A Real Time Home Automachine System Using Advanced Wireless Network Techniques

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Abstract

In this research work an advanced home auto machine technique are proposed with wireless network applications. In home applications many devices consume electrical energy heavily, due to this maintenance getting complex. Therefore, energy management and testing of appliances miniaturization is compulsory. In this study wireless communication-based GUI is implemented for hybrid home auto-machine. The Wi-Fi, Bluetooth and other gateway devices are continuously monitoring with runway scheduling algorithm. This technique is continuously monitoring the home appliances and balancing the energy management. The proposed algorithm providing high accuracy compared to existed methods.

Keywords: wireless communications, home auto machine, energy management, Wi-Fi, Bluetooth.

1. Introduction

The energy consumption demand was moderate in the past, when the first electrical grids were constructed in the late 1800s [1] and until the 1960s. Electricity operators used only simple measuring and control devices to operate the electrical grid at the time, such as electromechanical energy meters to monitor energy output and consumption. To read the energy consumption and switch on/off generators, these devices required human intervention. Furthermore, the customer side did not pay attention to energy use control. From the last decades of the twentieth century, as the number of customers grew, so did the demand for electricity, and the electrical grid became much more complicated. As a result, innovative strategies focused on emerging technologies had to be implemented in order to properly handle and monitor the energy production-consumption chain [1].

Electricity operators are currently transitioning from static to intelligent and real-time control systems [2], [3]. These systems make up an Advanced Metering Infrastructure (AMI), which includes features including energy theft detection, CO2 emissions reduction (through increased awareness of energy consumption while facilitating the integration of renewable energy sources), electrical grid remote control and command, and energy production savings (to the extent possible) due to real-time balancing. Nonetheless, population growth, urbanization, and irrational use of electrical energy both increase demand, making electrical energy management on the production side more difficult, particularly if the consumer side is ignored. More efficient and adequate results can be obtained by monitoring and regulating energy usage at the customer level. To begin with, by reducing consumer demand, the electricity bill can be reduced. Second, through intelligent management systems on the production side, real-time management and forecasting can provide electricity operators with a strong framework for balancing the production-to-consumption ratio over time and, as a result, effectively managing energy sources. Finally, from an environmental perspective, reducing energy usage and losses would result in lower CO2 emissions.

A Smart Home Energy Management System (SHEMS) is necessary to control energy consumption on the consumer side. In this sense, the device mentioned in this paper provides consumers with a powerful tool for managing and regulating their energy consumption by providing functionalities that allow for the monitoring and control of household appliances as well as the reduction of power demand. The SHEMS can be linked to the Smart Grid Management System (SGMS), providing information on consumer activity and energy usage to the electricity operator. Alternatively, even if the consumers' information is kept private, the SHEMS can benefit AMI indirectly by lowering energy consumption, which is beneficial to both parties (reducing energy production requirements on the production side and reducing the electricity bill on the customer side).

The developed SHEMS is an embedded system that includes a wireless monitoring and control system as well as a smart energy management algorithm. The Monitoring Devices (MDs) and a User Interface are integrated into the monitoring and control framework, which is the foundation of every SHEMS [4], [5]. (UI). Each MD is responsible for measuring the voltage and current consumed by each household appliance, calculating power and energy usage, and transmitting this data to a local central computer through a wireless Home Area Network (HAN), while the UI enables the consumer to track and manage the overall monitoring system as well as individual household appliances.

The data transfer can be based on a single wireless network technology, such as IEEE 802.11/Wi-Fi [6], [7], Bluetooth [8,] IEEE 802.15.4/ZigBee [9][10], or GSM (Global System for Mobile Communications) [11], or a hybrid network, such as a Bluetooth/Wi-Fi solution [12.] In this case, a gateway is used to convert the data packets being exchanged between the various protocols.

In terms of transmission overhead and time calculation, methods focused on distributed calculation and local in-network processing are more effective in terms of data processing and electrical quantity calculation [13].

In relation to similar work in this areas. In comparison to a centralized method, Ahsan et al. [13] address the advantages of distributed processing for home energy management systems. Since their app is for smart grid, it is primarily reliant on the energy provider. The proposed device has been tested on a mobile phone (Android app), but no MD hardware has been proposed. Ertugrul et al. [14] suggest a demand-based tariff home energy management scheme in which they attempt to reduce the household's peak demand. They also display the test equipment, but no details about the measurement accuracy are given. However, since it acts on any appliance without considering whether the user needs its activity later, this system can cause some inconvenience to the user. To prevent this annoyance, such an application should have a user priorities function that allows users to pick which appliances can be operated from the app and which ones cannot.

The authors of [4] present an energy bill forecasting application focused on an energy monitoring method for energy management. The authors believe that the monitoring system can be used as a learning tool, with the consumer exerting less effort in coping with it. They also display an application of the monitoring system that communicates through Wi-Fi.

In [9], Afonso et al. suggest an energy use and power quality control scheme. They demonstrate the measurement accuracy of their designed MD as well as the user interface they developed.

In [13], Ahsan et al. compare the benefits of distributed processing to central processing in the sense of a home energy management system. Since their app was designed for smart grid, it is heavily reliant on the energy provider. The proposed device was tested using an Android phone app, but no MD hardware is proposed.

As shown in Table 1, the proposed SHEMS is primarily designed for use in the case of payment by consumption slices. The payment in this type of system is based on the amount of kilowatt-hours (kWh) consumed over the course of a month. As a result, as the table indicates, as energy consumption grows, so does the price per kWh. The ultimate aim is to incorporate an energy management algorithm into the SHEMS, which controls the operation of household appliances based on energy consumption.

