technologies. In this project, the student's work is to study, present, develop and implement, choosing which communication protocols that would interlink with efficiency the many devices inside the ubiquitous environment.

For implementing and testing the protocols proposed here, it's being developed a protoboard module, table for mounting electronic experimental circuits, in the QualiHouse company, called control spot. The control spot will use the communication protocol I2C, internal for accessing the memory and the real time clock and external when its connected to automation spots. For covering bigger distances, Philips extensors can be used to interlink the control spot with the automation spot.

This document is organized in that following structure: in the second section the context of ubiquitous computation environment for residential automation is given. The third section is about the characteristics and necessities of the communication for the residential automation in the ubiquitous computation environment. In the forth section, the subjects are the protocols with and without wire, it's advantages and disadvantages for this application. The fifth section was dedicated to the project being developed with the pre-incubated company in the Trilha Incubator of Faculdade Integrada do Recife. There will be distinguished the initial plans and the changes in plan. The sixth section, as a conclusion, is a consideration about the subject, the attained result, problems found in the realization of this project and how to continue the research of the project. In the seventh section are the bibliography references. Finally in the last section are the mini-curriculums of this project authors.

2. UBIQUITOUS COMPUTATION ENVIRONMENT

In this section the ubiquitous environment for residential automation will be considered. Concepts like pervasive computation, physics and logic mobility, application performances context and smart environment will be introduced to explain the ubiquitous computation theories.

The pervasive computation is characterized as the one where the computational environment of the user is available anywhere, anytime. In this, exists the association of two types of mobility: the physics mobility of the equipments and the logic mobility of the data and applications (programs). The applications are variable, distributed, conscious of the context and take the follow-me form. For instance, a user of this system could make that his favorite music channel followed him to any room in the surrounding, without him needing to turn on or off any audio equipment in his motion through the surroundings. The adaptation is the most important requirement for these new applications serve their users [2]. This mobility brought new challenges for the application production that will have to adapt to these environments.

The physic mobility is related to the localization. The actual localization of the user, inside the surroundings, determine which performance context of the applications the user will demand. In this scenario, the notion of adaptation is related to the reaction to the change of state of the elements that compose the application context and alter its behavior.

Abowd & Mynnat [3] describe how to obtain contextual information analyzing five primordial aspects, called the five Ws:

- Who: should provide contextual information of all involved people in a certain activity assisted by computers.
- What: has the function to identify what the user is doing.
- Where: as referred, the localization context is the most used by systems sensitive to the context.
- When: the temporal context is important for indexing one seized information, for instance, inform for how much time one user was in a certain place.
- Why: it's not only to notice what the user does, but essentially *why* he acts like that.

In these environments where automatic behaviors happen, without the users needing to explicit their wishes, are called smart environment. When all interaction with the environment happens through automatic behaviors, characterize the invisible computation. With the physic mobility of equipments, logic mobility of applications in addition to the smart environment give us the ubiquitous computation [1][2][4].

The Chart 1 presents the existing relations between the computation concepts here considered regarding the mobility attributes and smart degree or functionality of the involved devices in each concept.

Characteristics	Pervasive Computation	Mobile Computation	Ubiquitous Computation
Mobility	Low	High	High
Intelligence Degree	High	Low	High

Chart 1 – Relation between the presented concepts

3. COMMUNICATION IN THE UBIQUITOUS ENVIRONMENT.

In order to all devices and equipments inside the ubiquitous environment can communicate, it's necessary the existence of communication protocols that all elements of this context can understand.

The discussion about communication protocols between the equipments and connectivity among many technologies, has provided that the big manufactures of the integrated circuit, electro-domestics and electro-electronics, network access providers, software and telecommunication services providers, associate in different work groups to create standard communication among them. These study groups create the rules that should be followed so the equipments can communicate when connected in network. The residential automation area is the most benefited by these studies[5].
The new technologies provide comfort, practice, productivity, economy, efficiency, profitability with additional enterprise valorization for its user. The objective with residential automation, according to Bettoni [6], is the integration of the access technologies to the information and entertainment, with business optimization, of the Internet, security, besides the total integration of the data network, voice, image and multimedia. This is only achieved through one unique project that involves infrastructure, devices and control software.

4. COMMUNICATION PROTOCOLS

In this section the physics environment protocols, also called low level protocols, are considered. First we'll present the serial communication protocols of the wireless technology that can be used to compose the ubiquitous environment. In the second part it will be presented some wireless communication protocols, also known as wireless, that besides of giving mobility to the control system and environment monitoring, can make connections of devices that may not be reached through cable network.

