A Generic Model for Smart House Remote Control Systems with Software and Hardware Simulators

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Abstract— **In this paper, a generic model for smart house remote control systems is proposed, implemented and tested using the software and hardware simulators presented with it. Smart house systems currently available lack a generic model for neither supporting different remote control modules nor standard testing beds. The comprehensive model presented in this paper supports both web and mobile remote access along with hardware and software simulator for testing and parameter estimation before actually building the house. Scenarios can be defined both in the system and simulator to test the long-term effects of different automation schemes, while supporting manual simulation speed control. With the proposed model in use, the analysts no longer need to rely on a physical house to analyze and design economic plans; leading to highly reduced design costs and time consumption.**

Keywords-smart house; model; remote control; simulator; web; mobile; anlaysis;

I. Introduction

Digital era introduces a new controllable device nearly every day. New wireless technologies also help the integration of remote controls into regular mobile devices for easy access to networks simply from everywhere. This increasing number of devices makes it harder for manufacturers to adopt a universal standard for controlling home devices. So a generic model for remote control of the devices in a smart house is needed.

Most of end-users can't simply choose a smart house system off-the-shelf which can rely on as a comprehensive system. This is because although recent works are done in designing the general overview of the possible remote access approaches for controlling devices [1], or in cases simulating the smart home itself [2, 3], and designing the main server [4], the design and implementation of an off-the-shelf smart home remote control application has been limited to simply the computer applications and just in cases mobile and web application development. These efforts has been designed and implemented separately from each other, using all different models. It is a difficult job to join the different platforms and models so that a comprehensive and general model can be developed for remote control of smart digital homes. For example, in [5-8], some remote monitoring systems are designed and implemented to allow remote access through Internet, while in [9-14] some mobile applications are presented for remote access and monitoring systems. None of the systems mentioned earlier follow a comprehensive model so that other possible design and implementation of additional modules can be added to the general system.

In this paper, a generic model for smart house remote control systems is proposed, implemented and tested using the software and hardware simulators presented with it. Smart house systems currently available lack a generic model for neither supporting different remote control modules nor standard testing beds. The comprehensive model presented in this paper supports both web and mobile remote access along with hardware and software simulator for testing and parameter estimation before actually building the house. Scenarios can be defined both in the system and simulator to test the long-term effects of different automation schemes, while supporting manual simulation speed control. With the proposed model in use, the analysts no longer need to rely on a physical house to analyze and design economic plans; leading to highly reduced design costs and time consumption.

II. Proposed Model Architecture

A. Preface

Due to the great importance of a precise and comprehensive design for smart houses, first we must design the principle parts of the system. The main modules of the system are (1) the processing and controlling center, (2) display and remote control module, (3) hardware module, and (4) simulator module. If these sections are correctly and efficiently connect to each other while perfectly functioning, it can be expected to have a firm baseline for further investments and improvements.

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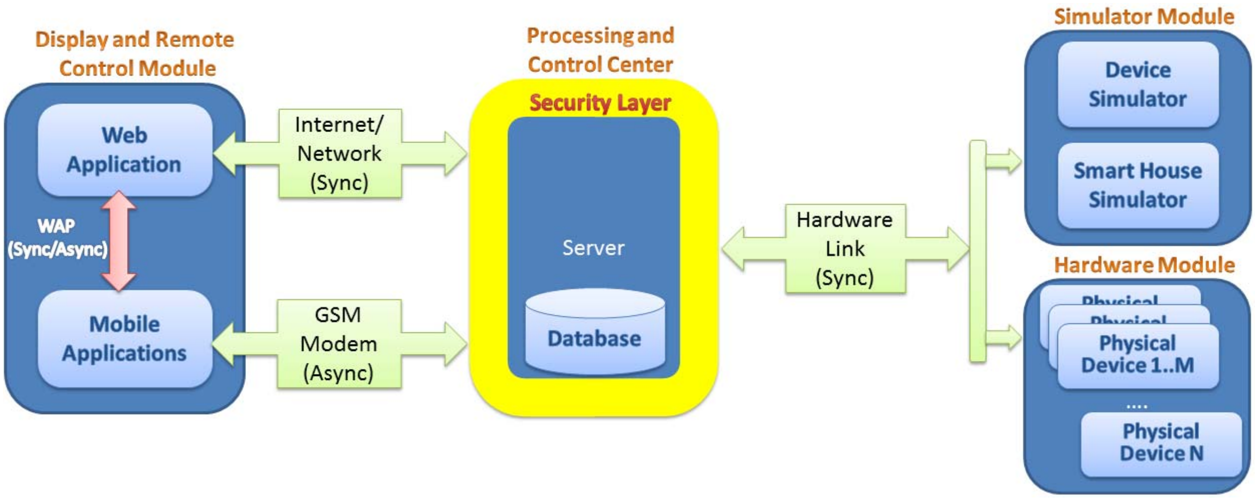

