

# Home Appliance Control System over Bluetooth with a Cellular Phone

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**Abstract** — *In this paper, we propose a home appliance control system over Bluetooth<sup>TM1</sup> with a cellular phone, which enables remote-control, fault-diagnosis and software-update for home appliances through Java<sup>®2</sup> applications on a cellular phone.*

## 1 INTRODUCTION

The rapid spread of Internet use at home inspires a new convenient way to use home network for controlling home appliances. However, there are some obstacles for the home appliance network to spread widely. The first problem is the initial cost of introducing the home network system with control terminal equipment. The second one is difficulty in changing all home appliances for networking at once, because of the long life cycle of the home appliances. The last one is the lack of mobility in the control terminal. This problem can be partly solved by using a portable PC as the control terminal, but other problems like long start-up time and short battery life would appear.

To solve those problems, Bluetooth for a communication medium and a cellular phone as the control terminal have been chosen in the proposed system. Bluetooth is a low cost short-range wireless technology. Bluetooth can connect the home appliances and the cellular phone without wire and we believe it will become a standard feature for cellular phones in the near future. We have attached a communication adapter to the home appliances in order to add a Bluetooth communication functionality. By using this adapter, a user doesn't have to buy new home appliances for adding communication functionality. Moreover the cellular phones can be used with short start-up time and its ability to access Internet can provide useful functionalities and services.

In consideration of the above solutions, we actually built the prototype of a home appliance control system with Bluetooth and a cellular phone. In section 2, the architecture of the home appliance control system is introduced. In section 3, communication adapters for adding Bluetooth communication functionality to the home appliances and cellular phone are explained. In section 4, Java applications for providing effective home network systems with appropriate usability are informed

## 2 HOME APPLIANCE CONTROL SYSTEM

Our system consists of home appliances, a cellular phone, Bluetooth communication adapters for the appliances, and a Bluetooth communication adapter for the cellular phone as shown in Fig. 2.1. Hardware and software for those adapters, Java applications running on the cellular phone and the interface software between the Java applications and the adapter have been made for the prototype system.

The home appliances and cellular phone can be connected wireless by adopting Bluetooth as a communication medium. And the home appliances can gain communication functionality easily by attaching the Bluetooth communication adapter. Moreover the cellular phone has functionality to access Internet, which user can use for downloading electric data through the Internet.

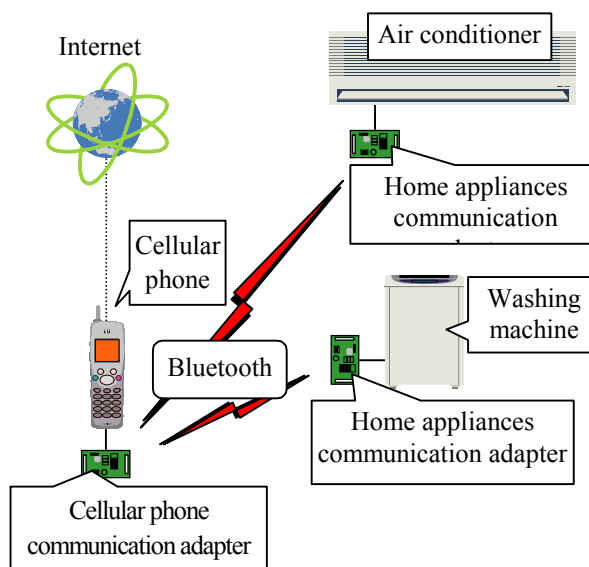


Fig. 2.1 System Overview

## 3 COMMUNICATION ADAPTER

The home appliance communication adapter and the cellular phone communication adapter use common board. Fig. 3.1 shows the hardware block diagram of the communication adapter board. The communication adapter hardware consists of a 20MHz 16bit CPU, SRAM and a Bluetooth module. The CPU is not so powerful, but has been used for its low cost availability. The communication adapter board is connected to the home appliance and to the cellular phone through serial ports.

Resideo Technologies, Inc. v. Ubiquitous Connectivity, LP

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RES935 - 1027, Page 1 Exhibit # 1027

<sup>1</sup> Bluetooth is a trademark owned by Bluetooth SIG, Inc.

<sup>2</sup> Java is a registered trademark of Sun Microsystems, Inc.

