

# DESIGN, DEVELOPMENT AND IMPLEMENTATION OF SMART HOME SYSTEMS USING RF AND POWER LINE COMMUNICATION

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## Abstract

*This paper discusses various aspects of a smart home system especially using RF and power line communication to access and controls your home. The design, development and commercial implementation of a Smart Home System (BestariHome) will be described. Current trends, key issues and standards are also discussed in detail. Finally, based on our broad experience from design to implementation some guidelines for smart home system designers and developers are discussed.*

## 1. Introduction

Today, you can easily control your home's mechanical systems and appliances over your cellular phone or Internet, and the lighting in your home can be set to save your money when you leave the room. The Internet provides even more incredible access to information and services. The Internet will become common and similar to the use of water, electricity and gas.

There have been several smart home projects undertaken by individuals over the last few years. The most popular of these has been Microsoft founder Bill Gates' residence on Mercer Island east of Seattle. The home includes art frames that can display different "paintings" on demand and customize the music played in a room based on the guest's preference.

In general, smart homes provide users with security, convenience and energy management features, as well as having added benefits for disabled individuals.

First part of this paper will discuss the basic features of a typical smart home system; the second part will describe the design and development of a Smart Home Systems (also known as *BestariHome*). Finally, we will share our implementation experience and suggest some guidelines for smart home systems designers and developers.

## 2. Smart Home Systems and Technologies

A smart home allows the entire home to be automated and therefore provide ease and convenience to everyday activities in the home. Automated control, edutainment features, communication features and smart appliances all contribute to the ease and convenience a smart home permits, and remote access to these features through telephone or Internet makes it even more convenient.

Table 1 shows the current and future trends in Smart Home Systems. Some of the interesting features in future Smart Home Systems are such as integrated solution using open architecture and standards.

**Table 1. Smart Homes: Current vs. Future**

| Current                                      | Future                           |
|--|----------------------------------|
| Affordable by high-end homes                 | Standard features in every home. |
| Vendor dependent                             | Open Standards and DIY Concept.  |
| Very expensive maintenance                   | Zero maintenance                 |
| Proprietary and Standalone                   | Integrated solution              |
| Not flexible and adaptable to new lifestyle. | Modular and expandable.          |

## 3. Energy Management

One of the major benefits of smart homes to consumers is their ability to incorporate energy management features. One smart home system manufacturer claims to be able to reduce the electricity bill by 30% depending on the home.

### 3.1 Lighting

The lights in a smart home can be turned on and off automatically and this will help you save on your electricity bill. Lights can be turned on only when they are needed. This can be done based on some sensor input or schedule.

In a typical smart home system whenever a person enters a room in the day time, the system will open the drapes instead of turning on the lights, but at night it would make sure the lights came on and they turned off when no one is in the room. This simple automation can prevent unnecessary wasting of electricity.

### 3.2 Heating and Air Conditioning

The water heating and air conditioning can be more efficiently controlled by a smart home system, saving tremendously on the cost of maintaining a consistent temperature within a large house. One smart home had an estimated heating bill of only one third of a normal house of the same size.

The smart home system saves money by simply being more efficient but added savings can be made because the house can be set to turn off air conditioning when no one is in the house.

### 3.3 Energy Usage Monitoring

Smart homes can even go further in energy management by keeping track of the energy usage of each and every appliance in the house, from the coffee maker o the washing machine. Such features allow you to know what is using too much electricity and adjust things accordingly. An appliance that is using too much energy can be turned off when it is not needed and help lower the costs.

## 4. Safety and Security

The smart home systems allow incorporating far greater features than the traditional alarm systems.

### 4.1 Safety

Safety features can do much more in a smart home than traditional alarm systems. Since almost every element in a smart home is networked together, an alarm can set into action any number of things. One such smart home would not only set off alarm when it detected a fire but would also turn on lights to show occupants the safest route out. Furthermore, it will unlock the doors, open windows to allow smoke to be

ventilated, turn off all the appliances and dial (through auto-dialer) to the nearest fire and rescue services.

### 4.2 Security

Some of the features of the traditional burglar alarm system include turning on and off lights when no one is at home and using video cameras to show the homeowner who is coming up the driveway. In a smart home, sensors and video cameras are used to detect outside movement.

If the security system senses an intruder, for example, the smart home system will trigger the camera to take a picture, digitize it and send it to the homeowner and the police via e-mail.

When the homeowners goes for a vacation the smart home system can be programmed to on and off certain lights and appliances randomly that would give an impression the presence of people inside the house.

## 5. BestariHome - Smart Home Systems

### 5.1 Objectives

The main objectives of this project are as follow:

1. To digitize every electronic device in a house.
2. To connect and link homes to computers, phones and home appliances.
3. To develop a base for learning, working etc.