Wire Technologies

A well known protocol and that is present in old computers is the RS 232 [9][10]. It's serial, spot to spot, of low cost, even so has a short range (maximum of 15 meters) due the susceptibility to noises. It needs separated tracks for transmission and reception. In the computers, it works with a UART chip that has the function of converting the parallels bits of the computer to the serial exit of the RS232 and vice versa. In older computers, the chip UART is the bottleneck of the transfer rates, because they work with small caches.
The RS422 protocol [10] is also a serial, spot to spot. It's considered as an improvement of the RS232, having transmission and reception tracks equilibrated, being more resistant to noises. It can reach 1200 meters. It's used as an extensor of the RS232. The RS485 protocol [10] is an evolution of the RS422, being serial, yet multi-spot. Can have up to 32 devices in network, working in differentiate bus of two wires, transmission separated from reception, can reach 1200 meters. The slave devices are accessed by unique address.
The X-10 – PLC (Power Line Carrier) [11] is a protocol that uses a tension track of the residence as a physics environment between the transmitter and receptor. It accepts up to 256 devices for addressing. It works with the a highest frequency than the wire for sending commands. It has developed in the last years. Yet acts with little flexibility, making it only open and close contacts.
The SPI [12] is a serial protocol, multi-spot, developed by Motorola. It uses 2 common wires for all devices, besides the wire for addressing each slave device.
The IEEE 1394 protocol [13] also known as FireWire, from Apple, is a plug and play port, that means, the devices connected in it already have installation drivers for it's functioning. It's also hot, that means the devices can be plugged and unplugged without needing to turn off the equipment. It's used a lot for video transmission because of it's big bandwidth.
The I²C protocol [13][15], original from Phillips, is licensed for a huge number of manufacturers. It has a two wire bus and uses addressing for communication between the devices. It can have up to 128 devices in the network, letting more than one master devices control the bus. It has controls to the conflicts and arbittraments for the use of bus by the master devices. Each device has it's unique address. Originally used only in electronics equipments, the manufactures companies has been developing interlinked circuits for adapting to other situations, for instance the extensors that can make the bus I²C to some hundred meters. After the survey of many serial communication protocols used in network of computers to general automation, we chose some for comparison, that for its characteristics could help to compose a scenario of the ubiquitous computation.

Wireless Technologies

From the wireless protocols that had been studied and had it's characteristics analyzed, we present here three that because of their application requirement in residential automation, had been considered efficient. The first two were chosen mainly for their covering characteristics. Are the Bluetooth [16] and Zigbee [17] technologies, the last one also known as homeRF. It's important to emphasize that these technologies don't compete between themselves and that, they complete each other in a residential automation project.
The Bluetooth technology allow the wireless communication among electronic equipments that can be computers, mobile phones, PDA, office equipments and mobile devices. A small microchip, having a radio transmitter, is inserted in a digital device. The Bluetooth technology make all the connections immediate. This favor a fast and secure transmission of data and voice, even when the devices are not in a direct line of vision. This communication happens through a radio interlacing device in the 2.4GHz frequency, that does not need a

license and is available almost any where in the world.
Bluetooth is more appropriate for applications like:
- PC synchronization, mobile phone and PDA;
- Audio applications like wireless phone;
- Files transference between PDA, PC and Printers.

Zigbee is a standard for wireless communication of low potency determined to applications involving many devices, for instance, sensors. Very versatile, with Zigbee is possible to create network in many topologies keeping the important characteristics from the protocol with a low time of access to the network, low time of activation of the slave devices and low waste. It works in the 2.4GHz frequency.
Zigbee have better performance in applications:

- Of control;
- Sensor network;
- Network with many devices;
- Small data package;
- Where the battery waste is critical.

The Chart 2 shows the main differences between this two protocols.
Another relevant difference between this two standards is the type of supplies of these devices. In Bluetooth applications, usually, the devices are recharged periodically, like mobile phones and PDAS, whereas in the Zigbee standard. these can be supplied with common alkaline batteries and the durability of those is above 2 years.
Analyzing these differences it's possible to say that Zigbee and Bluetooth are two different solution to solve problems in different applications. Even if little modifications may occur in this standards the main characteristics are kept. The differences between these standards come from the architecture in which they were developed [16].