Table 1. Energy consumption slices per month and their price in Morocco

Energy consumption slices per month	kWh price in Moroccan Dirham (MAD)
0 to 100 kWh	0.9010
101 to 200 kWh	1.0732
201 to 300 kWh	1.1676
301 to 500 kWh	1.3817
>500 kWh	1.5958

We differentiate between appliances that have direct contact with the user and those that have indirect contact with the user, which was the issue raised in [14]. The machine does not operate on those appliances in the first group because the consumer might be using them. For example, if the consumer and a television have a visual contact, the device would not switch off the television. However, in the event of an overuse, it can send a warning to the customer. The machine, on the other hand, can control the appliances without notifying the user, such as turning on/off a refrigerator, since there is no direct interaction between these appliances and the user. To give the consumer some anonymity, the proposed SHEMS is not completely connected to the electricity operator.

The concept and implementation of the SHEMS wireless monitoring and control system are discussed in this paper. The remainder of the paper is set out as follows. The design of the built wireless network and a description of its key wireless communication technologies are discussed in the second section. The hardware and software of the established MDs are presented in the third section. The hardware and functions of the gateway are defined in the fourth section. In the fifth segment, we present experimental results related to measurement accuracy and monitoring system functionality, as well as the built Graphical User Interface (GUI) and its results. With the end, we bring this paper to a close.

2. Wireless communication network

2.1. Network architecture

A wireless communication network is formed by several elements linked to each other in the established wireless monitoring and control system. The collected data and remote control commands are then transmitted through the network between the controlled appliances and the user and/or the algorithm in this manner. One or more wireless network technologies can be used to ensure the communication between the various network devices. We chose a hybrid approach based on two technologies for this system: IEEE 802.11/Wi-Fi and Bluetooth Low Energy (BLE). As seen in [16], which addresses the advantages of BLE for this form of use, the choice of BLE was made due to its low cost and low energy consumption. Wi-Fi, on the other hand, allows for quick access to the collected data through a computer or cell phone inside the local network. Furthermore, in a potential implementation based on the Internet of Things (IoT) model, it facilitates seamless connectivity with clients and servers located outside the home [17].

The proposed wireless monitoring and control system's network architecture is shown in Figure 1. Monitoring Devices (MD1 to MDn), a BLE/Wi-Fi gateway, a Wi-Fi Access Point (Wi-Fi AP), and client devices make up the network. The MDs are linked to the gateway through a Bluetooth Low Energy (BLE) network. The developed MD is built around a Cypress PSoC 4 BLE module [18], model CY8CKIT-143A, which serves as the communication and data processing unit. The Bluetooth 4.2 protocol stack is compatible with this module, which is built on a 32-bit ARM Cortex-M0 processor core. For data collection, programmable analog front-ends are used, and a Real Time Clock (RTC) is used for timing requirements.

The user may use a computer or a mobile phone to access the data and monitor the MDs through the gateway, as shown in Figure 1. The gateway hardware is based on a Raspberry Pi 3, and the communication between the client devices and the gateway is provided by a Wi-Fi network using the Wi-Fi AP. This part serves as a local central device to ensure communication with all other devices in the wireless monitoring and control system. The gateway is also used to store and perform calculations on the collected data.

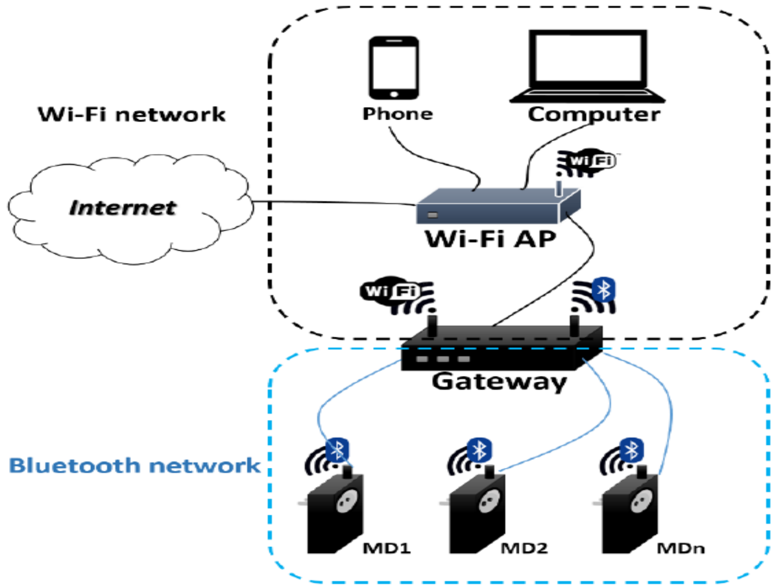

Figure 1. Architecture of the developed wireless monitoring and control network

2.2. BLE overview

Physical layer

BLE is a wireless communication technology that uses 40 channels spaced 2 MHz apart in the 2.4 GHz Industrial, Scientific, and Medical (ISM) band. BLE prevents interference by using frequency hopping, which is a reliable mechanism. BLE uses Gaussian Frequency-Shift Keying (GFSK) modulation and has a data rate of 1 Mbit/s over the air. BLE uses three advertising channels (channels 37, 38, and 39) to allow for system discovery, as seen in Figure 2. The other 37 channels are used for data transmission after they have been discovered and connected. To defend against interference from IEEE 802.11/Wi-Fi networks, advertising channels are assigned to various parts of the spectrum.

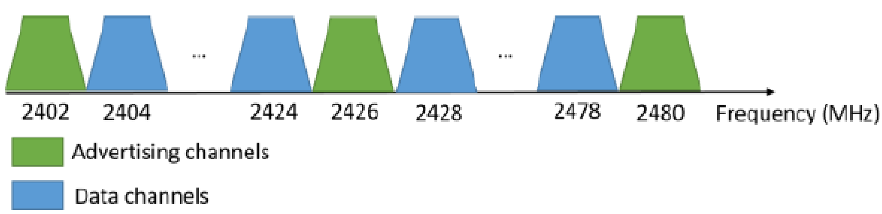

Figure 2.BLE radio frequency channels

BLE Stack

The BLE protocol stack is shown in Figure 3. The controller and the host are two members of the protocol stack. The physical layer, which is in charge of packet transmission and reception over the air, and the link layer, which is in charge of advertisement and scanning, as well as the production and maintenance of links, is also part of the controller. The timing control and queueing of incoming and outgoing packets are also managed by the BLE stack. The Host-Controller Interface is how the controller interacts with the host (HCI).