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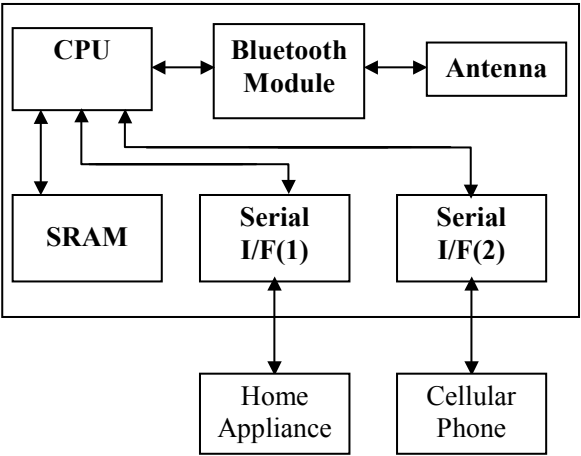


Fig. 3.1 Hardware Block Diagram of the Communication Adapter Board

Table 3.1 shows the memory size of the CPU and external SRAM on the adapter. Since we couldn't expect program size, we arranged large memory for the adapter.

Table 3.1 Memory Size of the Adapter

Component		Size
16bit CPU	ROM	256KB
	RAM	16KB
External SRAM		512KB

3.1 Home Appliance Communication Adapter

The home appliance communication adapter has two communication interfaces, Bluetooth and serial. For communicating with a Bluetooth module, we have implemented a serial driver, Bluetooth protocol stack and Bluetooth profile for Bluetooth interface. We applied SPP (Serial Port Profile) which can perform virtual serial communication in the Bluetooth profiles. This adapter is also connectable with the appliances by using serial driver implemented on the adapter for serial interface.

Furthermore, we have implemented the adapter control program for controlling software listed above, and we built all the software to run on the adapter.

Therefore, the appliances can communicate with the cellular phone control terminal via Bluetooth SPP by this adapter.

Software block diagram of the home appliance communication adapter on the CPU is shown in Fig. 3.2.

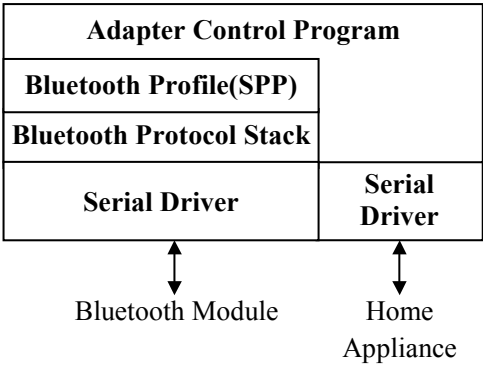


Fig. 3.2 Software Block Diagram of the Home Appliance Communication Adapter

We held down the program size to 136.4KB in ROM. So, it was enabled to run the program on the CPU internal ROM. On the other hand the program used 108.7KB RAM, so external SRAM was required. We are planning to reduce the size of RAM requirement.

3.2 Cellular Phone Communication Adapter

Hardware components and software modules for the cellular phone communication adapter are similar to ones for the home appliance communication adapter described above. In place of the serial driver for communicating with the appliances, the driver for supporting cellular phone's proprietary protocol over the serial port is used.

In our study, we chose to make the adapter, in order to give flexibility for the prototype system. But we are planning to use the cellular phone with built-in Bluetooth produced commercially in near future.

Software block diagram of the cellular phone communication adapter on the CPU is shown in Fig. 3.3.

4 JAVA APPLICATION

To examine the system and evaluate the efficiency and usability, four applications have been made for the cellular phone.

- 1.Remote Control Application
- 2.Program Update Application
- 3.Fault Diagnostic Application
- 4.Electric Manual Application

All of the applications are written in Java with consideration to the limitation of display size, and performance. Because Java applications are independ to the platform, a user isn't limited by the type of cellular phone he is using.

