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# INTEL GALILEO BASED HOME AUTOMATION SYSTEM IN MALAYSIA

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## Graphical abstract


## Abstract

Several home automation systems have been rapidly introduced in the recent years. However, the consumer adoption of home automation systems has been immensely slow. Moreover, most home automation systems available in the market are designed for western countries and do not have certain features that are crucial for consumers in tropical countries like Malaysia. Therefore, this paper identifies the possible criteria for this slow adoption and evaluates the potential of Intel Galileo for addressing these problems. Four popular home automation technologies are analysed and surveys are conducted to identify the needs of electricity and water consumers in Malaysia. A low cost, secure, user-friendly, easily installed and flexible Intel Galileo based home automation system that caters the needs of Malaysians is presented. The system is integrated with an Android application and uses a Wi-Fi network. To demonstrate the feasibility and effectiveness of the proposed system, the design and prototype implementation of a basic home automation system based on the Intel Galileo is developed and evaluated based on several tests and interviews. The proposed system can be used as a reference to increase consumer adoption of home automation systems in tropical countries.

*Keywords*: Home automation, intel Galileo, sensor systems

## Abstrak

Beberapa sistem automasi rumah telah diperkenalkan dengan pesat sejak kebelakangan ini. Namun, sistem automasi rumah ini masih kurang diterima pakai. Selain itu, kebanyakan sistem automasi rumah yang terdapat di pasaran direka untuk negara-negara Barat dan tidak mempunyai ciri-ciri tertentu yang penting untuk pengguna di negara-negara tropika seperti Malaysia. Oleh itu, penyelidikan ini berfungsi untuk mengenal pasti kriteria yang mungkin menyebabkan sistem automasi rumah kini kurang diterima pakai dan juga menilai potensi Intel Galileo untuk menangani masalah yang didapati. Empat jenis teknologi automasi rumah yang popular telah dianalisa dan satu kaji selidik telah dijalankan untuk mengenal pasti cara penggunaan tenaga elektrik dan air oleh pengguna di Malaysia. Sebuah sistem automasi rumah Intel Galileo yang berkos rendah, selamat dan mesra digunakan, mudah dipasang dan fleksibel telah dibentangkan. Sistem ini menggunakan rangkaian Wi-Fi dan diintegrasikan dengan aplikasi Android. Untuk menunjukkan kebolehlaksanaan dan keberkesanan sistem yang dicadangkan ini, sebuah prototaip asas telah dibina dan dinilai berdasarkan beberapa ujian dan temuduga. Sistem yang dicadangkan ini boleh digunakan sebagai rujukan bagi meningkatkan penerimaan pengguna terhadap sistem automasi rumah di negara-negara tropika.

*Kata Kunci*: Automasi rumah, intel Galileo, sistem sensor

## 1.0 INTRODUCTION

Home automation is the introduction of technology within the home to enhance the quality of life of its occupants, through the provision of different services such as telehealth, multimedia entertainment and energy conservation [1]. Automation systems are used to monitor and control the energy usage of electrical appliances and equipment [2]. There are many other devices that can be connected to the home automation system such as motion sensors, temperature sensors, etc. to provide convenience and security to the users [3]. These systems provide users with benefits in terms of safety, comfort, power saving and communications [4].

Although a number of home automation technologies were introduced throughout the years, it can be seen that the implementation of these systems in households remains low. The slow consumer adoption of home automation systems reflects that the existing technologies introduced could have certain criteria that do not fulfil consumer needs. The use of home automation systems in tropical countries like Malaysia is rather low as well. This is probably because most existing home automation systems available in the market are designed to meet the needs of western countries consumers. For instance, popular home automation brands that are used in the western countries like HomeSeer [15] and Savant [16] provides many useful and beneficial features, but features like fan and water control that are crucial for tropical countries consumers' lifestyles are not supported. Another popular brand known as Control4 [17] offers fan control to help circulate air, but water control for bathrooms are not provided. The use of these existing systems is not practical enough to be used in tropical countries that do not have four seasons but have hot and humid weather throughout the year like Malaysia.

In this study, several existing popular home automation technologies are analysed to identify the possible criteria that will affect consumer adoption of home automation systems. Surveys are conducted to determine the needs of electricity and water consumers in Malaysia. Eventually, a home automation system based on the Intel Galileo that caters the needs of Malaysians is presented. The system uses a secure Wi-Fi network which reduces installation cost and complexity, and it is integrated with a user-friendly Android application to act as virtual switches that can control home appliances and update their states (on/off/automatic) in real time. Several sensors are connected to the home automation system to automatically control certain appliances. The Android application developed is also able to calculate electricity and water consumption and record the usage history. The use of Intel Galileo as the master controller and the Arduino Uno as the slave controller provides improved convenience and flexibility with a lower cost.