Figure 1. The proposed generic model of a smart house control center with four main modules and subparts.

B. Proposed Generic Model

Fig. 1 illustrates the main parts of the proposed model, including the main modules and their subparts. The mentioned four main parts of the system are described below:

1) Processing and Control Center

The most crucial and important part of a smart house controlling system is the processing and control center (PCC). Every communication in the system must first transmit through PCC before they can cause an action. Sensors and actuators connect to PCC using their device controllers. Every condition that is based on several sensors will be evaluated in PCC and if all criteria are in acceptance range, PCC will trigger an action and some actuators will act. A security layer is needed around the main server of the PCC. This is mainly because an infiltration in the PCC might cause severe damage and will danger the safety of the system. The database in PCC is also of great importance, making the security layer even more needed.

2) Display and Remote Control Module

Comprehensive user interaction with the system occurs through display and remote control module. This module consists of several communication applications, such as web and mobile software. The mobile software is able to transfer data asynchronously through a GSM (Global System for Mobile Communications) modem using SMS messages, from and to PCC. It can also connect to web application using either synchronous or asynchronous connection using mobile WAP (Wireless Application Protocol), e.g. GPRS, EDGE, WiFi, etc.

The web application itself is connected synchronously to the PCC, receiving sensor information and transmitting actuator signals. An interface for end user is also available in the web application, enabling the user to view, add and edit sensors, actuators, objects, scenarios, etc. Map view of the device locations is also presented in both web and mobile application for better visualization and user interaction.

3) Hardware Module

PCC is connected directly or via device controllers to hardware devices. There can be several hardware devices, each with different sensors and actuators, including location sensor. Any supported hardware linking system (e.g. ZigBee) or network protocols can be used to link the PCC to hardware devices. Each device must have a unique ID to be recognizable by PCC and web applications. The connection should be synchronized so that in case of any change in the device sensors, it must be transferred to PCC immediately and vice versa for actuator commands.

4) Simulator Module

Due to expensive costs of testing and diagnosing smart house models or controlling systems, a simulator module is embedded in the model, both for a single hardware device simulation and an all-purpose smart house simulation. The smart house simulator supports scenarios and speed control for easy simulation of long-term situation of a real smart house to help analysts assess their proposed model of home automation.

C. Main Contributions

The proposed model described briefly above handles many currently available problems in designing and implementing smart house control systems. Some of the main contributions of the proposed model are as following:

1) Generic Model for Smart House Control Systems

Most of the smart house control systems, currently being used in industry and research, lack a generic model that fully considers multiple interfaces, simulating modules, and different means of remote communication with the main server. This model can be used as the first generic model for industrial and research fellows so that the improvements can be focused on the subparts and modules of the system rather than encountering challenges toward matching different models for a scientific comparison about improving smart house control systems.

2) Comprehensive Remote Interfaces

Regular smart house control systems lack different means of remote communication with the end user at once. For example, the locally implemented smart house control systems usually work only with a panel provided that is installed somewhere in the house. Others might include mobile applications through the local network and only a few supports internet accessibility. This model provides two most preferred means of remote communication from outside the house, which are through web application and mobile device, so that any preferred device can be used to monitor and control the smart house from anywhere in the globe. Using the GSM modem, the mobile devices can also use short messaging to control the smart house and to receive alerts, warnings or current status of the house.