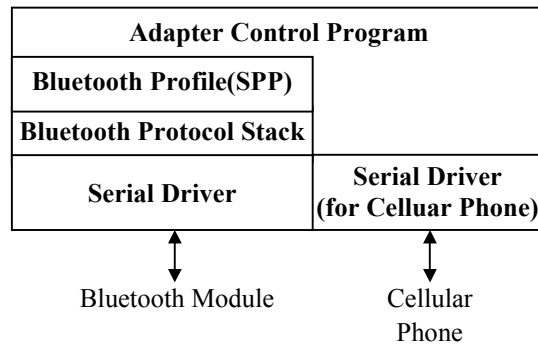


Fig. 3.3 Software Block Diagram of the Cellular Phone Communication Adapter

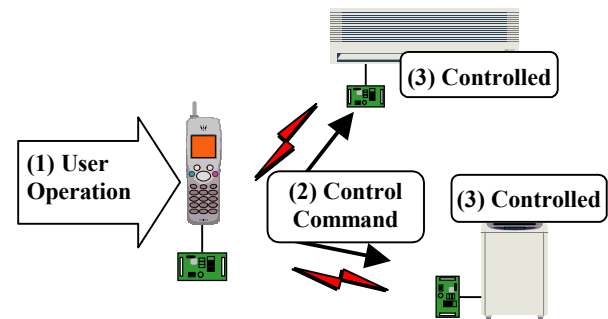


Fig. 4.2 Remote Control System

## 4.2 Program Update Application

New programs or data can be downloaded to the appliances from the cellular phone. This feature realizes the update services through the Internet via the cellular phone and therefore is useful for the appliances which usually will be used for many years. Moreover, it becomes possible to offer functionalities particular for each user by using this application.

Fig. 4.3 shows a procedure that the home appliances update the program by using this application.

- (1) A user chooses a requesting program of a home appliance from a service site homepage by the cellular phone.
- (2) The requested program information is transmitted from the cellular phone to the service site through the Internet.
- (3) The cellular phone downloads the program from the service site.
- (4) The home appliance program uploads the program by transmitting the downloaded program from the cellular phone to the home appliance through the communication adapters.

## 4.3 Fault Diagnostic Application

Fault diagnostic application can receive an error code from a home appliance and analyze it when a home appliance needs diagnosis. This application can also display some tips and strategies for solving problem and making arrangements to call a repair engineer in a serious case. And a user can efficiently tell the contents of fault to the repair engineer.

Fig. 4.4 shows a procedure that the cellular phone displays fault diagnostic content of home appliances by using this application.

- (1) A fault generates in a home appliance.
- (2) The home appliance transmits an error code to the cellular phone through the communication adapters.
- (3) The content of the fault corresponding to the error code is displayed on the screen of the cellular phone.

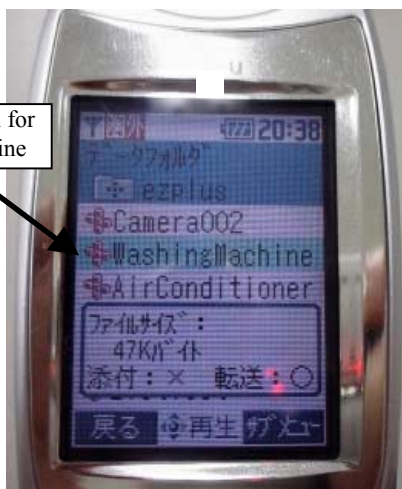


Fig. 4.1 List of Java Applications

## 4.1 Remote Control Application

Commands for the appliances to set up parameters, starting the operation, and stopping the operation are executed by remote control application. With this application, the cellular phone can be used as remote controller for various home appliances.

Fig. 4.2 shows a procedure which a user controls the home appliances from a cellular phone using this application.

- (1) A user operates a home appliance control by the cellular phone.
- (2) In order for the operation to invoke, a control command is transmitted to home appliance from the cellular phone through the communication adapters.
- (3) The home appliance is controlled according to the control command.

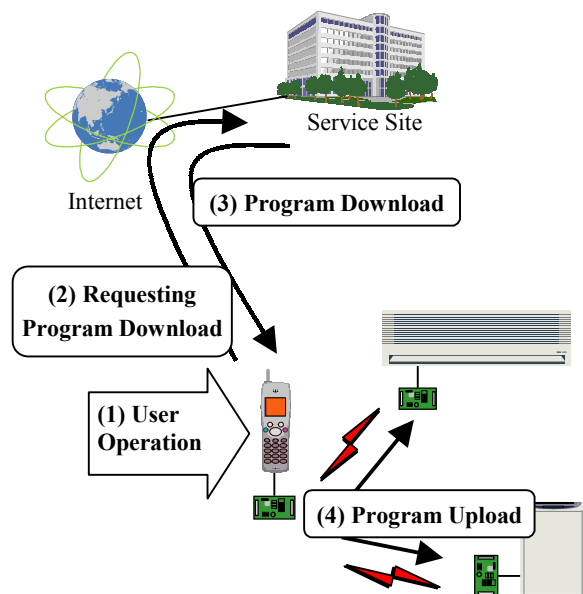


Fig. 4.3 Program Update System

(4) The downloaded manual is displayed on the screen of the cellular phone.