In order to demonstrate the feasibility and effectiveness of the proposed system, the design and prototype implementation of a basic home automation system is developed and evaluated based on several tests and interviews. This study can be used as a reference to increase consumer adoption of home automation systems in tropical countries like Malaysia. In the following sections, the advantages and disadvantages of the existing home automation technologies in the literature are discussed, and the criteria affecting the consumer adoption of home automation systems are proposed. After that, the details of the proposed system architecture are explained, followed by an evaluation on the system prototype. Lastly, the paper is concluded and possible future works is discussed.

## 2.0 RELATED WORK

A large number of researches about home automation systems are conducted especially in the recent years [5], [6], [7], [8]. Normally, the common focus of these researches is to identify the best approach that can be used to develop the home automation system. This matter is very important as it influences the consumer adoption of home automation systems. In this section, various home automation technologies are discussed and the possible criteria of the slow adoption are proposed.

### 2.1 SMS & GSM

A home automation system based on SMS and GSM technology is introduced in 2012 [5]. The proposed system consists of two main components: the GSM modem and the micro-controller. Since each SMS contains username and password and every SMS being exchange requires user authentication, the system is secure from intruder access. This system does not require any special modification on network infrastructure and has a great amount of flexibility and scalability, as the system can run anywhere as long as there is GSM network coverage. However, the GSM based home automation has some drawbacks due to the high system running cost, as every single SMS of network connectivity is a paid service. Moreover, accessing the home automation despite of the user's location is not necessary as common users only use the system when they are at home.

### 2.2 Bluetooth Module

Besides SMS & GSM, Bluetooth technology is also introduced as one of the applicable home automation technologies [6]. The proposed home automation system controls home appliances from a PC using Bluetooth modules. This system consists of a primary controller and a number of Bluetooth sub-controllers. The use of wireless Bluetooth technology does not require a lot of physical wiring. Hence, the complexity of the installation is greatly reduced. However, the disadvantage of this system is that the sharing of a single Bluetooth module between

numerous appliances incurs an access delay. If the modules are not shared, the cost to implement the system will be too costly. In addition, the system lacks of user-friendliness as it cannot be controlled remotely using a mobile device.

### 2.3 Cell Phone & Arduino BT

In 2011, the design and implementation of a home automation system based on the Arduino BT board and a cell phone connected to the board via Bluetooth is presented [7]. The system is secure as the Bluetooth technology acquires pairing password from users before they are allowed to access the Arduino BT and control home appliances. This adds a protection from unauthorized users and intruders. The implementation of the cell phone remote control also adds usability to users. However, the system can only control one appliance at a time and does not support automatic mode. Furthermore, the wireless Bluetooth communication between the cell phone and the Arduino BT is limited to 5-30m in a concreted building and it has a slow bit rate of 2.1Mbps.

### 2.4 ZigBee & Wi-Fi

Another home automation technology that was introduced is the ZigBee. Using this technology, a home automation system is implemented for the monitoring and control of home appliances [8]. The wireless technology of ZigBee and Wi-Fi eliminates the hassle of running wires. This overcomes the problem of intrusive installations as the system can be easily set up and does not need any complex architecture. Since Wi-Fi networks and Wi-Fi enabled devices such as mobile phones are common for all typical households nowadays, the cost to implement Wi-Fi networks in home automation systems can be greatly reduced. ZigBee's low power consumption and open specifications makes the devices ideal for battery-operated uses. However, technologies such as Bluetooth, microwave ovens and cordless telephones can cause interference with ZigBee [12]. Moreover, the cost of a single ZigBee controller is expensive, which is about RM940 (Amazon.com).

### 2.5 Criteria Affecting Consumer Adoption of Home Automation

From the analysis on the popular home automation technologies, five possible criteria that may affect consumer adoption are proposed, they are: the security, usability, cost of the system, complexity of the architecture, and the installation of the system. Security of the system should be strong enough to gain user confidence in using the system. The system should be designed in a way that can minimize the risk of system hacking by unauthorized users. Usability is another important criterion that users are looking for in a system. The use of mobile devices to control the home appliances helps to increase user-friendliness. Cost of the system should be affordable for average-income groups in order to increase the rate of consumer adoption. If the system requires high cost of installation and maintenance, majority of the potential users may not be able to afford the implementation of the system at their homes. The architecture should be flexible so that users can easily add new appliances to the system. Lastly, installation of the system should be easy enough in a way where no special modification on network infrastructure is needed. The use of wireless technology is a good tool in reducing the complexity of the installation.