3) Model Analysis Before Building the House

Using only the smart house simulator and no actual hardware present, the whole system can work efficiently and properly using all the remote control interfaces and PCC. The simulator can include many different devices with complete sensors, actuators, and a location sensor; enabling the user to control a complete smart house without actually building one. The time control and scenario defining capabilities of the simulator can help analysts retrieve model properties in short-term and long-term tests; e.g., energy consumption.

4) Improved Hardware Diagnosis with Device Simlulator

The hardware device simulator provided in the model can act as a single separate device with diagnostics options up to binary level. Each device can get a separate IP address and port number and supports both analogue and digital sensors, and binary switches acting as actuator. In case of a malfunction in a device, this simulator can be used to check the values sent and received from the hardware device simulator so that the problem can be diagnosed easier before manipulating the actual hardware device.

III. Implementation

The proposed model is implemented using different languages and platforms that are linked together perfectly due to the conciseness of the proposed model. The implemented parts of the main modules and their subparts are described below:

A. PCC Implementation

The PCC is implemented in C# language and is able to connect to the webserver, mobile devices using GSM modem and hardware devices, software simulator and hardware simulator using UDP protocol all in one place. This implementation supports different timer control and server options. Fig. 2 shows the implemented PCC used in the proposed system.

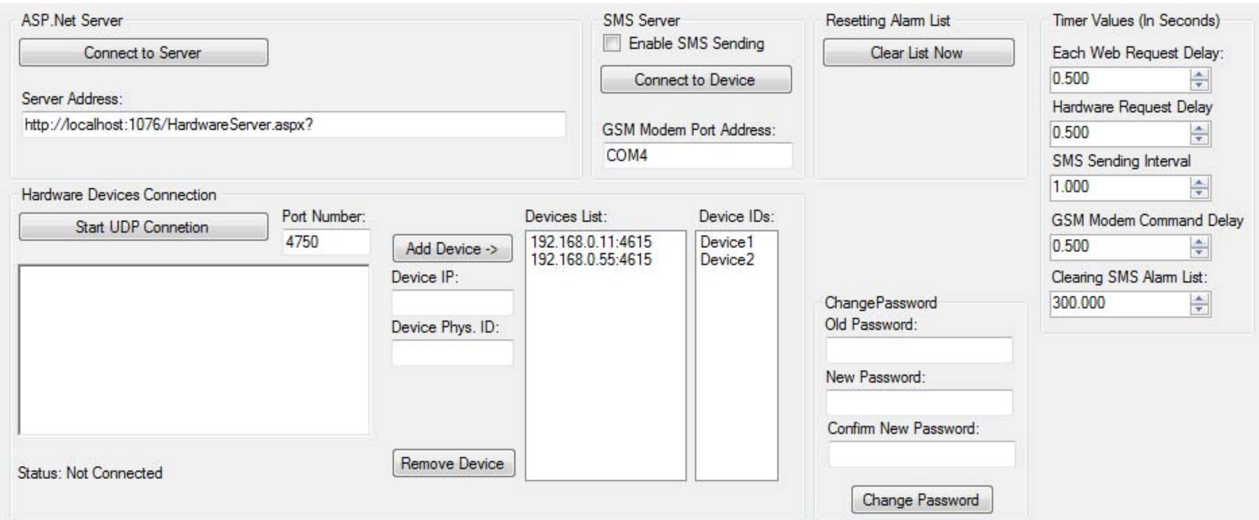

Figure 2. The implemented PCC of the proposed system. Controlling options of different modules of the system is implemented and displayed in one location.