The upper protocol layers, such as the Logical Connection Control and Adaptation Protocol (L2CAP), Generic Access Profile (GAP), Generic Attribute Profile (GATT), and the application layer, are handled by the host. The L2CAP layer is in charge of providing data services to the upper layers, multiplexing and segmenting packets for the controller, and reassembling packets from the controller before sending data to the upper layers. The GAP layer specifies the generic procedures that are used in device pairing and linking. The GAP layer is in control of various Bluetooth modes (advertising, scanning, connect, etc.). GAP peripheral and GAP central are the two GAP system functions. The computer advertises its presence in the first, waits for scan requests, and acknowledges connections from GAP central devices in the second. The device's second function is to search for advertisements from the GAP peripheral and begin the connection process.

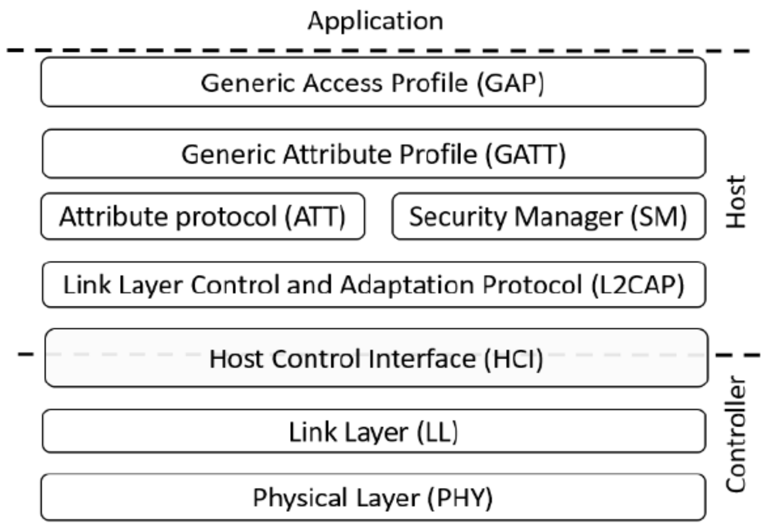

Figure 3.BLE protocol stack

Profiles, Services and Characteristics

The BLE uses profiles to ensure application level layer interoperability between devices (Figure 4). To interact, two devices must have the same profile specified. A profile is made up of services, each of which is made up of one or more similar characteristics that define a device's role. A collection of predefined services is given by the Bluetooth SIG (Special Interest Group) [19]. The BLE profile describes the GATT functions and facilities that must be provided by the devices. GATT has two types of roles: server and client. The first one is for the device that contains the data or state that needs to be sent. The computer that receives data from the GATT server or configures its state is the second one. A customized profile is used in the monitoring system, which combines the Generic Access service, the Generic Attribute service, and two customized services called Electrical Measurement (EM) and Monitoring Device Control (MDC). Voltage characteristic, Current characteristic, PowerAVG characteristic, PowerFact characteristic, and Energy characteristic are some of the characteristics found in the EM service. The control characteristics are contained in the MDC service.

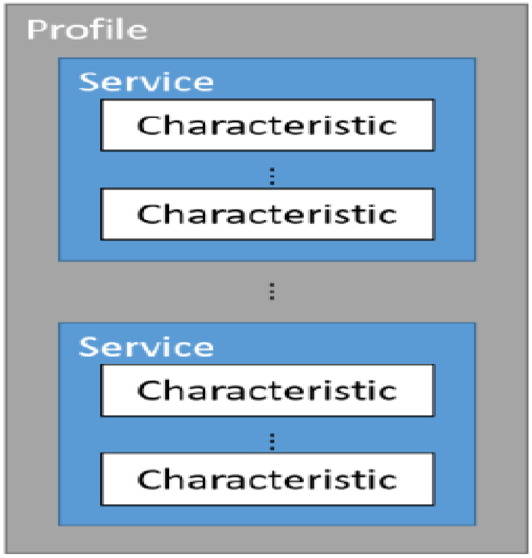

Figure 4.BLE data hierarchy

3. Monitoring device development

3.1. Developed monitoring device hardware

Figure 5 depicts the formed MD as a block diagram. It includes voltage and current sensors, signal conditioners, the communication and processing unit, as well as a relay for controlling the appliance's on/off. The instantaneous voltage and current are determined, and the power and energy are estimated as a result. The MD is designed for a 230 V/50 Hz single-phase grid.

The MD board and its power supply board are shown in Figures 6 and 7, respectively. A voltage divider based on resistors is used as a sensor in Figure 6 for the voltage chain. 0.00057 is the output-to-input ratio. The AMC1100 isolation amplifier comes after the voltage sensor. To protect against high voltage, this component ensures separation between the grid and the processing core. Since the AMC1100 differential output voltage includes a negative component, but the processing unit's Analog-to-Digital Converter (ADC) accepts only positive signals, we added a signal conditioner based on operational amplifier (Figure 8) to provide an offset in such a way that we only have a positive signal.

For the current chain, we used the TA12-100 current transformer as a sensor. This part has a current ratio of 1000:1 and a precision of 1 percent [20]. We used a 220 ohm resistor in its output to get a maximum voltage of 1.5 V for the maximum current. A fixed offset voltage was also applied to one of the current sensor's output terminals (Figure 9) to allow the reading of the negative part of the current signal.

The sampling frequency of the processing unit's integrated ADC is 5000 samples per second. We should mention that the Shannon sampling criterion is well-liked. As stated in the subsection, the electrical quantities are computed in software within the communication and processing device.