## 3.0 SYSTEM ARCHITECTURE

A survey was conducted to identify the needs of electricity and water consumers in Malaysia so that a suitable home automation system can be proposed according to their needs. A number of 70 respondents made up of a quite well-balanced gender of males & females and of different ethnicities participated in the survey. Their age range from 19 to 58 years old and they are involved in a variety of occupational fields such as doctor, dentist, accountant, teacher, student and others. From the results gathered, majority of the respondents own at least one mobile device and have Wi-Fi network at home. 97% of them have three or more fans at home, 85% of them bathe two or more times a day, and 96% of them take more than 5 minutes when they bathe. Thus, it can be deduced that for common Malaysian households, fans are major home appliances and water consumption for personal hygiene throughout the year is much higher than western countries because of the hot and humid weather in Malaysia. Moreover, 65% frequently forgot to turn off the fan when they leave the room and 51% of them do not turn off the tap when they apply shampoo or brush their teeth. These habits lead to a waste in energy and water. Consequently, the survey results have led to a conclusion that the automation of fans and water taps are fundamental and essential features that would cater the needs of Malaysians.

Therefore, a system architecture that is secure, user-friendly, low-cost, flexible and easily-installed home automation system that includes fan and water tap automation is proposed. The overview of the conceptual architecture is illustrated in Figure 1. The Intel Galileo that has built-in Ethernet port is used to act as the master controller of the appliances while the Arduino Uno is used as the slave controllers. Each home appliance will be connected to an Arduino Uno that integrates a relay and a Wi-Fi module to enable a wireless communication between system's devices. Several sensors will be implemented with the home appliances where necessary, such as the motion sensor to automate the turning on and off of a light and the bathroom water flow. The system will use a secure Wi-Fi network to avoid intrusive installations with a lower cost, and an Android application controlled using mobile devices like smartphones or tablets to increase user-friendliness. The proposed architecture is

straightforward and flexible, as new appliances can be easily added into the system.

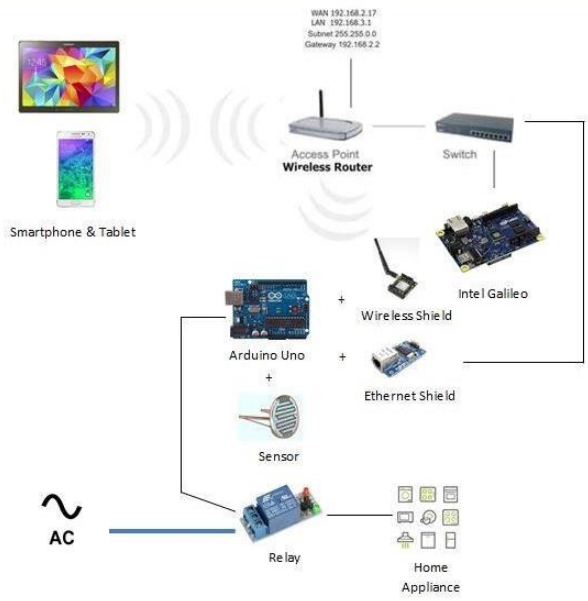


**Figure 1** Overview of Conceptual Architecture

### 3.1 Intel Galileo

The Intel Galileo is a microcontroller board based on the 32-bit Intel Quark SoC X1000 application processor. It is the first board based on Intel x86 architecture designed to be hardware and software pin-compatible with shields designed for the Arduino Uno [9]. The Intel Galileo board is somewhat similar to the Arduino BT board as discussed above, but it has higher specifications in terms of the processor speed, RAM and cache capabilities. It also has a built-in Ethernet port. For the proposed system, the Intel Galileo is connected to the switch which is linked to a router. Users can set a list of pre-defined rules (automatic user modes) using the Android application and transmit these commands to the Intel Galileo. For example, users can choose to turn on the fan, water the plants and boil water in the kettle daily at 6pm. Then, the Intel Galileo that acts as the master controller will communicate the set of commands to the home appliances through the Arduino Uno.