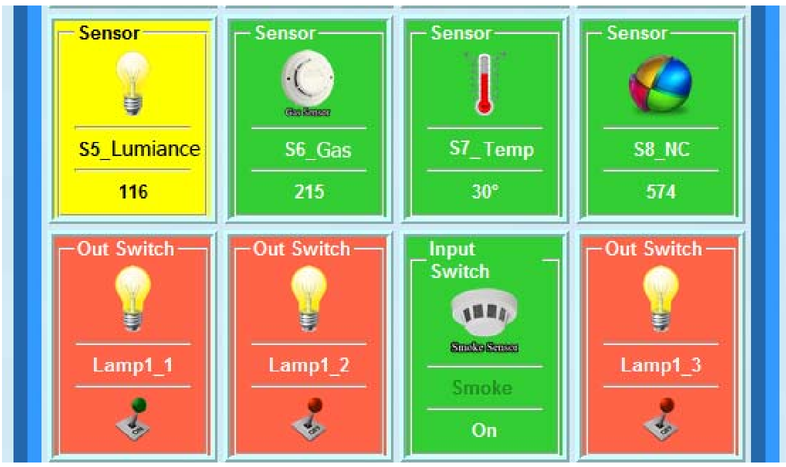

Figure 3. Some of the sensors and actuators of a single hardware device with different alarm levels and values in the web-based remote control system.

B. Display and Remote Control Module

The display and remote control module, as mentioned earlier, consists of different remote control interfaces for controlling the smart house remotely. The implemented web and mobile applications of the proposed system are described below:

1) Web Application

Web-based application for remote control of the system using internet-supported devices, such as PCs, Laptops, Smartphones, etc. is implemented using ASP.Net with different capabilities. These capabilities include sensor, actuator, object, and scenario manipulation. Different sensor and actuator type templates are also presented so that any kind of devices can be used and added to the system, e.g. IP cameras, toggle switches and multi-value sensors or actuators. The general map of the system supports skims at a glance capability so that in case of any alarm or warning in the objects, multi-color indicators are displayed to track and fix the abnormal device statuses. Fig. 3 shows a screenshot of a single device sensors and actuators in the web-based remote control center. As it can be observed, different device parts have different values, have different alarm level and have a different UI element based on the type of the sensor or actuator.

2) Mobile Application

Based on the customer's choice of personal mobile device, the proposed model helps developers to design and implement any version of mobile device software based different platforms. In the proposed system, two different versions of mobile platforms are developed for use in two different platforms, i.e. J2ME and Windows Mobile. Fig. 4 shows a screenshot of the Windows Mobile implementation of the mobile device remote controller for the smart house controlling system that shows the list of the sensors and actuators of an Air Conditioner with the values and types listed beside their names. As it can be seen in options of the software, there are two options for sending the commands by SMS or using regular WAP services, like GPRS or internet-connected WiFi.

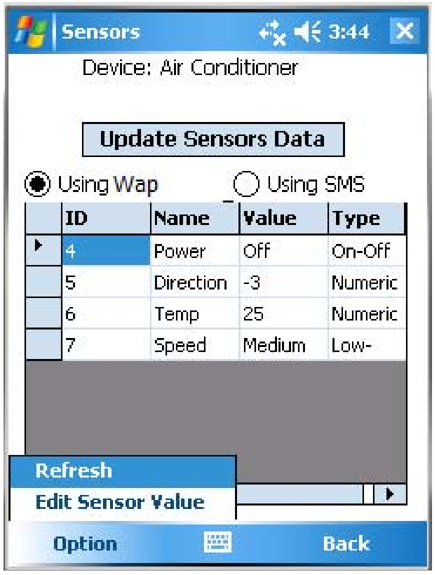

Figure 4. Windows Mobile implementation of the mobile device remote control application of the smart house controlling system.

C. Simulator Module

One of the important parts of the proposed model and system is the simulator module and its subparts. The two different simulators proposed in the model are implemented in the system and are described as follows:

1) Smart House Simulator

The smart house simulator that is implemented to be used in the proposed model is illustrated in Fig. 5. This simulator can connect to PCC, load the devices with their icons in the map, provide object manipulation and scenario defining facilities, and use timer management to control the speed of time in the simulation.

The software simulator uses the schema in Fig. 6 to communicate data with the PCC. As it can be inferred, the server always makes the first connection attempt towards the status updating and retrieves the results immediately.