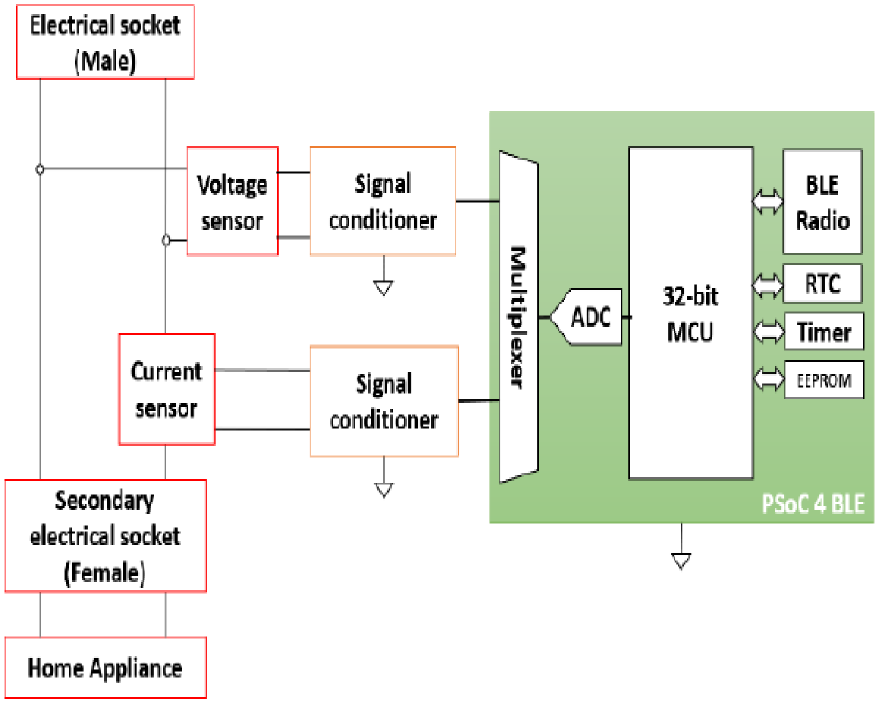

Figure 5. Monitoring device block diagram

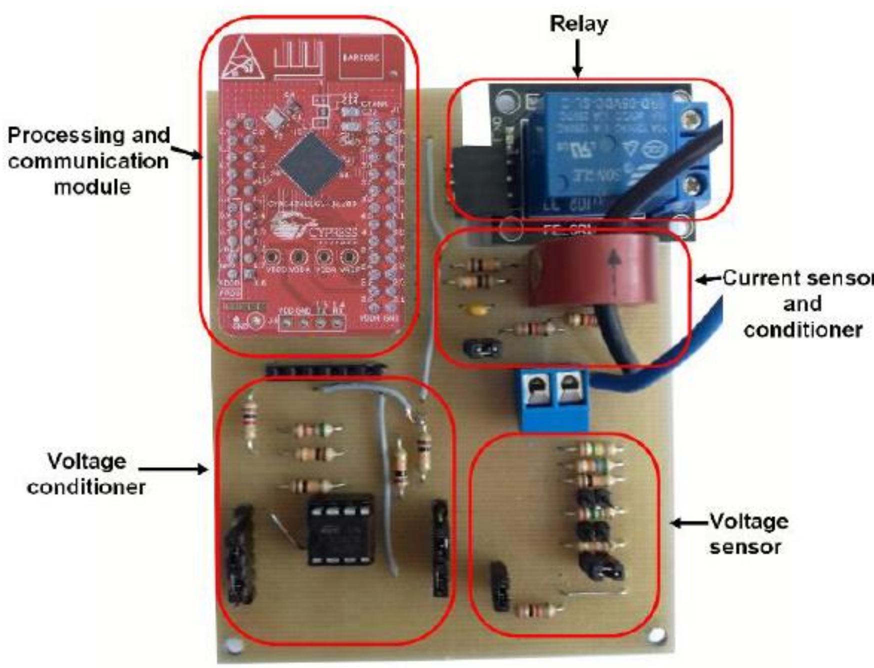

Figure 6. Monitoring device circuit board

Figure 7. Monitoring device power supply

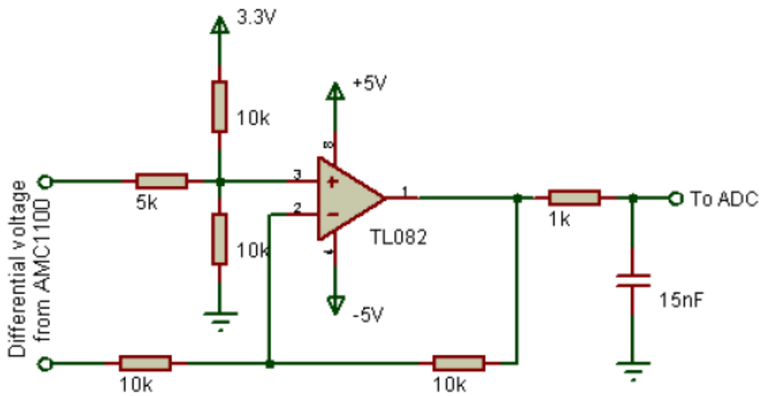

Figure 8. Voltage conditioner circuit

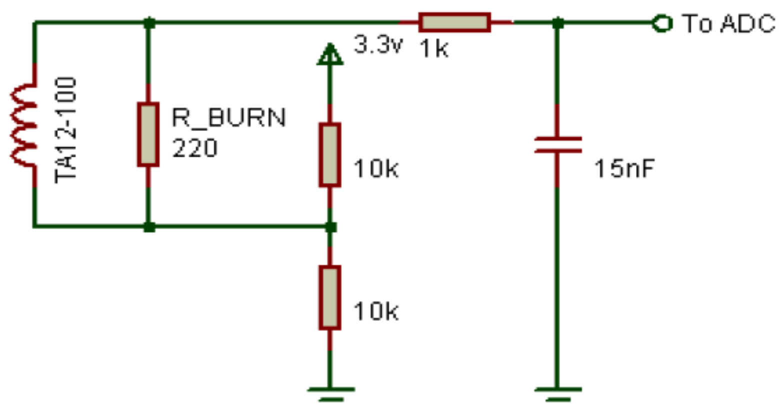

Figure 9. Current measurement and conditioner circuit

3.2. Software computation and system calibration

After each conversion, the ADC sends an interrupt to the microprocessor, informing it that new instantaneous current and voltage values have been stored in the corresponding registers. We use a flag to warn the interrupt function that there is new data to be processed since the interrupt function can only execute the bare minimum of instructions.

