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A Practical Home Security System via Mobile Phones

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Abstract: - This manuscript addresses the design and implementation of a practical home security system (PHSS). This system realizes its mobile surveillance via mobile phones by the planted Java applet. The challenge is that PHSS works independently under the existing Internet Service Providers (ISP) and telecoms. End-users can monitor their home and properties anywhere and anytime on the screen of their mobile phone. Furthermore, PHSS can be also applied to vehicle surveillance without the restrictions of ISPs. This system has been completed and verified in houses and vehicles.

Key-Words: - Home security, mobile surveillance, PHSS

1 Introduction

The importance of home security has greatly increased in recent years. Relying on huge computing power and friendly user interface, the most recent surveillance systems are primarily PC-based ones. To satisfy the application in different conditions, surveillance systems have also been implemented in many ways to accomplish the objectives. The DSP-based real-time surveillance system has been realized in [1, 2]. Sato et al. [3] presented a hybrid intelligent surveillance system consisted of an embedded system and a PC. [4], [5] and [6] addressed the web-based monitoring system with Java applet. However, these surveillance systems perform surveillance jobs without mobility. That is the monitoring works cannot be carried out unless the user is near a PC or some embedded computer system.

Since mobile phones have become prevailing, while house and property security demands are continually increasing, the integration of the mobile phone and a surveillance system becomes more meaningful so that people can know the security of their properties anytime, anywhere. Mobile phones are at present, quite ubiquitous and increasingly sophisticated. A mobile phone can not only be treated as a communication unit, but as a camera, a web browser, a music box, a game platform, or even a wireless remote controller, since so many services are provided on a mobile phone. Corcoran et al. proposed a photography service which offered the possibility to access and manipulate uploaded pictures directly by Wireless Application Protocol (WAP) or iMode services via mobile phone [7]. They also presented a combined battery-charger and picture upload unit to solve the two-hour talk-time limitation of a fully charged mobile phone in their investigation. Nikolova et al. developed a gateway to enable the control of consumer electronics devices connected to the home network from a mobile phone. The gateway intermediates are wired between the home network and a wireless communication network using Home Audio Video interoperability (HAVi) and WAP specification, respectively [8], named HAVi-WAP UI.

Recently, a video clip system [9] has developed a way to transfer the video stream to a mobile phone through Ethernet from PCs. A new kind of wireless image system [10] provides users the image information by multimedia message service (MMS). However, for the users, to read a MMS in mobile phone need several operational steps. Although [9] and [10] still have a lot of room to improve, it can be found that the mobile phone is exactly a nice solution for a remote surveillance appliance.

In this paper, a practical home security system (PHSS) is addressed and has been realized via mobile phones. PHSS is a RISC-based embedded system. μCLinux is chosen as the embedded OS on the low cost server of PHSS. The doorbell, Infrared sensors, and other motion sensors play the roles of trigger sources to enable PHSS to carry out its surveillance job. End-users can monitor their properties in house or on vehicle anywhere and anytime by the mobile phone in hand. Once PHSS was triggered, users receive a notification and browse the desired images captured from the CCD/CMOS cameras connected to the embedded surveillance server (ESS) of PHSS on the screen of their mobile phone.

The challenge of this security system is that PHSS must work independently under the existing Internet Services Provider (ISP) and telecom. In particular, the ESS of PHSS can be installed in houses or outdoors without a physical IP address supporting. Besides house surveillance, PHSS can also be applied to vehicle security. Recent vehicle surveillance systems, [11-12], provide real-time short messages to notify users when something has happened to their car. Nevertheless, the users just know something has happened but understand what happened on their cars. Because [11, 12] do not provide real-time images. PHSS can fully support this requirement.

This paper consists of six sections and is organized as follows: Section 2 presents the system overview and the software of PHSS is described in Section 3. The mobile phone programming is addressed in Section 4. Section 5 gives the experimental results and potential applications. Finally, Section 6 discusses the conclusions.

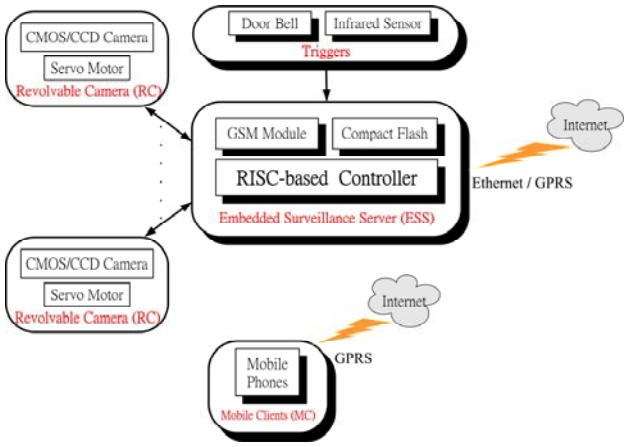

Fig.1 PHSS system overview

2 The System Overview of PHSS

PHSS, as shown in Fig.1, consists of four parts; embedded surveillance server (ESS), triggers, mobile clients (MCs), and revolvable cameras (RCs). ESS is composed of a RISC-based controller, a GSM module, and a CompactFlash card. The Linux kernel, related device drivers and the applications are implanted on ESS. The GSM module enables the mobility of this surveillance system.