Characteristic	ZigBee	Bluetooth
Standard (MAC + PHY)	IEEE 802.15.4	IEEE 802.15.1
Transference rate	250 kbps	750 kbps
Current in Transmission	30mA	40mA
Current in Rest	3uA	200uA
Connections	Spot to Spot	Multi-spot
Range (meters)	25 - 60 m	10 m
Access time in network	30ms	3s
Slave transition time (sleeping for active)	15ms	3s
Channel access time	15ms	2ms

Chart 2 - Differences between ZigBee and Bluetooth

The third wireless technology is the called label RFID (Identification for Radio Frequency) [19]. It is a small passive transmitter, that is, without supply, that when approached to an appropriate reader, can transmit the information, with the energy that receives from the reader. Has been used in the commerce, as protection against robbery of merchandises. It starts to be used as access control, authenticating its users, when he shows the card to a reader, in a distance of two to five centimeters. It uses frequency band of 125 kHz. With a small power plant, the labels start to be active and because of this proper supply, they can be read from some meters of distance.
These cards have the Motorola as its main manufacturer and possess some protocols, between them the wiegand, the mag-stripe, the racs, citing only some here. The wiegand protocol possess many formats or structures. The 26 bits format uses two bits for control, being the first and last one. The manufacturers use 8 bits, called code of facility, with information of who manufactured that card, and 16 bits are free to register its user information.

5. CHOICE AND IMPLEMENTATION OF THE PROTOCOLS FOR RESIDENTIAL AUTOMATION

To control the sensor and actuators devices that will exist in each room of the residence, initially an sketch of an electric circuit was elaborated, called point of control, where a bigger microcontroller plays the role of central organ. We are working with PIC16F88 of the Microchip[20] microcontroller. This microcontroller possess I2C and RS232 bus. Have 16 doors that can be programmed as entries or exits. For the rooms, where will have the automation points, an integrated circuit GPIO (General Purpose In Out) of the Philips will be placed, of PCA9501 [21] code, it is a CI of general purpose of working with entries and exits, making the connections between the sensors and actuators. With the use of the GPIO we will be able to use analogical and actuators sensors, that are cheaper.
As the integrated circuits will be from Philips or its associates, we won't have difficulties in creating a bus for using in the I2C protocol, where all the modules will be able to change information, through the only address of each component of this network. To be able to cover bigger distances, we will use the extensors, also of the Philips, that work with two bus. These extensors, like the P82B96 code, work with I2C in two wires in bus and with four wires, two for transmission and two for reception, in the other bus. These are the tressed pairs of transmission and reception that make the bus be able to extended to some hundreds of meters. Other integrated circuits had been placed in the I2C bus to complement the device functionalities. Figure 1 below shows an sketch of the initial ideas of the project.
A memory EEPROM, memory not volatile, in the integrated circuit 24FC512 of the Microchip [20], will have the function to store, for example, the

registries with the requested access authorizations from an user. If the computer that is making the supervisory and host of authentication function is not working, the authentication, that verifies the information for the access authorization, could be given by the microcontroller, consulting the memory located in the point of control.

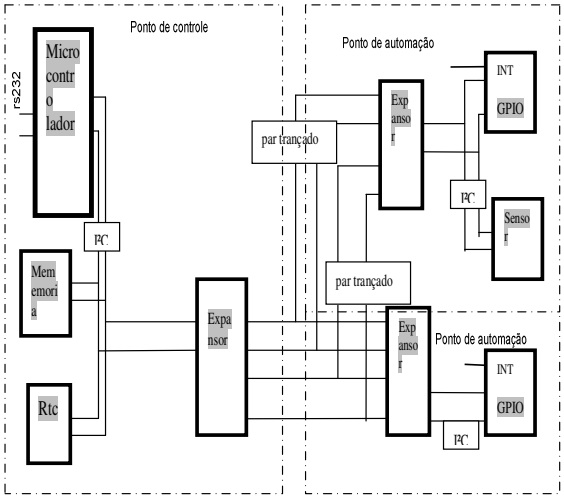

Figure 1 - Initial sketch of the project

Also, in case of imperfection of the authentication server, it's in this memory that will be stored the information of the allowed or denied accesses. When the server start ti function again, it will be brought up to date with the information kept in the memory.

A clock calendar RTC (Real Timer Clock), of code PCF8583P by Philips [22], will provide the marking of the time to index the events registers that will be stored in the memory. The storage of the events with date and hour is important for posterior use in audit reports, for example.