Using Eqs. 1, 2 and 3, we measure the instantaneous voltage, instantaneous current, and instantaneous power in the application task.

$$v = G_v(k_v.V_{REG} + V_{DCOFF})V_{REF} \qquad (1)$$

where $G_v$is the voltage gain used to calibrate the voltage chain gain, $k_v$is a coefficient used to transform the value of the ADC register into a real value$\left(equal\ to\ \frac{1}{ADC\ resolution}\right)$, $V_{REG}$is the numerical value of the voltage stored into the corresponding register, $V_{DCOFF}$is the voltage offset used to calibrate the offset into the voltage chain, if any, and$V_{REF}$is the voltage reference.

$$i = G_i(k_i.I_{REG} + I_{DCOFF})I_{REF} \qquad (2)$$

Each term is the same as in the voltage equation, except it is applied to the current chain.

$$p = v.i \qquad (3)$$

We describe a Low Sampling Rate (LSR) in the application task function (infinite loop), which corresponds to 5000 samples of instantaneous values and a time interval of one second. We use the equations in Table 2 to measure the RMS (Root Mean Square) values, active power, energy, and other quantities for each LSR, where N is the number of samples in one LSR and$E_i$and E_{i-1}correspond to the current and previous energy values, respectively. The energy consumed in the previous LSR is denoted by the term$\frac{P_{AvG_i}}{N_s}$where$N_s = \frac{3600}{LSR}$. the energy unit is Wh in this situation.

Table 2. Expressions used to calculate the electrical quantities

Electrical quantity	Formula
RMS voltage	$V_{RMS} = \sqrt{\frac{1}{N}\sum_{i=1}^{N} v_i^2}$
RMS current	$I_{RMS} = \sqrt{\frac{1}{N}\sum_{i=1}^{N} i_i^2}$
Average power	$P_{AVG} = \frac{1}{N}\sum_{i=1}^{N} p_i$
Power factor	$PF = \frac{P_{AVG}}{V_{RMS}.I_{RMS}}$
Energy	$E_i = E_{i-1} + \frac{P_{AV\,G_i}}{N_s}$

The system should be adjusted to remove errors caused by component tolerance values, such as resistors used in amplifiers and ADC offset circuits, in order to achieve the required accuracy. The calibration method may be done numerically or analogously. To prevent hardware problems, we use numerical methods in our system. Since the measurement chains are linear, we can only calibrate the device for one point of the load to correct the measurement.

These steps are used to remove the DC offset:

(i) Ground relation of the input measurement device.
(ii) Setting the gain variable to one.
(iii) Testing a range of instantaneous voltage and current values.
(iv) Calculating the average voltage and current values.
(v) Taking the found values and multiplying them by -1.
(vi) Recording the final results in the relevant variables.

The following steps are used to calibrate the gain:

(i) The use of a reference signal (220 V and 5 A).
(ii) Receiving a range of RMS voltage and current values.
(iii) Using Eq. 4 to correct the gain.

$$G_x = \frac{Reference\ value}{The\ average\ of\ the\ measured\ values} \quad (4)$$

where x may be either v or i depending on whether the gain is voltage or current..

(iv) To prevent a device recalibration, the values of the measured gains are stored in the corresponding variables as well as in the EEPROM.

4. Gateway development

4.1. Gateway hardware

We wanted to use a Raspberry Pi 3 as the gateway in our monitoring framework. This board has a specific collection of features that make the implementation of such systems easier. It features a Broadcom BCM2837 System-on-Chip (SoC) with a quad-core ARM Cortex A53 processor, 1 GB of RAM, integrated Bluetooth Low Energy and IEEE 802.11n wireless network support, General Purpose Input Output (GPIO), and other data interfaces. These qualities are necessary to create the appropriate gateway.

4.2. Gateway functionalities

BLE communication

The BLE protocol stack is integrated into the gateway, allowing communication with the MDs. To collect data, we built Python-based scripts that run as services. The gateway, operating as a GATT client, establishes a BLE link with an MD every 5 minutes, notifies it to update its characteristics, and begins reading the system characteristics with these scripts. The contact between the gateway and the MD is depicted in Figure 10. We should point out that advertisement is only used the first time the system is connected to the network. The gateway then uses the previously saved bonding details to establish a link with the MDs. Figure 11 is also condensed, so that not all incidents are represented.