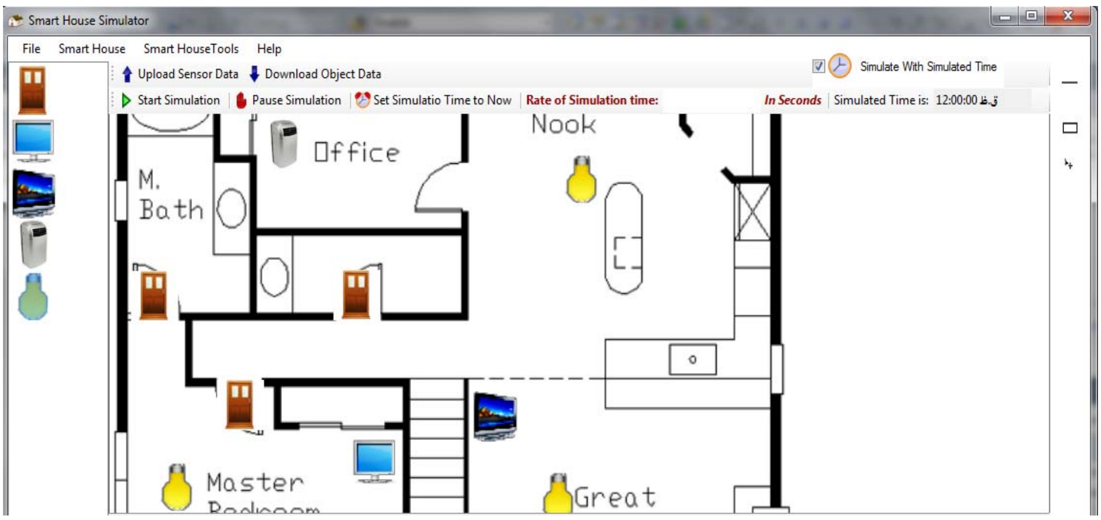

Figure 5. The implemented smart house simulator software with a map and several devices loaded.

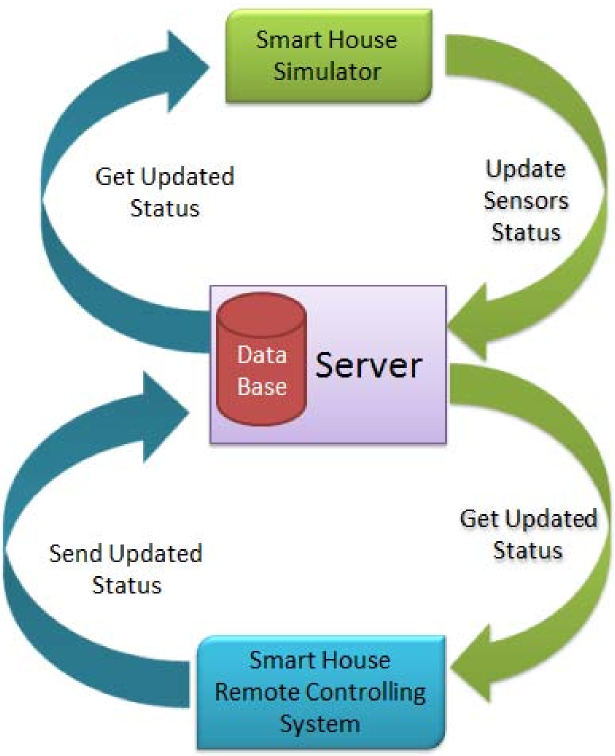

Figure 6. Connection structure between the PCC server, smart house simulator and smart house remote controlling system.

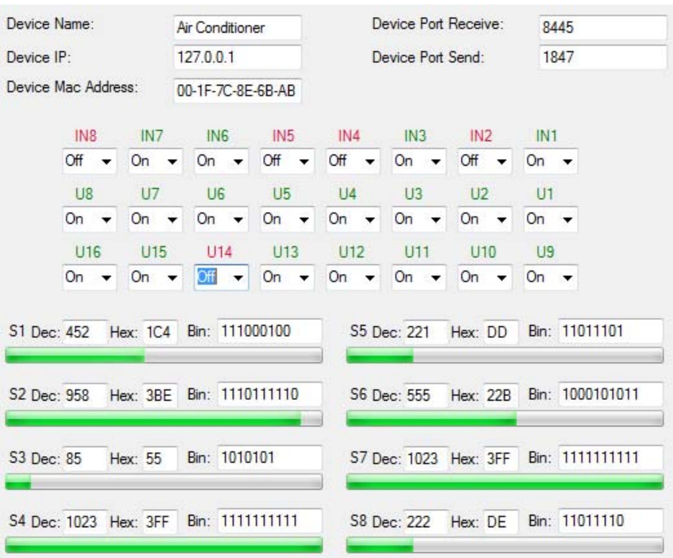

Figure 7. Hardware device simulator including different options for viewing and seting sensors and actuators values.