The motion sensors and doorbell are assigned as the triggers in PHSS. The doorbell is integrated to build a communication link between users and the visitors to avoid intruders, whom might try to determine if the house empty by pressing the doorbell and receiving no answer.

Furthermore, ESS is also triggered by an infrared sensor or other motion sensors, when someone moves within its sensing scope. The RCs will begin capturing successive images, if it receives a trigger signal from the ESS. These images were compressed into JPEG format and stored in storage units, i.e., CompactFlash card. The notifications for these events will be sent to the users by short messages through the GSM module on ESS.

Besides, MCs offer the users to real time acquire the information about their home condition over the Java program embedded on their mobile phones through GPRS. Moreover, the users can give the rotating commands to ESS for controlling the cameras which are carried by servo carriers. Then, these cameras will capture the pictures at different view angle and the more information can be observed for the users

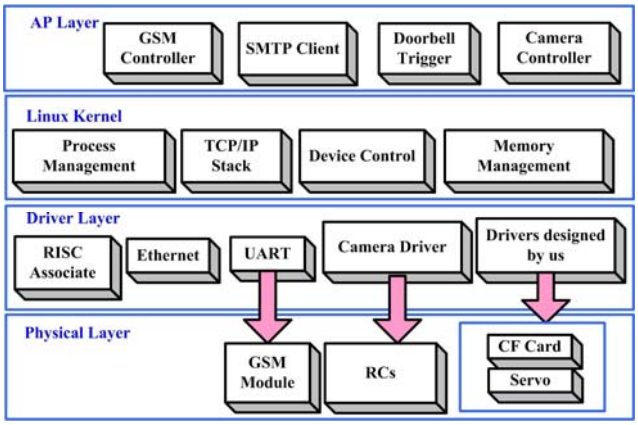

Fig.2 The software architecture of ESS

3 The Softwares on ESS

Figure 2 shows the software architecture of ESS, which is the core technology of PHSS. μClinux is chosen as the embedded OS on ESS. Drivers that correspond to the hardware are developed to control all system components. The OS is divided into three parts; Linux kernel, driver layer and application layer. The detail development is described as follows.

3.1 Linux Kernel

In a UNIX system, several concurrent processes attend to different tasks. Each process asks for computing power, memory, network connectivity, or some other resource from the system resources. The kernel is the largest chunk of executable code responsible for handling such requests. Although the distinction between the various kernel tasks is not always clearly marked, the kernel can be functionally split, into four parts; process management, device control, TCP/IP stack, and memory management [13].

3.2 Driver Layer

Linux kernel can not control the hardware correctly without drivers. There are many drivers in the operating system, such as RISC associates, Ethernet and all kinds of peripherals. Therefore, we only address the used drivers designed for PHSS.

3.2.1 CompactFlash Card Driver

To store compressed images, a CompactFlash card is integrated with the ESS. It is treated as a block device for the Linux OS. The driver is successfully developed to control the CompactFlash card that allows the Linux kernel to read and store data based on the FAT file system.

3.2.2 Servo Carrier Driver

The servo carrier is a kind of character device because it has a serial operating signal. It is controlled by the PWM signals with different duty cycles. The servo carrier driver that generates the PWM signals with corresponding duty ratio using the timer interrupt of RISC is developed.

3.3 Applications

The following applications are designed to enrich the functionality of PHSS.

3.3.1 Camera Capture

This application sends the image capturing request to the RCs connected to ESS, receives the JPEG images from RCs and stores them into the CompactFlash card. This application is written very flexibly to control several RCs. The running flowchart of this application is plotted in Fig.3.

3.3.2 GSM Module Control

The GSM module works with the AT commands and links to the COM port of ESS to make a phone call or send a short message to the user. If the user decides to trigger the system to capture images, he/she can send a short message to ESS and this application will carry out the command. Table 1 lists the codes for the supported function names in the short message sent from the user to ESS.