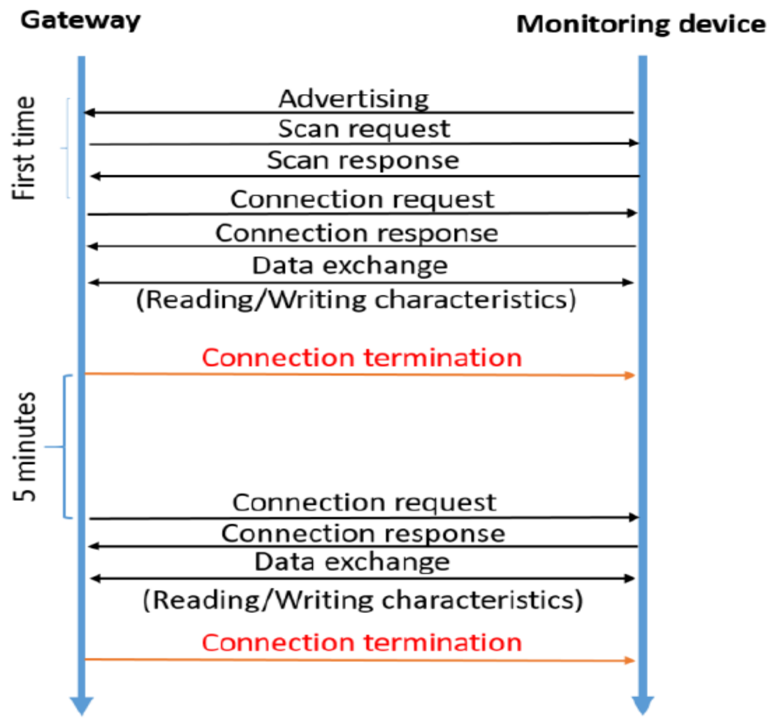

Figure 10. BLE packets exchange between the gateway and the monitoring device

Wi-Fi communication

Via the Wi-Fi AP, Wi-Fi connectivity is used between the gateway and the client user. This correspondence serves two purposes for us. The first prerequisite is for control commands to be forwarded. We use a script that acts as a server for this. In this case, the user interface plays the function of a client, sending requests to the server, and the gateway forwards the commands to the appropriate MD based on the requested data. The client computer also needs to be able to access data consumption stored in the gateway. The user interface is designed to bind to a SQL (Structured Query Language) database, which is where the collected data is stored, for this reason.

Data processing

In terms of communication overhead and time calculation, local in-network processing and distributed calculation are more efficient. We preferred to divide data processing between the MDs and the local central device (gateway) in our system so that the MD processor is not overworked. The MD processor conducts a light measurement of RMS voltage and RMS current values, as well as accumulating energy consumption. On the other hand, in the local central device, we perform reliable energy consumption calculations and data processing for all MDs and over the entire duration, as well as the generation of energy consumption statistics.

Data storage

In the gateways, we installed a SQL database to store the energy consumption values and other data, such as overvoltage and overcurrent values and times, and so on. We opted to hold information in the gateway because, in most situations, the user might switch off the client device (computer or cell phone), resulting in data loss due to a failure to create a link..

5. Experimental results and discussion

5.1. Measurement accuracy

We conducted measurement accuracy tests to assess the efficiency of the established MD. The RMS current and RMS voltage were also checked for accuracy. The RMS voltage value can range from 0.8 Vref to 1.15 Vref, according to [21]. As a result, we tested our device in the [176 V - 253 V] range, keeping in mind that the reference voltage is 220 V. For the full-scale input range, which corresponds to the range [0 A - 5 A], we checked the RMS current accuracy. The calculated values were compared to those given by an effective power measurement system in both cases. Eq. 5 is used to determine the relative error of measurement:

$$Error(\%) = \frac{Mesured\ value - reference\ value}{reference\ value} \times 100 \quad (5)$$

Figure 11 and Figure 12 display the effects of the measurement accuracy tests. The voltage error of the measurements taken by the formed MD is shown in Figure 11. The maximum relative error that has been reported is less than 0.2 percent. In the same way, Figure 12 depicts the existing mistake. For RMS current values below 0.5 A, the overall relative error seen is less than 1%, and it does not surpass 0.5 percent for the other values.

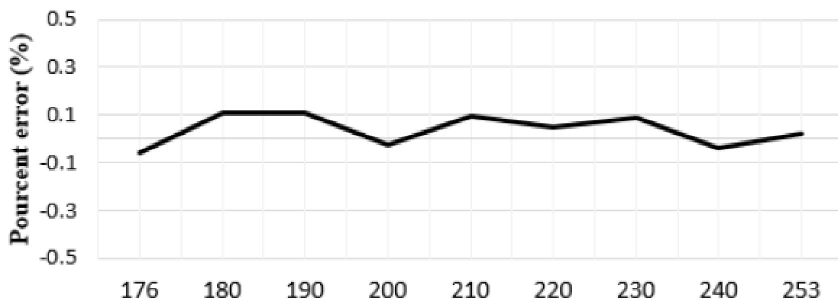

Figure 11. Voltage measurement error.

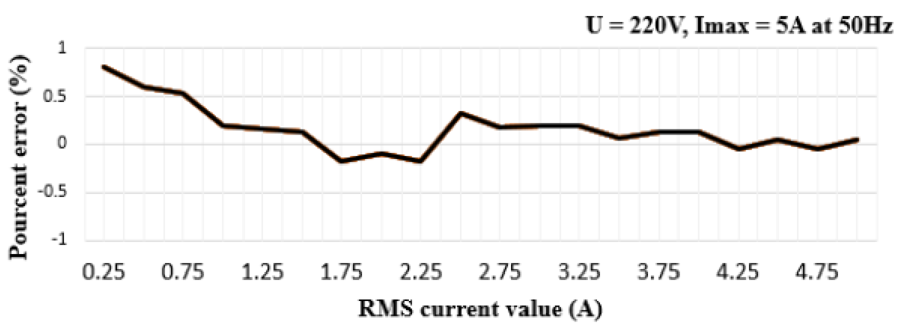

Figure 12. Current measurement error

5.2. User interface

We developed a Graphical User Interface (GUI) for the customer to track and control the household appliances to complete the creation of the wireless monitoring and control system, as shown in Figure 13. The processing portion of this GUI was created with Java 8, and the user-friendly interfaces were created with JavaFx. It enables the user to connect new MDs to the monitoring system's network, as well as configure, edit, and delete them. As shown in Figures 14 and 15, the Interface provides a tab to visualize daily power usage as well as monthly and annual energy consumption. In addition, as seen in all of the figures, a series of actions are available to trigger or disable an MD, switch on/off a household appliance, and schedule an appliance's turn on/off. The consumer can also display real-time power usage information for his household appliances (Figure 16). The figures show an example for a test load with a theoretical current of 0.65 A. Starting at 10:25 a.m., the tests were run with this load. We added another load that consumes 2.5 A after an hour. Later, by increasing the second load, we increased the current consumption.

6. Conclusions

We introduced a wireless monitoring and control system in this paper, which enables residential customers of electrical operator services to track and control the individual energy usage of a group of household appliances. The

Smart Home Energy Management System is built around this monitoring system (SHEMS). The developed system provides the customer with a useful tool for obtaining accurate information about his or her energy usage and, as a result, the ability to conserve energy and reduce his or her electricity bill.

