Design of a Residential Gateway for Tele-Homecare Systems

Hsi-Feng Lu 1, Huan-Wen Tzeng 2, Ming-Chiao Chen 3 and Jiann-Liang Chen 4
1 National Dong Hwa University, 1, Sec. 2,Da Hsueh Rd., Shou-Feng, Hualien,Taiwan, Republic of China, d9221005@em92.ndhu.edu.tw
2 National Taiwan Normal University, No. 162, HoPing E. Road, Sec.1, Taipei 106, Taiwan, Republic of China, hwtzeng@cc.ntnu.edu.tw
3 National Dong Hwa University, 1, Sec. 2,Da Hsueh Rd., Shou-Feng, Hualien,Taiwan, Republic of China, joe@em92.ndhu.edu.tw
4 National Dong Hwa University, 1, Sec. 2,Da Hsueh Rd., Shou-Feng, Hualien,Taiwan, Republic of China, lchen@em92.ndhu.edu.tw

Abstract

This work proposes a novel architecture for tele-homecare system. The proposed system architecture has four parts: wireless sensor node, residential gateway, diagnosis system and mobile System on a Chip (SoC). The residential gateway, which is based on OSGi, is the hub of the tele-homecare system, providing connectivity to the outside world of home networking and deployment of medical services over a wide area network to home network appliances. Vital signs sensing is achieved by wireless sensor nodes integrated with medical device.

Key Word: Tele-homecare system, sensing, residential gateway, artificial intelligent, SoC, OSGi platform

1. Introduction

The use of new technologies to provide remote healthcare is a growing trend in the world. The aging population and the push for more efficient delivery of hospital services have fueled this growing demand urgently. In this paper, we propose a tele-homecare system architecture to fulfill this need. The developed tele-homecare system includes four parts: sensor node for data sensing, residential gateway (RG), diagnosis system for prediction, regression analysis and mobile SoC (see Figure 1). Wireless Sensor Node (WSN) and RG are the focus in this paper. WSN for vital signs sensing and acquisition is an embedded system, which integrated the wireless sensor node and medical devices. RG serves two primary purposes: as a communication gateway between the home and the outside world, and as a hub to connect and manage tele-homecare appliances in the home. The Open Services Gateway Initiative (OSGi) [1] meets these requirements by providing various wide area network access and a managed, extensible framework to connect various devices in a local network. The diagnosis system is an expert system, located in the monitoring station in the hospital as an assistance to medical team for prediction, regression analysis. The mobile SoC provide a convenient device for deployment and homecare.

Figure 1. The developed tele-homecare system

A RG based on OSGi for tele-homecare system was designed in this study. The OSGi service platform supports network delivered services for a remote device that can then run locally or in conjunction with other network resources. The specification is explicitly designed to be open and synergistic with a wide range of existing networking and computer technologies and enhances virtually all current networking standards and initiatives. In the same way, the specification adds value to existing wired and wireless networks while being neutral to and complementing cable, 3G, 802.11, xDSL and other high-speed access technologies. It allows service providers to deliver value-added services of their own and selectively allow delivery of
services provided by third party providers. The OSGi compliance program establishes a common specification third parties can use to create value-added services that can be delivered over a variety of networking systems using platforms incorporating compliant OSGi service platforms.

The remainder of this paper is organized as follows. Section 2 discusses some related works. Section 3 gives the details of design of the proposed residential gateway. Wireless medical sensor is proposed in Section 4. The paper is concluded by Section 5.

2. Related Works

The small size and low power consumption of the radio module make wireless sensor node an attractive option in medical sensors. The wide availability of wireless communication channel and a small footprint make it suitable for integration with health care sensor devices. There have been many efforts in this area [2-6]. They have convinced that the combination of wireless communication and sensor is a feasible solution for tele-homecare. But their proposals are lack of a powerful manageable and extensible component, the residential gateway.

The RG is implemented based on the OSGi. OSGi Service Platform now can work with wide area technologies like xDSL, Cable modems, Satellite, ISDN and POTS and local area networks like Bluetooth, HAVi, HomePNA, HomeRF, USB, IEEE1394 and VHN. By defining a standard execution environment and service interface, OSGi promotes the dynamic discovery and collaboration of devices and services from different sources. Moreover, an approach toward extending the OSGi framework to support interoperability with mobile devices is proposed in [7].