2) Hardware Device Simulator

For testing a single hardware device, a device simulator is implemented. This simulator acts as a real hardware device with an independent IP address and port number. This simulator provides the facility to view and set the digitalized analogue sensor values in binary, hex and decimal. This simulator provides a perfect opportunity not only for developing the software without physical implementation, but also for system diagnostics. Fig. 7 illustrates a view of the hardware simulator for a device with several sensors and actuators, including both binary and digital ones.

D. Hardware

Based on the inner protocols of communication, a physical hardware device is also created, using UDP packages for communication with PCC. In the next section, a testing scenario is defined and employed on the implemented version of the model to test the model consistency.

IV. Test and Analysis

To test the system, different parts of the system are connected together, and several sensor values are manipulated in either the real hardware device or any of the two simulators. As it can be seen in Fig. 8, the PCC is successfully connected to one of the hardware devices, sent a request and received a sensor update successfully. The PCC is also synchronously connected to the web server so that the remote control through an Internet browser is now online. Fig. 9 is also showing that the hardware device has received the UDP packages and is now connected to PCC and other system parts.

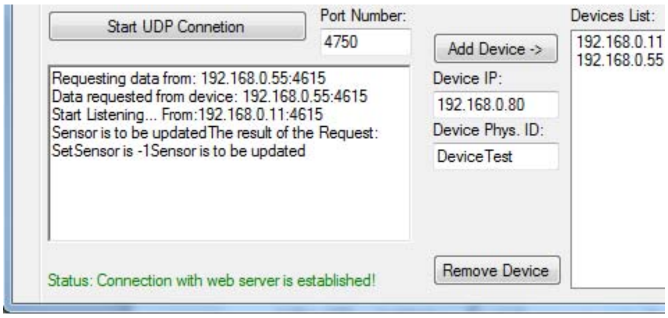

Figure 8. PCC succesfully connected to different parts of the system and working as a bridge to connect hardware to remote control module.

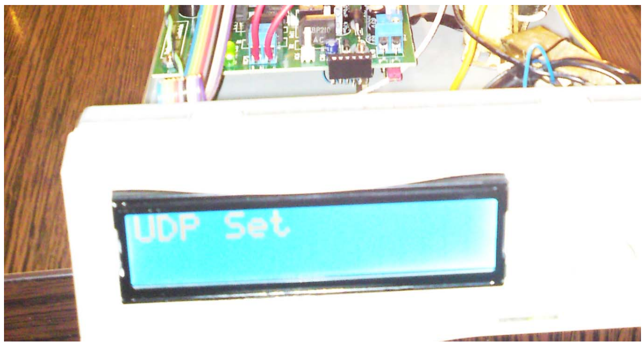

Figure 9. The hardware device working properly and connected using UDP network protocol to the PCC and hence remote control module.

V. Conclusion and Future Works

In this paper, a generic model for smart house remote control systems is proposed, implemented and tested using the software and hardware simulators presented with it. The comprehensive model presented in this paper supports both web and mobile remote access along with hardware and software simulator for testing and parameter estimation before actually building the house. With the proposed model in use, the analysts no longer need to rely on a physical house to analyze and design economic plans; leading to highly reduced design costs and time consumption.

The proposed model can be used in future to assess different automation parameters to gain the optimal schema or placement of different appliances in the house. New parameter estimation modules can be added to the model to ease this job. Different communication means can also be tested and evaluated for linkage between the different modules to efficiently minimize the latency and cost effectiveness. Also, medical and healthcare remote control systems can be embedded into the model so that a separate module for patient supervision can be added to the system.

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