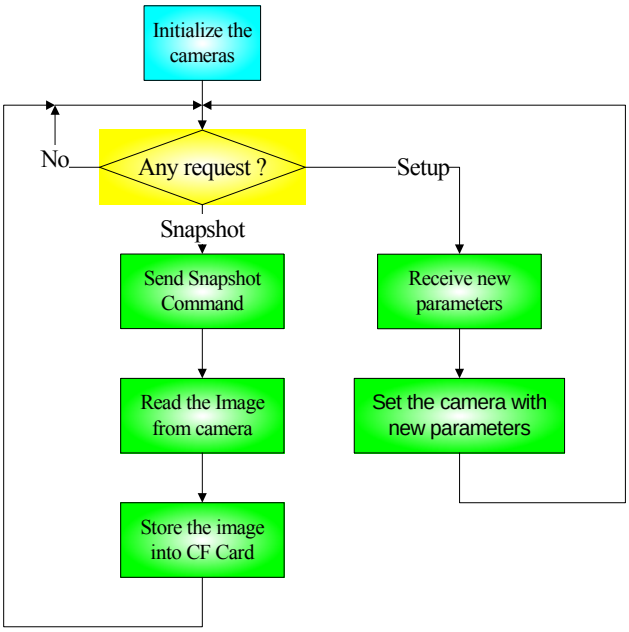

Fig.3. The camera capturing control application flowchart

3.3.3 SMTP Client

ESS will send an E-mail to users when something occurs. The captured JPEG images will be attached to the E-mail to provide complete information to the user.

3.3.4 Doorbell Trigger

The doorbell is integrated in PHSS to check visitors' purpose for coming. PHSS is trigged by the pressed doorbell and dials the house owner's mobile phone automatically. The voice channel between the visitor and the owner is quickly established. As shown in Fig.4, the house owner can see the visitor's image on their mobile phone and talk to him/her directly between the intercom and the

Table 1: Code list for the supported functions in short message.

Functionalities	*Commands*	*Formats*	*Descriptions*
Enable Camera 1	'A'	"A[num]"	Enable camera 1 to capture and transfer [num] images to the user.
Enable Camera 2	'B'	"B[num]"	Enable camera 2 to capture and transfer [num] images to the user.
Enable both cameras	'C'	"C[num]"	Enable both cameras to capture and transfer [num] images to the user.
Image resolution setting	'X'	"X[num]"	Set the capturing image resolution. 1. VGA (640x480) 2. QVGA (320x240) 3. QCIF (176 x 144)
User's phone number setting	'P'	"P[num]"	Set the user's mobile phone number so that PHSS can dial or send the warning messages to the user.
User's email address setting	'E'	"E[address]"	Set the user's email address so that PHSS can send a warning email with the attached JPEG images to the user.
Reset	'R'	"R"	Reset the system.

mobile phone, respectively. PHSS not only monitors house properties, but also prevents thieves from breaking into the user's house, since the house owner talks to visitors directly even when he is not at home.

Fig.4 The doorbell integration in PHSS

4 Mobile Phone Programming

The development kit we used to build Java programs for a mobile phone is Wireless Tool Kit (WTK) provided by Sun. The elementary program is verified by the simulator that WTK provides, as shown in Fig.5.

Fig.5 Mobile phone simulator provided by WTK

Since more and more mobile phones support Java programming, the J2ME Java version is addressed for developing applications on mobile devices. But the API of J2ME is not as complete as that of J2SE. There are still many restrictions in developing the Java program. The socket programming is used to establish the connection between ESS and the mobile phone. The server-push method is applied in the data transmission between them. That is, the mobile phone will not download the files until the server is ready for the downloading. Figure 6 shows the state chart of this method and Fig. 7 is the processing flowchart of this program on a mobile phone.

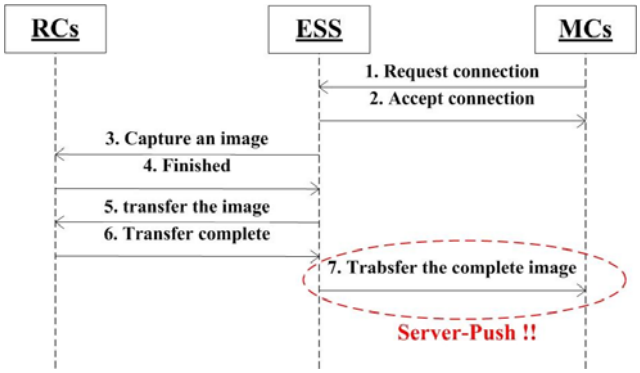

Fig. 6 The state chart of server-push we addressed.

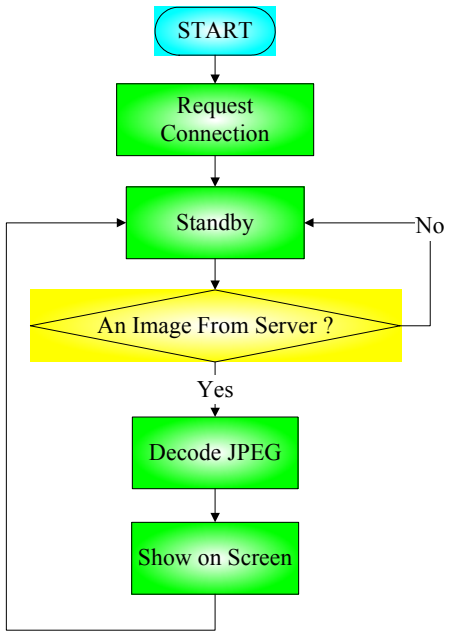

Fig. 7 The processing flowchart of the program on a mobile phone

To guarantee the workability of this program, the simulators provided by the mobile phone manufacturers are necessary since not all mobile phones can fully support the J2ME. Figure 8 shows one of the simulators.