Besides handling automatic user modes, the Intel Galileo is also used to calculate the electricity and water usage of a household. The formulas used to calculate the electricity consumption of a single electrical appliance are:

- Daily Energy Consumption in kWh = (Wattage * Hours Used Per Day) / 1000
- Monthly Energy Consumption = Daily Energy Consumption in kW * Number of Days Used per Month

For example, a light bulb usually uses up to 60 W of electricity. If the usage is about 5 hours per day, from 7pm to 12am, the daily energy consumption will be (60 W * 5 hour) / 1000 = 0.3 kWh, while the monthly energy consumption of the light bulb will be 0.3 kWh * 31 days = 9.3 kWh. Hence, if a light bulb is operating for 5 hours per day and 31 days continuously, the electricity consumed will be 9.3 kWh. To calculate water usage, a flow meter will be integrated to act as a flow rate sensor. Hall effect is utilized in the flow meter using a small fan shaped rotor which is placed in the path of the liquid flowing. The liquid flowing will push against the fins of the rotor, causing it to rotate. The shaft of the rotor is connected to a hall effect sensor (an arrangement of a current flowing coil and a magnet connected to the shaft of the rotor). A voltage or pulse will be induced as this rotor rotates [14]. In this flow meter, every litre of liquid passing through it per minute will output about 4.5 pulses. This is due to the changing magnetic field caused by the magnet attached to the rotor shaft. The number of pulses will be measured and the flow rate in litre per hour will be calculated using the Intel Galileo. Then the readings will be sent to the mobile device Android application.

### 3.2 Arduino Uno

The Arduino Uno is a microcontroller board based on the ATmega328. It has 14 digital input/output pins, 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button [10]. Although Arduino Uno do not have on-board LAN port interface but it is compatible with many shields including the Ethernet Shield with Micro-SD and Wireless Module Shield. This makes the Arduino Uno more convenient to be modified and easier to add-on new functions or sensors. For the proposed system, the Arduino Uno which acts as the slave controller is embedded with home appliances, a relay and a Wireless Module Shield to enable a wireless communication with the Android application and the Intel Galileo. For automatic user mode, several Arduino Uno will receive commands from the Intel Galileo and control home appliances according to the set of commands. For manual mode, the Arduino Uno receives commands directly from users through the mobile device to control the home appliances.

### 3.3 Wi-Fi Network

Wi-Fi is a term for wireless local area networks (WLAN) that use specifications in the IEEE 802.11 family and offers wireless networking through the use of radio frequency [11]. A Wi-Fi network uses Wi-Fi Protected Access 2 (WPA2) to provide both security and privacy [12]. In the proposed system architecture, Wi-Fi is used as a tool for secure wireless communications to provide access to the home automation system with Wi-Fi enabled devices. Wi-Fi is the chosen communication standard because majority of the homes in Malaysia have Wi-Fi networks and Wi-Fi enabled devices such as smartphones and tablet. This reduces the cost and complexity of installation as users can use the readily available Wi-Fi infrastructure at home to implement the home automation system. On top of that, the high data rate nature of Wi-Fi provides

more flexibility to add new appliances to the system. Moreover, users are familiar with this technology.

### 3.4 Android Application

Android is a mobile operating system (OS) that is designed primarily for touchscreen mobile devices such as smartphones and tablets. Android is the most widely used mobile OS and the highest selling OS as of 2013, leading this OS to be the market leader in 135 countries including Malaysia [13]. Thus, Android was selected as the platform for the development of the application for users to control the system. The Android application enables users to control the system remotely via mobile devices connected to the Wi-Fi. The application also allows users to check electricity and water consumption of their home appliances. This helps to increase the user-friendliness of the system.

### 3.5 Sensors

The proposed system implements several sensors to automate electrical appliances such as the light, fan, water tap and other necessary appliances for Malaysian households. They are the Passive Infrared (PIR) Sensor and the Infrared LED Emitter & Detector to detect motion, and the temperature sensor to detect room temperature.

The PIR Sensor detects changing patterns of passive infrared emitted by objects within the sensor range of approximately 6 meters. They are small, inexpensive, low-power and energy-friendly [18], thus making it an effective tool to detect motion for automation. On the other hand, the Infrared LED Emitter & Detector generates signals based on proximity or reflectance of an object within the field-of-view of the emitter or detector [19]. This will be used to build a presence sensor to be placed at the entrance or exit of rooms. It works by counting the number of people in a room for automating appliances. These sensors will be used to automate the turning on and off of lights, fans and water taps in homes, depending on the condition of the home compound.