In regards to the circuit supplying, we will use direct-current tension of 5 volts for integrated circuits (microcontroller, memory and extensor) and 12 volts direct-current for the lines of transmission and reception. However, the clock will be fed by an battery of 3 volts. If problem with energy happens, we will not need to set the clock for continuation of the equipment functioning, when the energy is back.

In the automation points, beyond counting on the GPIO making the connection with sensors and actuators, we can also add integrated circuits in the local I2C bus. An example would be to place in the bus a sensor that could work directly with I2C.

As the project of protocols studies needs to walk next to the pre-incubated company projects, the responsible engineers for the QualiHouse, taking care of the services order of customers, had made small changes in the course of the project. It was necessary to develop, implement and test a module of point of control, for access control. In figure 2 show an sketch of the module that is being mounted and the communication protocols used.

This module has two card RFID readers, one to register access of entrance and another one for exit. These readers work with the wiegand protocol, in the 26 bits format. When the user shows the card the reader, this reads it, through radio frequency, of the information contained in the card and sends through two wires (D0 and D1) to the microcontroller. The bits are sent irregularly.

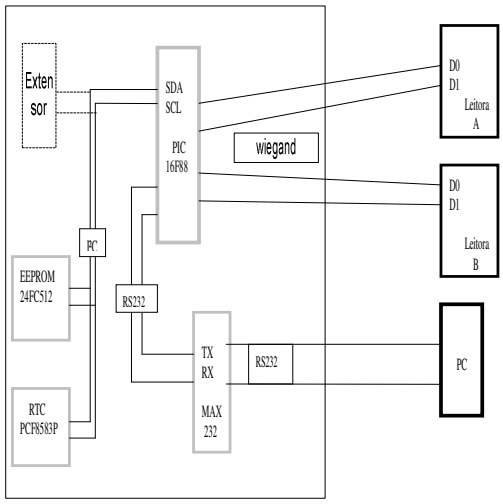

Figure 2 - Actual sketch of the project

Each bit is sent in a pulse of 50 microns second per 1 millisecond of pause. The microcontroller, a PIC 16F88, working with clock internal of 8 MHz, receives the data from reader and: 1º case: it sends to the computer through its interface RS232, using the serial protocol of same name, to make the authentication of the card user. If it has in its data base access authorization, the microcontroller will send commands so that the door is opened and signaling, through led green in the reader, of the allowed access. If not, the led red will signal denied access.

2º case: it searches in the EEPROM memory, through its I2C interface, the authorization for access in case that the computer is for some reason off service,. The EEPROM memory will contain enough data of the users whom have permission to access that controlled port. The information of the allowed and denied accesses will be stored in the memory.

The tests of this module of control, with the assembly made in a protoboard, had been executed and the result was satisfactory. The QualiHouse staff already ordered to manufacture the pressed circuit board, where the definitive components will be mounted. After assembly of the electric circuit in definitive board, will be made the software definitive programming that will be loaded in the microcontroller and the final tests.

6. CONCLUSION

An environment ubiquitous must possess adaptiveness systems, that follow its users,

independent of its localization, interacting in the new context. These systems need to store the habits history of its users to be able to take care of them. The communications protocols for the automation of these environments must be chosen in accordance with the involved existing equipment or the ones that will still be acquired for the residence. Cost versus benefit must be pursued, because usually the user will not have to pay for what he won't consume, or better, enjoy.

We can consider that the considered objectives for this project had been reached: acquisition of new knowledge in the ubiquitous computation area, its needs and characteristics: knowledge of the residential automation, devices and manufacturers involved in the area and knowledge of diverse protocols and its applicabilities.

Due to the changes in the archetypes developed for the QualiHouse, in the second version of the project, as integrated circuit we need to create a supported board to receive shown in figure 2, it was not yet possible the tests with the real time clock. The QualiHouse not yet acquired the component, however the pressed circuit board will be manufactured, considering its future existence.

Another component, the integrated circuit P82B96, network I2C extensor for bigger distances, will not be implanted in this stage. One of the problems is that the integrated one that the QualiHouse received from courtesy of the Philips uses SMD (device of surface assembly) technology. To use this type of it, without weld use, and connect this support in protoboard. Studies for this purpose are in progress. The drawing of the support circuit board is already done.

In sequence of these studies we should, after solving the I2C bus extensor problem, and tests with the real time clock, implement the wireless technologies. As of a start the bluetooth will be used as a distance controller to set in motion the devices for door opening. The Zigbee technology will probably be used in the implementation of an automation point that may not be reached by the wired technology, for example, a presence sensor outside of the residence area.

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