3. Residential Gateway

Figure 1 illustrates the architecture for tele-homecare, in which RG serves as a gateway between the end user of the medical sensing devices and the service providers (the monitoring station in the hospital). The operators perform their tele-homecare tasks by managing the services on the RG, managing a potentially large network of service platforms, running services from many different service providers.

The residential gateway includes the following function blocks: bundle manager, platform monitor, configuration manager, device discovery and permission manager. Management and medical services were also developed for the tele-homecare system. These services are services of sensor node for data sensing, services of diagnosis system and services of mobile SoC. Since tele-homecare is a highly critical system, the communication channel backup plan is an important issue in the residential gateway design.

This study investigates the potential role of the OSGi-based residential gateway, and implements the OSGi-based residential gateway services in a tele-homecare system. This novel architecture is revealed to be a managed, extensible and elegant framework for a tele-homecare network. Figure 2 depicts the OSGi-based residential gateway architecture.

Figure 2. OSGI-based residential gateway architecture

The remainder of this section describes in details the important issues relating to the design of a residential gateway for a tele-homecare system.

A. OSGi Framework

The OSGi specifications define a standardized, component oriented, computing environment for networked services. Configuring OSGi Service Platform as a residential gateway (embedded the as well as servers), adds the capability of managing the life cycle of the software components in the residential gateway from any part of the network. Software components can be installed, updated, or removed on the fly without needing to disrupt the device operation. Software components are libraries or applications that can dynamically discover and use other components. The OSGi Alliance has developed many standard component interfaces for common functions such as HTTP servers, configuration, logging, security, user administration, and XML.

The core component of the OSGi Specifications is the OSGi Framework, which provides a standardized environment to applications (known as bundles). The OSGi Alliance specifies many services in addition to the framework. Services are specified using a Java interface. Bundles can implement this interface and register the service with the Service Registry. Clients of the service can find it in the registry, or react to it when it appears/disappears.

The OSGi Release 3 services are presented below.

- Framework Services: Permission Administration, Package Administration and Start Level
- Protocol Services: HTTP Service, UPnP Service and Jini Service
- Miscellaneous Services: Wire Admin Service and XML Parser Service

The OSGi specifications allows multiple, Java-based components to cooperate efficiently in a single Java Virtual Machine (JVM). The presence of OSGi-based middleware in many different industries is forming a large software market for OSGi software components. The rigid definition of the OSGi Service Platform enables components that can run on a variety of devices, from very small to very big. Adoption of the OSGi specifications can therefore decrease software development costs and provide new business opportunities. Therefore the OSGi meets the residential gateway requirements for tele-homecare systems by providing various wide area network access and a managed, extensible framework to link various devices in a local area network.

Security in the OSGi framework is based on Java and the Java 2 security model. The Java programming language is designed to restrict the range of possible programming constructs. For example, buffer overflows used in viruses are impossible in Java. Access modifiers in Java limit the visibility of the code to other programmers. The OSGi extends this model by allowing private classes, which are not available in a standard fashion in Java. The Java 2 security model provides a comprehensive model to check access by code to resources. The OSGi adds full dynamic permission management that is compliant to Java 2.

B. Residential Gateway as a Home Portal

The home portal provides an integrated view of the available services at home. We believe that applications should be able to register their UIs at least provide the home portal web page with a listing of available services. This approach would enable a real plug and play system with new devices introduced to home, and at least a minimum degree of interoperability between different tele-homecare appliances.

The concept of remote management outlined in [8] derived from the OSGi reference model, was adopted in this investigation. Remote management involves two distinct roles, with one entity acting as the agent (recipient) and the other acting as the manager (sender) of management commands. The service platform entity that receives the management instructions is called the management agent, and the entity responsible for managing the service platform is called the operator. Management agents are defined and implemented with the following distinct servlet-based web interface pages:
- Bundle manager: for life-cycle (see Figure 3) and start level control of bundles
- Platform monitor: to monitor the service platform
- Configuration manager: for bundle configuration management
- Device discovery: to discover medical device and install device driver
- Permission manager: to manage bundle permission

Figure 3 displays the bundle life-cycle. The Bundle has to run the install command to carry on the configuration. The status of the bundle is INSTALLED after completing the setup. The Start command must run to reach the ACTIVE status. The Stop command must be run before purging the bundle. The user then runs the Uninstall command to remove it from system.