Additionally, since fans are major appliances in Malaysian households, the temperature sensor is used to automate the spinning speed of fans according to the surrounding temperature to save electricity and increase usability. As temperature increases, the voltage across a diode of the sensor increases at a known rate. By precisely amplifying the voltage change, an analog signal that is directly proportional to temperature will be generated [20]. This sensor is inexpensive, precise, do not need calibration, and has consistent readings.

## 4.0 PROTOTYPE IMPLEMENTATION

The prototype of the proposed system is depicted in Figure 2. As illustrated, an Intel Galileo based home automation system is implemented to monitor and control home appliances. Since the two major home appliances used in Malaysia are the light and fan, the prototype was developed using a light bulb and a mini fan. The controlling of water flow is not implemented in the prototype as a high cost and plumbing installation is needed for the prototype development. The Wi-Fi network is set up for the prototype using a standard Wireless ASDL Modem Router. An Intel Galileo Gen2 Development Board, an Arduino Uno Board and a relay module is used to develop the prototype. The sensors used in this prototype are the Passive Infrared Sensor, also known as PIR sensor or motion sensor, two pairs of Infrared Emitter & Detector, and the Temperature Sensor. The materials used are as shown in Figure 3.

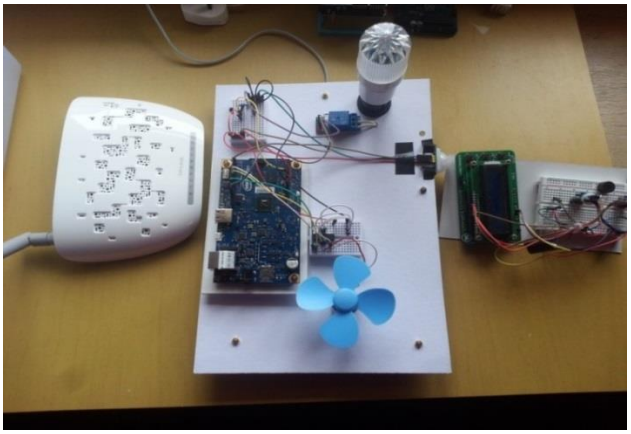

**Figure 2** System Prototype

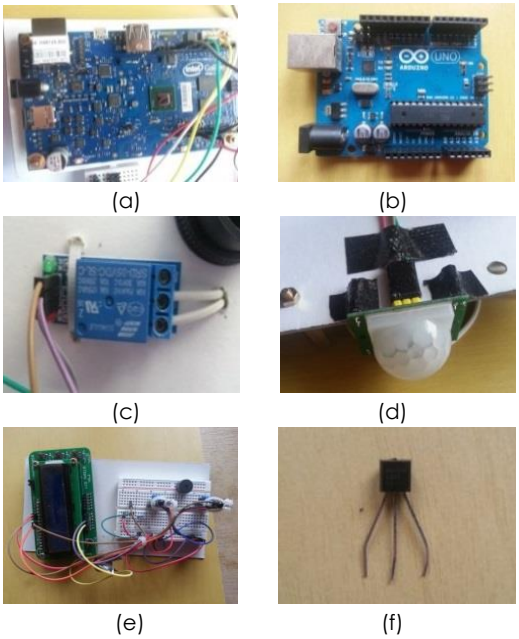


**Figure 3** Materials Used for Prototype Development: (a) Intel Galileo Gen2 Development Board; (b) Arduino Uno Board; (c) Relay Module; (d) Motion Sensor; (e) Two Pairs of Infrared Emitter & Detector integrated with Arduino Liquid Crystal; (f) Temperature Sensor

The Intel Galileo acts as the master controller that receives a set of predefined rules sent by users via their

mobile devices. These commands will then be sent to the respective home appliances via the Arduino Uno, which is the slave controller. The Arduino Uno controls the turning on or off of the appliance according to the commands received by the Intel Galileo. The Arduino Uno can also control the appliances according to the commands received directly from users via mobile device. This depends on the home automation mode (automatic/manual) set by users.