The MDs, the gateway, and the client devices are all interconnected in the presented monitoring scheme. Between the MDs and the client devices is the gateway. It is connected to the MDs via Bluetooth Low Energy (BLE), and thus collects data and sends commands via this link. The client devices are also linked to the gateway through a Wi-Fi network.

Experimental tests were used to assess the performance of the established MD. We obtained errors of less than 0.2 percent for voltage measurements and less than 0.5 percent for current measurements. The MDs' accuracy tests follow the minimum requirements [22].

To round out our framework, we created a user interface that allows the customer to track and manage the MDs. Apart from the application scenario mentioned in this paper, the built hybrid wireless network can easily be applied to other smart home applications that share the same communication infrastructure, such as monitoring and control of lighting, heating, and security systems, by connecting the appropriate sensors and actuators to the PSoC 4 BLE modules.

We intend to introduce a residential energy management algorithm in the future to monitor the energy usage of electrical appliances and provide a comprehensive method for the consumer to regulate and reduce his overall energy consumption.

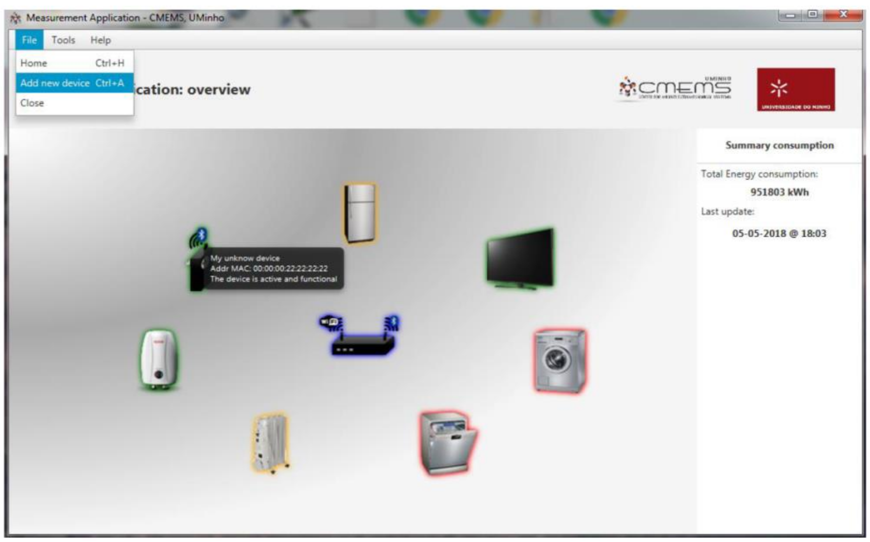

Figure 13. Home screen of the developed GUI

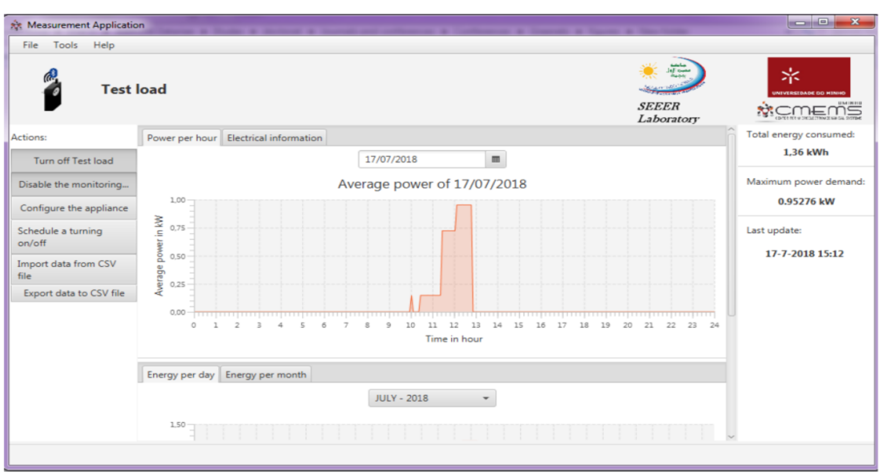

Figure 14. Example of power consumption chart provided by the GUI

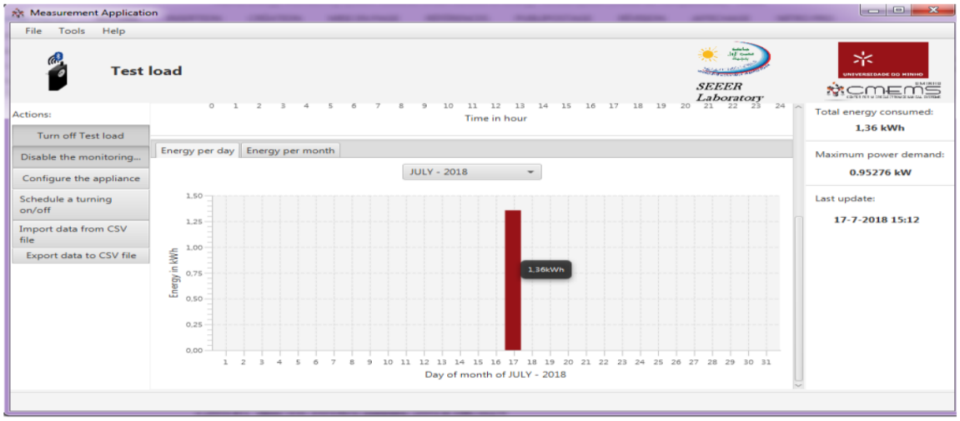

Figure 15. Example of energy consumption chart provided by the GUI

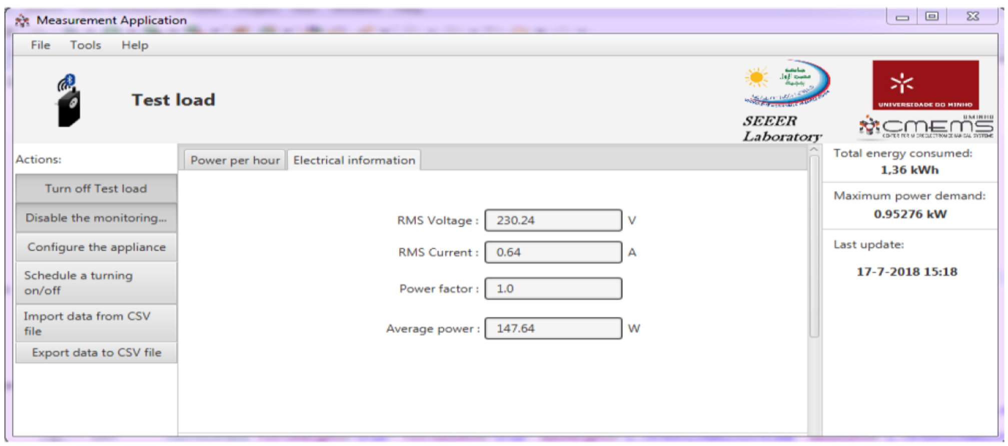

Figure 16. Example of real time electrical information provided by the GUI

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References

1. R. R. Mohassel, A. Fung, F. Mohammadi, and K.Raahemifar, “A survey on Advanced MeteringInfrastructure,” Int. J. Electr. Power Energy Syst., vol. 63,pp. 473–484, 2014.
2. Z. Jebroni, H. Chadli, E. Chadli, and B. Tidhaf, “Remotecalibration system of a smart electrical energy meter,” J.Electr. Syst., vol. 13, no. 4, pp. 806–823, 2017.
3. Z. Jebroni, H. Chadli, B. Tidhaf, A. Benlghazi, and A.Tahani, “Gain Correction and Phase Compensation of aSmart Electrical Energy Meter,” in 2016 InternationalConference on Engineering & MIS (ICEMIS), 2016.
4. C. Chupong and B. Plangklang, “Electricity bill forecastingapplication by home energy monitoring system,” in 2017International Electrical Engineering Congress, iEECON2017, 2017.
5. Z. Jebroni, J. A. Afonso, and B. Tidhaf, “Home EnergyMonitoring System Towards Smart Control of EnergyConsumption,” in Green Energy and Networking, 2019, vol.269, pp. 40–53.
6. Sharma, A. Verma, and M. Bhalla, “WiFi home energymonitoring system,” in 2016 International Conference onInformation Technology, InCITe 2016 - The NextGeneration IT Summit on the Theme - Internet of Things:Connect your Worlds, 2016, pp. 59–61.