Users can download the continuous real-time images to their mobile phones from ESS anywhere if this Java applet has been embedded in their mobile phones. The computing power and memory size of the mobile phone are both much lower than other peripherals so that software decoding of the received JPEG images relies on the J2ME API, createImage (DataInputStream in), to decode the JPEG images on mobile phones.

Fig. 8 The simulator provided by some manufacturers

The GUI developed on mobile phones is shown in Fig. 9. The top of the screen in Fig. 9 displays the date and time of the captured image, and the two buttons on the bottom are "Option" in Chinese and "Stop", respectively. The "Stop" button can suspend the image transmission, as illustrated in Fig. 10, and resume transmission by pressing the "Resume" button.

5 Experimental Results

PHSS has been completely implemented with the functions mentioned above. Users promote their surveillance systems with mobility so that they know the circumstances of their properties anytime and everywhere. The Java program developed for mobile phones enables users to see real-time images through GPRS protocol. Images are transmitted from the triggered ESS so that if someone is sensed by the settle sensors, a short message is sent to the user to notify of an emergency. The Java applet on their mobile phone shows the real-time continuous QCIF images on the screen

The actual average bandwidth of GPRS is approximately 8K to 10K bits per second for the downloading data transmission rate. The QCIF JPEG image size is approximately 1K Bytes so that the mobile phone can download the compressed image data from ESS display the decoded JPEG image in three seconds per image by our developed Java applet. The processing time will be reduced if GPRS can gain a faster download speed. Table 2 shows the performance comparisons between PHSS, [9], and [10]. PHSS owns more widespread applications than others with its mobility. PHSS supports multi-camera service and friendly one-key-operation interface that [9] and [10] cannot.

Fig. 9 The GUI developed on mobile phones

Fig. 10 The GUI on suspended mode on mobile phones

PHSS is a low cost multipurpose embedded surveillance appliance especially developed for home security demands. Similar to house surveillance, PHSS can be installed in vehicles, as shown in Fig. 11, to notify the car owner by a short message and real-time images if someone violates his car. ESS can transmit images to the owner through GPRS and these images serve as evidence for the police.

Table 2: Units and corresponding symbols

	PHSS	*[9]*	*[10]*
Continuous Snapshot	Yes	No	Yes
Server System	Embedded System	Embedded System	Personal Computer
Number of Cameras	Not Limited	1	Not Limited
Operating Convenience	One Key	More than One Key	More than One Key
Extension Ability	Excellent	Good	Good
Image Transmission Path	GPRS / Ethernet	GPRS	Ethernet

In this application, PHSS can also integrate the GPS navigation module into a mobile phone so that the car owner can hold the robbers' images and the car position on the screen of their mobile phones without the call center.

Fig. 11 The PHSS installed in the vehicle

Furthermore, PHSS can also be applied to the homecare systems and the assist in accidents with tele-consultation. When children or aged persons get hurt at home, PHSS can be the bridge between the patients and the medical station. The patient's family can then receive important instructions from doctors. Because time before the ambulance arrives is critical, communications with medical personnel is vital.

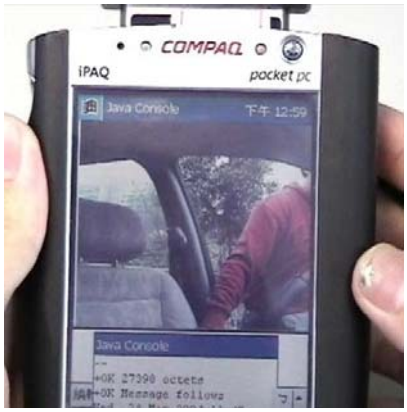

Fig. 12 The processed Java program on PDA

The Java program can also be installed to PDA with little modification since the computing power is stronger than that in a mobile phone. The functions mentioned above are all realized through Wi-Fi, as shown in Fig. 12.

6 Conclusions

This paper addresses the design and implementation of a practical home security system via mobile phone through GPRS communication protocol. PHSS realizes the mobile surveillance concept and is successfully verified. PHSS works under existing telecom infrastructures and ISPs without any modification, so that a new popular application on a mobile phone is created. Moreover, PHSS not only can be applied in home surveillance and vehicle security, but also to tele-consultation and homecare systems with little modifications.

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