The motion sensor is used to detect motion and automate the turning on and off of the light and fan. If a motion is detected, the light and fan will be switched on. When no motion is detected anymore, the light and fan will be automatically switched off. The motion sensor is also used to automate the water flow of water taps, but this is not implemented in the prototype. On the other hand, the pair of infrared detectors is used to count the number of people in a room to automate the turning on and off of the light and fan. This sensor will be placed at the entrance or exit of rooms. An Arduino Liquid Crystal is used to display the number of people that enters a room. When a user enters a room, the number of people in the room will be incremented by one. If there are one or more people in the room, the light and fan will be switched on. When no users are in the room, the appliances are switched off. Lastly, the temperature sensor is used to automate the spinning speed of the mini fan according to the surrounding temperature. The sensor will be placed as far as possible from the fan in order to detect the most accurate room temperature. If the temperature increases, the mini fan will spin faster. A basic Android application is developed to control the prototype remotely with a mobile device. The application allows users to add new rooms, add new appliances, turn on and off appliances, and check the electricity and water usage of the household. Some screenshots of the important interfaces are shown in Figure 4.

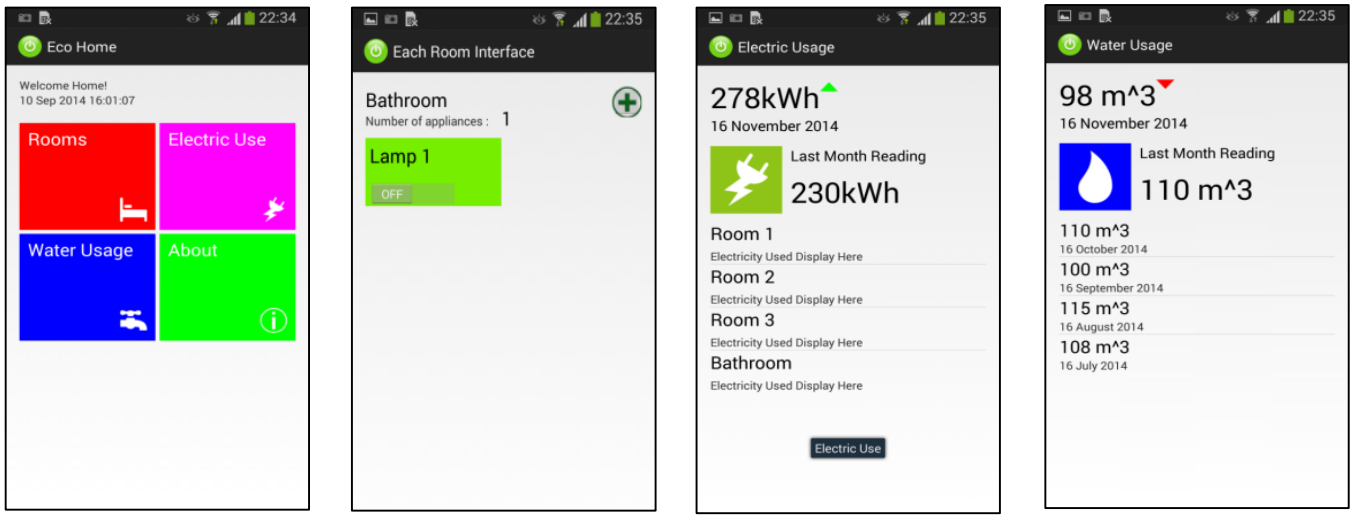


**Figure 4** Screenshots of the Android application

## 5.0 EVALUATION

The proposed system is evaluated based on the five criteria that are proposed earlier. The evaluation shows that the proposed Intel Galileo based system is secure, has good usability, low cost, flexible and can be easily installed. The mentioned criteria together with their explanations and evaluation results are listed in Table 1.

In order to demonstrate the feasibility and effectiveness of the proposed system, the prototype developed is evaluated using both quantitative and qualitative methods. To test if the sensors and the Android application are successfully integrated with the system, the system is subjected to a simulation test with a high level usage as the qualitative analysis. The light and fan states are changed remotely for 20 times using the Android application connected to a Wi-Fi network, 20 times using the motion sensor, and 20 times using the infrared detectors. The Android application and the motion sensor has shown 100% correct functionality with all 20 tests successful, while the infrared detectors showed 91% of successful detections with 18 out of 20 tests successful.