C. Residential Gateway as a Middleware

Middleware is software to help manage the complexity and heterogeneity of distributed systems. Middleware is defined as a layer of software above the operating system but below the application program, providing common programming abstraction across a distributed system, thus providing a higher-level building block for programmers than Application Programming Interfaces (APIs), such as sockets, are provided by the operating system. The use of middleware significantly cuts the burden on application programmers by relieving them tedious and error-prone interface programming.

A tele-homecare system incorporates many medical devices, both required and optional, for monitoring and collocation the vital signs. The required medical devices include two-way interactive video, telephonic stethoscope and blood pressure and pulse measurement tools. The optional medical devices include oximetry, the EKG, glucose meter and thermometers. The home networking environment also has many wired and wireless communication protocols such as serial link, USB, IEEE1394, power line, wireless LAN and Bluetooth. This variety of devices and protocols make application programmer a significant challenge. The OSGi specification is a managed, extensible framework for applications and network devices middleware. Consequently, OSGi is an important component of the tele-homecare appliance middleware.
D. Network Management Issues in Tele-homecare system

The wireless medical sensors in this proposed architecture are powered with battery. Power efficient is very critical for these devices. The architecture has many wireless medical sensors and protocols. The following specific network management issues need to be considered:

- Power management: the power level of every device, the on/off switch of each sensor on every device and the power level tuning of the wireless medical sensor communication
- Configuration management: the sensor network topology
- Management through sink node: the sink node of the Mote bridging and providing management to all other sensors in the sensor network

4. Wireless Medical Sensor

Bluetooth supports 64Kbps audio link and up to 732.2Kbps data links, providing sufficient data rates for gathering biomedical signals. However, advances in micro-electro-mechanical systems (MEMS) technology, wireless communications and digital electronics have enabled the development of low-cost, low-power, and multifunctional sensor nodes [9]. Hence, sensor networks can be applied to tele-homecare systems. For example, the Mote designed by U.C. Berkeley is a good platform for wireless medical sensors for tele-homecare. The small size and wireless connectivity of these medical sensors means that they do not obstruct patients in their everyday activities. This feature is particularly significant when monitoring is required over a long period of time or during some specific activities. The proposed wireless medical sensor design addresses the following requirements:

- Automatic sensor network configuration
- Wireless medical sensor plug and play services
- Generic sensor network access method

The design of wireless medical sensors in the proposed tele-homecare system includes several smart sensor nodes organized in a Bluetooth piconet and a control node that serves as the master of the piconet. In case of the Mote, wireless medical sensors constitute a sensor network, which can employ any available sensor network framework [10,11]. Each sensor node is capable of controlling and storing data from several sensors. The designed wireless medical sensor consists of a microprocessor, a memory storage unit, one or more sensors and a wireless communication interface (see Figure 4).

5. Implementation

The residential gateway was implemented on a Linux system. Knopflerfish [12], a complete open source OSGi R3 framework, was utilized. Given that residential gateway ought to be an embedded system, the operating system and those required bundles were compacted to the order of several Mbytes. This size fits an embedded system with few resources.

The medical sensor connected to personal computer through serial link is popular. The wireless medical sensors were simulated with U.C. Berkeley mote sensor nodes. Figure 5 illustrates the interface between the residential gateway and wireless medical sensors. The sink node is an interface between the residential gateway and the wireless medical sensors through the serial link. All the wireless medical sensors communicate with the sink node via wireless channel.

The wireless medical sensors sense and acquire vital signs and periodically transmit them to residential gateway via the sink node. The medical services installed on residential gateway using the service provider processes these data and forwards them to the diagnosis system in the hospital monitoring station. In case of an urgent event, the residential gateway will triggers an alarm for the medical stuff in the monitoring centre. Figure 6 shows the example vital signs sensed by the wireless medical sensors.
6. Conclusion

This study proposed a tele-homecare system based on the OSGi service platform and the wireless medical sensor. The OSGi framework enables flexibly and user-friendly health care monitoring. Medical sensors with wireless connectivity, light weight and low power consumption maximize quality life for tele-homecare patients. The sensing vital signs of patients are critical and have to be transmitted to the monitoring centre in real time. Future work will explore the provision of QoS in the OSGi-based residential gateway for tele-homecare systems.

7. References


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