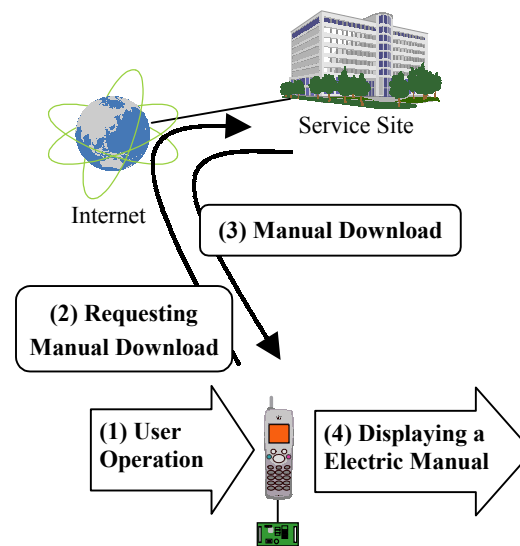


Fig. 4.5 Electric Manual System

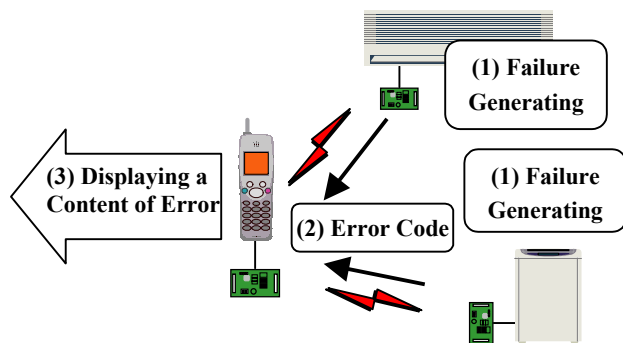


Fig. 4.4 Fault Diagnostic System

#### 4.4 Electric Manual Application

This feature shows the operation guidance on the cellular phone display instead of using limited functional display on the appliances or printed manuals. If this manual is linked with home appliances control, the further improvement in user interface is expectable.

Fig. 4.5 shows a procedure that the cellular phone displays the manual of home electronics on the screen of the cellular phone by using this application.

- (1) A user chooses a requesting manual of a home appliance from a service site homepage by the cellular phone.
- (2) The requested manual information is transmitted from the cellular phone to the service site through the Internet.
- (3) The cellular phone downloads the manual from service site.

#### 4.5 Examination of the Application

We have implemented a Java application described above for an air conditioner and a washing machine. Fig. 4.6 shows the menu of four applications with other applications for a washing machine. Fig. 4.7 shows the remote control application for a washing machine when "Operate" is chosen in Fig. 4.6.

In the first prototype of the application, the application was generating all screen objects used in the application at the time started. In this case, it took 2.2 seconds for the application to be ready.

For good user interface, we assumed that a user takes out a cellular phone and use the application immediately. We challenged the method of generating a screen object if needed instead of generating all screen objects at first. The time required became 1.4 seconds. We adopted the method of generating a screen object if needed.

The result of start-up time is just only for prototyping. In the future, start-up time will improve as the cellular phone processor become faster. On the other hand, BREW (Binary Runtime Environment for Wireless)<sup>TM3</sup> is an example of new platform for cellular phone appeared. With all those features, we can consider new applications for various uses.

<sup>3</sup> BREW is a trademark of QUALCOMM Incorporated.



Fig. 4.6 Menu of the Application



Fig. 4.7 The Remote Control Application

## 5 CONCLUSION

Our prototype system for the home appliances could be built with small footprint and low power CPU with Bluetooth communication adapters, and program size of ROM was 136.4KB.

The Java applications mentioned above are tested on our prototype system. And the result showed certain efficiencies. The application menu structures were reconsidered to achieve performance and usability improvement. We improved start-up time from 2.2s to 1.4s. Consequently, the start-up latency has

been negligible on the latest cellular phone with higher application and CPU performance confirmed.

Up to here, system architecture, the efficient applications, and a brief evaluation result related to usability are described.

As a conclusion, user's cellular phone can be used as the controller terminal in our system. In addition, applying communication adapters, home appliances with the long lifecycle can easily obtain network functionalities after purchasing. Moreover it was shown clearly that our prototype system was realizable with low cost requirement.

## REFERENCES

- [1] Bluetooth Specification Core Version 1.1 (<http://www.bluetooth.org>)
- [2] Bluetooth Specification Profile Version 1.1 (<http://www.bluetooth.org>)



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