For the qualitative analysis, interviews were conducted from the 5th of December 2014 to 12th of December 2014 with 10 electricity and water consumers of different occupational fields like teacher, auditor, technical staff, etc. from different regions of Malaysia. The objective of the interview is to evaluate end users' perspective of the proposed system and find out if the proposed system has the potential to improve consumer adoption on home automation systems in Malaysia. First, the proposed system architecture was briefly described to each participant with the use of the figure shown above (Figure 1), followed by a verbal justification on the reasons why the system is designed this way and the benefits it would bring. Then, the participants were allowed to test out the prototype with the Android application on

a mobile device. Since water tap automation was not implemented in the prototype, the concept of the proposed design is verbally explained to the participants. According to the feedback collected, all 10 participants are of the same opinion that the Android application is easy to understand and use, and the ability to control home appliances remotely with the application is very useful. Next, 9 out of 10 participants agree that the usage of the sensors on lights, fans and water taps are effective in conserving energy and water for their homes. Only one participant felt that the implementation of sensors to control water flow is unnecessary as the participant's water usage at home is not costly. The proposed system is estimated to cost about MYR 600 in order to implement in homes, and all 10 participants are willing to pay for it as the system is considered low-cost and affordable. Moreover, the ease of installation and the flexibility to add new appliances to the system using wireless technologies is favoured by all participants and all of them have a secure Wi-Fi access at their homes. From the results obtained, it can be deduced that the proposed system has a great potential to improve consumer adoption of home automation systems in Malaysia.

**Table 1** The comparison and evaluation by proposed criteria

| Criteria | SMS & GSM [5] | Bluetooth Module [6] | Cell Phone & Arduino BT [7] | ZigBee & Wi-Fi [8] | Intel Galileo & Wi-Fi |
|---|---|---|---|---|---|
| **Security** | **Secure** – SMS exchange requires user authentication | **Insecure** – no security measures implemented | **Secure** – Bluetooth pairing requires password | **Secure** – secure Wi-Fi communication | **Secure –** secure Wi-Fi communication |
| **Usability** | **Fair –** can monitor appliances remotely anywhere using cell phone SMS | **Poor** – controls system through PC, cannot control system remotely | **Fair –** can control one appliance at a time remotely at home using cell phone app | **Good** – can control the system remotely anywhere online using any Java-supported devices | **Good –** can control one or many appliances at a time remotely at home manually or automatically using cell phone app |
| **Cost** | **High** – every SMS of network connectivity is a paid service | **Moderate –** Bluetooth modules are expensive, but the sharing of the Bluetooth module among appliances reduces cost | **Low** – Use of Bluetooth technology to control appliances reduces cost | **High** – Use of Wi-Fi network reduces cost but the ZigBee module is expensive | **Low** – use of Wi-Fi network reduces installation cost |
| **Architecture** | **Flexible –** can easily add new appliances to the system | **Very Flexible –** can easily add new appliances to the system, especially with the use of Bluetooth modules | **Flexible –** can easily add new appliances to the system | **Very Flexible –** can easily add new appliances to the system, especially with the use of ZigBee modules | **Flexible –** can easily add new appliances to the system |
| **Installation** | **Easy –** no special modification on network infrastructure is needed | **Easy** – wireless Bluetooth technology reduces the complexity of installation | **Easy** – wireless Bluetooth technology reduces the complexity of installation | **Easy** – wireless Wi-Fi and ZigBee technology reduces the complexity of installation | **Easy** – wireless Wi-Fi technology reduces the complexity of installation |
| **Other Remarks** | GSM network allows user to access the system even from outside of home but this implementation requires a high cost | Access delay due to the sharing of a single Bluetooth module between numerous appliances | Bluetooth communication between cell phone and Arduino BT is limited to 5 m -30 m in a concreted building, and it has a slow bit rate of 2.1 Mbps | Wi-Fi offers a wider range of 32 m and higher bit rate of 600 Mbps, and Bluetooth, microwave ovens and cordless telephones can cause interference with ZigBee | Intel Galileo as master controller while Arduino Uno as slave controller with Android application and Wi-Fi network overcomes many limitations |

## 6.0 CONCLUSION

This paper has proposed five possible criteria that may affect consumer adoption of home automation systems. In brief, the criteria are: the security, usability, cost of the system, complexity of the architecture, and the installation of the system. This paper also presents an analysis on the survey conducted to identify the

needs of electricity and water consumers in Malaysia. It is deduced that fans are major home appliances and water consumption for personal hygiene throughout the year is much higher than western countries because of the hot and humid weather in Malaysia. However, features like fan control and bathroom water control are not offered in home automation systems provided by western countries.

A low cost, secure, user-friendly, easily installed and flexible Intel Galileo based home automation system is proposed and implemented. The use of Intel Galileo as the master controller and the Arduino Uno as the slave controller, together with the Android application and the Wi-Fi network helps lower the cost and avoid intrusive installations, at the same time providing good security and usability. The proposed architecture is straightforward and flexible, as new appliances can be easily added into the system. The system design includes the automation of fans and water taps to cater the needs of Malaysians.