### 5.2 Design Principles

The design of the *BestariHome* systems uses the 3-level generic specification. The 3-level generic specification is shown in Figure 1. Level 1 is the Basic Infrastructure, Level 2 is the Context Specific Requirements and finally Level 3 is meant for User Specific Functions.

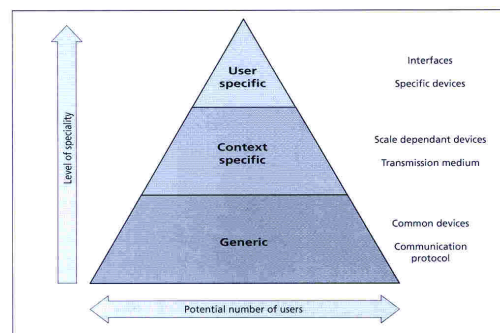


Figure 1. The 3-Level Generic Specification

In addition, every level includes the following features:

- Functionality
- Ease of Installation
- Reliability and Maintainability
- Affordability
- Upgradeability
- Interactivity
- Flexibility and Adaptability

The design of smart home systems should take into consideration of existing houses and new houses. Installing smart home systems in new houses (under development) is very straightforward. This means, any cabling works can be done during the construction stages. However, most of the existing home owners don't like hacking, plastering and repainting of walls in order to install smart home systems.

We need to think ways to overcome this problem so that the existing home owners will enjoy the benefits of the smart home systems. One of the options is to use existing cables in every home. We can use the power line cable to transmit data to control electrical devices in a home. The other option is using wireless technology. However, to use wireless technology for the entire house is very expensive.

Finally, we decided to use the power line and wireless (RF) technology. We choose this option because it's more cost-effective, affordable and sustainable. Security portion of the smart home systems will use the wireless technology while the home automation part will use the power line technology.

### 5.3 Technologies

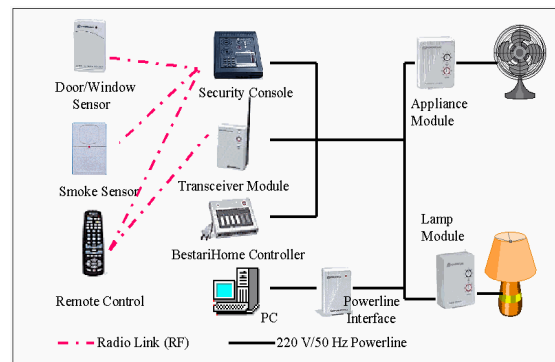
Using a combination of Radio Frequency (RF) and Power Line carrier technology, BestariHome allows home owners to remotely control their home security devices and electrical appliances via wireless, open standard and modular systems. The system also allows home owners in any part of the world to access their home via the Internet and telephone without additional infrastructure such as fiber optics network and broadband connection.

*BestariHome* system is 'wireless' in that some components work on RF while others require no additional wiring (apart from those already available in a house). This means no hacking and replastering of existing walls, no cables and wiring charges [1].

### 5.4 Features

Small and slim wireless sensors are used for home security. These sensors are attached to doors and windows to detect any break-ins. The sensors communicate with a security console through RF signals. The security console will trigger the auto dialer to call up to four telephone numbers (including hand phones) to notify break-ins.

We use powerline technology for home automation which sends signals through the existing 220V/50 Hz AC wiring in the house. Any electrical appliance in the house can be controlled with the help of two components; transmitters (eg. console or remote control) and receivers (eg. switches or plug-in modules). Figure 2 shows the communication architecture of *BestariHome*.



**Figure 2. Communication Architecture of *BestariHome***

The home owner can remotely control devices in his home by clicking on a couple of menus on the PC. The PC will send commands to electrical devices via power lines. The home owner can arm or disarm the alarm system, turn lights on or off lights or any electrical appliances and even control the sprinkler system to water his garden from any part of the world.

### 5.5 Implementation

The installation of smart home systems was awarded based on tender bidding process. We were chosen based on our technology advantage. Figure 3 shows the process that took place during the implementation of smart home systems. The system diagram of smart home systems is shown in Figure 4. The location of the sensors, console and other components of smart home systems are based on the Tender Specification. However, slight changes need to

be done based on the system performance at show houses. Once the project consultant approved the installation of smart home systems in the show houses, we started to replicate the approved system in the rest of the houses. In the process of doing infrastructure work (eg. laying cables), we need to work closely with other sub-contractor