7. W. Guido R. Hiertz, Dee Denteneer, LotharStibor,YunpengZang, Xavier Pérez Costa, “The IEEE 802 . 11Universe,” vol. 48, no. 6, pp. 62–70, 2010.

8. Bluetooth Special Interest Group (SIG), Specification of theBluetooth system. Master table of contents &compliancerequirements. Version 5.0, December 2016.
9. J. A. Afonso, F. Rodrigues, P. Pereira, H. Gonçalves, and J.L.Afonso, "Wireless Monitoring and Management ofEnergy Consumption and Power Quality Events," inProceedings of the World Congress on Engineering, 2015,vol. I.
10. P. Baronti, P. Pillai, V. W. C. Chook, S. Chessa, A. Gotta,and Y. F. Hu, "Wireless sensor networks: A survey on thestate of the art and the 802.15.4 and ZigBee standards,"Comput. Commun., vol. 30, pp. 1655–1695, 2007.
11. Rashdi, R. Malik, S. Rashid, A. Ajmal, and S. Sadiq,"Remote Energy Monitoring, Profiling and ControlThrough GSM Network," in Arabian Journal for Scienceand Engineering, 2012, pp. 184–188.
12. Y. Bikrat, D. Moussaid, A. Benali, and A. Benlghazi,"Electronic and Computer System for Monitoring aPhotoltaic Station," in 2018 International Conference onIntelligent Systems and Computer Vision (ISCV), 2018.
13. U. Ahsan and A. Bais, "Distributed Smart HomeArchitecture for Data Handling in Smart Grid Architecturedistribuéed'unemaisonintelligente pour la gestiondesdonnéesdans un réseau intelligent," Can. J. Electr. Comput.Eng., vol. 41, no. 1, pp. 17–27, 2018.
14. N. Ertugrul, C. E. McDonald, and J. Makestas, "Homeenergy management system for demand-based tarifftowards smart applicances in smart grids," in Proceedings of the International Conference on Power Electronics and Drive Systems, 2017, pp. 511–517.
15. Electricity tariffs. [Online]. Available:
16. http://www.one.org.ma/FR/pages/interne.asp?esp=1&id1=3&id2=113&t2=1.
17. J. A. Afonso, A. J. F. Maio, and R. Simoes, "PerformanceEvaluation of Bluetooth Low Energy for High Data RateBody Area Networks," in Wireless PersonalCommunications, 2016, vol. 90, no. 1, pp. 121–141.
18. Al-fuqaha, M. Guizani, M. Mohammadi, M. Aledhari, and M. Ayyash, "Internet of Things: A Survey on EnablingTechnologies," Commun. Surv. Tutorials, IEEE, vol. 17, no.4, pp. 2347–2376, 2015.
19. Cypress Semiconductor, "CY8CKIT-042-BLE-A Bluetooth® Low Energy 4.2 Compliant Pioneer Kit." [Online].Available:https://www.cypress.com/documentation/development-kitsboards/cy8ckit-042-ble-bluetooth-low-energy-42-compliant-pioneer-kit.
20. Bluetooth Special Interest Group (SIG), "GATT
21. Services."[Online].Available:https://www.bluetooth.com/specifications/gatt/services.
22. TA12-100 datasheet. [Online]. Available: http://en.yhdc.com/product1371.html?productId=492
23. ONEE-BE, "Technical specification - electronics energymeter for low voltage customers," 2014.
24. International Electrotechnical Commission (IEC, "IEC62053-21 – Electricity metering equipment (a.c.) – Particular requirements – Part 21: Static meters for activeenergy (classes 1 and 2)," 2003.