The feasibility and effectiveness of the proposed architecture have been successfully evaluated using both quantitative and qualitative methods through tests and interviews. The evaluation has highlighted the stability of the proposed system. The potential of the proposed system has been practically proven with the implementation of the prototype. Interviews conducted have shown a positive attitude towards the developed home automation system. The proposed system is of great potential to improve Malaysian consumer adoption of home automation systems.

The future work may be to further enhance the home automation system by implementing the plant watering system via soil humidity sensors, and automated clothes hanger that can automatically avoid getting the rain using the humidity sensor. Other features that can also be implemented in the future to enhance the Intel Galileo based home automation system are the security system, door lock monitoring and control, gas leakage detection, as well as voice control.

The home automation system is very flexible and many other features can be easily implemented in the future. Thus, useful features can be integrated to cater the needs of specific users.

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## References

[1] Bromley, K., Perry, M. and Webb, G. 2003. Trends in Smart Home Systems, Connectivity and Services. [Online]. From: http://www.nextwave.org.uk. [Accessed on 25 October 2014].

[2] Liu, W. H. E. and Pearson, D. 2011. Consumer-Centric Smart Grid. *In Proc. 2011 IEEE Power Engineering Society Innovative Smart Grid Technologies (ISGT)*. 1-6.

[3] Suba, F., Prehofer, C. and Gurp, J. V. 2008. Towards a Common Sensor Network API: Practical Experiences. *In Proc. 2008 SAINT International Symposium on Applications and the Internet*. 185, 188.

[4] Moraes, F., Amory, A., Calazans, N., Bezerra, E. and Petrini, J. 2001. Using the CAN Protocol and Reconfigurable Computing Technology for Web-Based Smart House Automation. *14th Symposium on Integrated Circuits and Systems Design*. 38-43.

[5] ElKamchouchi, H. and ElShafee, A. 2012. Design and Prototype Implementation of SMS Based Home Automation System. *2012 IEEE International Conference on Electronics Design, Systems and Applications (ICEDSA)*.

[6] Sriskanthan, N., Tan F. and Karande, A. 2002. Bluetooth Based Home Automation System. *Microprocessors and Microsystems*. 26(6): 281-289.

[7] Piyare, R. and Tazil, M. 2011. Bluetooth Based Home Automation System Using Cell Phone. *2011 IEEE 15th International Symposium on Consumer Electronics (ISCE)*.

[8] Gill, K., Yang, S.H., Yao, F. and Lu, X. 2009. A ZigBee-Based Home Automation System. *IEEE Transactions on Consumer Electronics*. 55(2).

[9] Intel. Intel Galileo Boards and Kits – What Will You Make? [Online]. From: http://www.intel.com. [Accessed on 13 November 2014].

[10] Arduino. Arduino Uno. [Online]. From: http://www.arduino.cc. [Accessed on 13 November 2014].

[11] Rouse, M., Morris, D., Hanlin, J. and Walker D. 2004. Wi-Fi. [Online]. From: http://www.techtarget.com. [Accessed on 20 November 2014].

[12] Wi-Fi Alliance. Discover Wi-Fi Security. [Online]. From: http://www.wi-fi.org. [Accessed on 20 November 2014].

[13] Mahapatra, L. 2013. Android Vs. iOS: What's The Most Popular Mobile Operating System In Your Country? [Online]. From: http://www.ibtimes.com. [Accessed on 20 November 2014].

[14] Sanjeev, A. 2014. Measure Water Flow Rate and Quantity Arduino DIY Project. [Online]. From: http://diyhacking.com. [Accessed on 4 December 2014].

[15] HomeSeer. [Online]. From: http://www.homeseer.com. [Accessed on 6 January 2015].

[16] Savant. [Online]. From: http://www.savant.com. [Accessed on 6 January 2015].

[17] Control4. [Online]. From: http://www.control4.com. [Accessed on 6 January 2015].

[18] Adafruit. PIR Motion Sensor Tutorial. [Online]. From: http://www.instructables.com. [Accessed on 10 July 2015].

[19] Me210. IR Emitter/Detector Circuit Overview. [Online]. From: http://me210.weebly.com. [Accessed on 10 July 2015].

[20] Adafruit. Temperature Sensor Tutorial. [Online]. From: http://www.instructables.com. [Accessed on 10 July 2015].