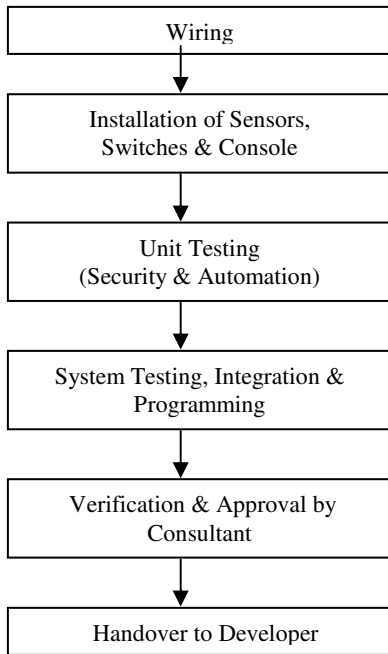


Figure 3: Smart Home Implementation Process Flow

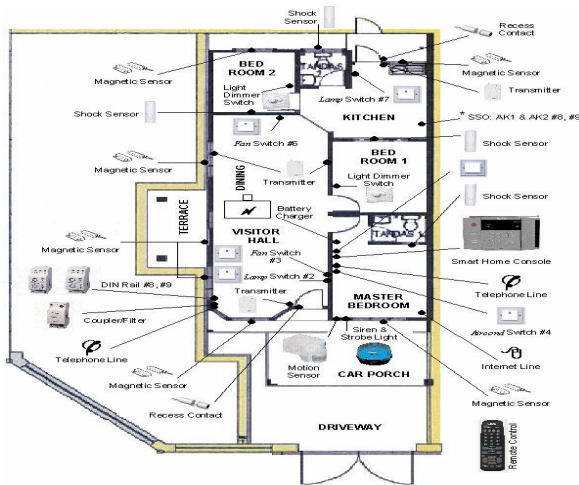


Figure 4. System Diagram of *BestariHome* [2]

## 6. Helping Disabled and Elderly

Smart home system manufacturers strive for mainstream acceptance by broad section of the community but the nature of the technologies makes itself especially useful to the elderly and people with disabilities.

### 6.1 Independence

Smart homes allow people with disabilities maintain an active life because most of the everyday activities in a home are automated. Simple activities such as turning on a light switch or changing a television channel can be difficult for someone with arthritis or some other inhibiting disability. Some smart home comes with a built-in speech recognition system which allows lights and appliances to be turned on or off without the user having to do it manually.

### 6.2 Communication

Smart homes can also help the elderly and disabled by making communication with friends and doctors easier. The telecommunication features in a smart home systems allow the home owner notify family and friends in case of emergency [3].

## 7. Key Issues

Smart Home Systems can both reduce costs and increase productivity and comfort. At the moment there are no standard guidelines for buyers or developers on the minimum features for a Smart Home Systems. The relevant authorities should make this guideline available so that the buyers know the minimum specification of a Smart Home System.

There are too many proprietary Smart Home Systems in the market. As a result system integration is one of the major issues when different systems are used. A disciplined approach to standards and protocols is needed to ensure system interoperability [4].

There is a shortage of trained, knowledgeable and certified professionals in the design, development, installation and integration of Smart Home Systems. Education and training must be provided and promoted at all levels (eg. architects, engineers and developers) in all segments of the industry.

## 8. Guidelines for Designers and Developers

There are some guidelines for designer; these guidelines could be considered as a basic to construct a smart home;

1. User-centered design involves users in the early stage of design; take their life style [5].
2. Work closely with architects, engineers and all the sub-contractors.
3. The design of the smart home systems should be user-friendly, modular, adaptable and affordable. This allows the users to add more features when necessary.
4. Smart home systems should be thought of as essential part of design process and not an after-thought.
5. Seeing technology as enabling and empowering is essential to the design process, whilst it is important to recognize that inappropriate design is disabling and unempowering.
6. Assessments and judgments should consider how the person is to interact with the technology from a psychological, emotional, physical and social perspective [6].
7. Technology requires regular maintenance and it is essential that the system is regularly checked to ensure it still meets the needs it was designed to meet and the costs for this are put into any designs.
8. Training is essential for assessors and for installers and maintenance personnel. Everyone who encounters the smart home system should understand what it is supposed to be doing and be able to assess if it is not performing appropriately.

## 9. Conclusions

The degree of confidence in Smart Home technologies is inadequate largely because lack of awareness and understanding of its value. An integrated communications infrastructure is the essential foundation in the efficient use of Smart Home Systems. The housing developers, smart home system designers and manufacturers, homeowners and other related parties should play a prominent role in realizing smart homes in Malaysia [4].

A smart home system must be designed for the interoperability of the home's devices, systems and networks. The housing developers should incorporate affordable smart home features in their developments.

Smart home system designers and manufacturers need to design system, which are cost effective, reliable, flexible and adaptable using sustainable technologies, open architecture and standards.

## 9. References

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