Cross-platform Obstetric Monitoring Information System based on the Internet of Things

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Abstract

With the gradual liberalization of China's fertility policy and the popularization of maternal health management, the demand for high-quality obstetric medical resources is increasing. In recent years, the digital obstetric system has paid more and more attention to the information management, especially fetal monitoring data. This research combines the Internet of Things and Cloud Service technologies to design a multi-platform obstetric information management system, which realizes the informatization and cloud analysis of fetal heart monitoring data. This system is mainly divided into three layers, including: controller layer, management layer and application layer. The controller layer is the wireless control interface of the fetal monitoring device based on the TCP protocol. The management layer is mainly responsible for the caching, storage and cloud synchronization of fetal monitoring data. The application layer implements report printing, log management, cloud analysis and device management. Moreover, based on the application layer, this work designs a web client and an Android client to realize the cross-platform interaction of obstetric information system. This system will greatly facilitate the management of pregnant women and help the intelligence of the obstetric information system.

Keywords

Obstetric Monitoring; The Internet of Things; Cloud Service.

1. Introduction

With the changes in people's concept of fertility, reproductive health and the quality of the birth population have been paid more and more attention. Fetal heart rate monitoring data is a basic and important parameter in obstetric data, and a key indicator reflecting the developmental state of fetal body. Clinically, fetal heart rate monitoring is generally collected by electronic fetal monitoring (EFM) device, which is currently the most commonly used non-invasive intrauterine monitoring method [1]. However, traditional EFM data is difficult to digitally manage and analyze due to manufacturer restrictions, wired communications, and complicated operations. This severely restricts the development of the obstetric information system.

In recent years, with the development of the Internet of Things (IoT) and cloud service technologies, traditional monitoring devices have gradually transformed to IoT devices, especially in the fields of mobile medicine and healthcare [2]. But in contrast, this technology has relatively few applications in the field of fetal monitoring. In IoT domain, although the bluetooth-based wireless fetal monitor proposed by Bhong et al. [3] and the ZigBee-based wireless fetal monitor proposed by Goutam et al. [4] had been successfully achieved the wireless transmission of EFM data, these systems have failed to achieve fetal monitoring data management and cloud analysis. In data management domain, Zhang et al. [5] proposed a remote fetal monitoring system based on virtual instruments, which sends the collected fetal heart signals to the PC device and connects to the hospital service center through the gateway. Although this method achieves centralized management of data, it only achieves centralized storage and viewing of EFM data, and fails to achieve auxiliary analysis with the advantage of server. Moreover, the system needs to be forwarded with the help of a PC device, which is not suitable for mobile monitoring scenarios.

To solve the deficiencies in the informatization of fetal monitoring data mentioned above, this article proposes an obstetrics information system based on the IoT and cloud service technology, which realizes wireless access, data cloud management, and cloud analysis of fetal heart monitoring equipment. In previous work [6], we proposed a wireless probe networking technology based on non-standard communication protocols, which establishes a foundation for the wireless communication of EFM devices. At the same time, for multi-platform access scenarios, the Android client and web client were implemented to realize cross-platform data management.

2. System Architecture

2.1 System Overview

The cross-platform obstetric information system proposed in this paper is mainly divided into three layers, including: control layer, management layer and application layer, as shown in Figure 1. The controller layer is the wireless controller interface of EFM devices based on the TCP protocol, which supports multiple EFM devices to access the obstetric information system through the wireless communication channel. The management layer is mainly responsible for the caching, storage and cloud synchronization of EFM data. The application layer realizes report printing, log management, cloud analysis and device management.

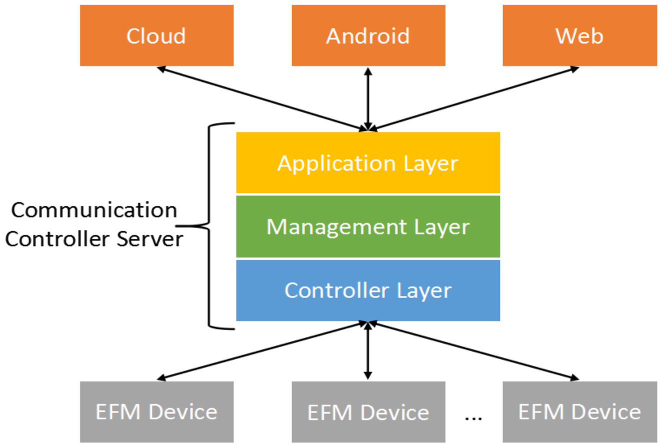

Figure 1. The overall structure of the system

2.2 EFM Device

The EFM device integrates a fetal heart contraction probe acquisition and processing unit, a wireless communication unit, an offline acquisition storage unit, and an online firmware upgrade unit. EFM device supports both online and offline modes. In online mode, the EFM device sends fetal heart rate and contractions data to the server in real time. In offline mode, the EFM device caches data in the local flash, the EFM device reports the EFM local cache status when connecting to the server, and the server can optionally update the offline data to the central database.

2.3 Controller Layer

The controller layer consists of the physical layer, network layer and transport layer, as shown in Figure 2. The physical layer adopts the same communication channel and format as the EFM device to realize the transmission and reception of radio frequency data. The network layer is implemented using TCP long connections, so heartbeat messages need to be sent intermittently to maintain the connection between the client and the server. The transport layer encapsulates the TCP protocol

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according to functions of the EFM device. And it is divided into three types, including parameter packet, data packet, and upgrade packet. The parameter packet controls the configuration such as the switch and gain of the EFM device. The data packet transmits the collected fetal heart data. The upgrade packet realizes the online upgrade of EFM device firmware. In addition, scenarios such as packet errors, packet out-of-sequence, and packet loss may occur due to harsh conditions such as internal channel interference in the hospital. To solve these problem, our system also implements cumulative acknowledgment, error retransmission, and blocking control mechanisms in the controller layer.

2.4 Management Layer

The management layer interacts with the controller layer through the data control and cache interface. It realizes the processing and storage of different event from the controller layer. The core of the management layer is to realize data management and cloud synchronization, including cloud data synchronization, maternity history binding, EFM devices list, system log and other information. In our system, the data control and caching interface is implemented through the Redis database. Obstetrics information and medical record data are stored persistently through SQLite database. And the cloud server is realized by the Alibaba RDS server based on the OSS system.

2.5 Application Layer

The application layer interface provides different services to the client, including: printing reports, monitoring log management, EFM device management, cloud data synchronization and cloud analysis. Optionally provide different service items according to the configuration of different clients.

2.5.1 Cloud Server

The cloud server is mainly responsible for storing pregnant information, medical advice information and EFM device information. The cloud server implements an HTTP request to update the local database through the cloud synchronization interface of the application layer. In addition, the cloud server also realizes the intelligent analysis function of data. When the client initiates a request to the cloud analysis interface, the application layer first calls the cloud data synchronization interface to synchronize the EFM data. Then, the cloud server analyzes and evaluates the data in the cloud. Next, the cloud server returns the analysis report to the local server. At this point, the client can download the report.

2.5.2 Android Client

The Android client is a convenient application based on the TCP protocol to quickly view the fetal heart contraction curve. The basic workflow of the Android client is shown in Figure 2. First, establish a TCP server on the server side to respond to the Android unit connection service. After the Android client establishes a TCP connection, the server will forward the latest data packet bound to the EFM device to the Android client. The Android client can also send a control command word to the server to realize the parameter control of the EFM device.

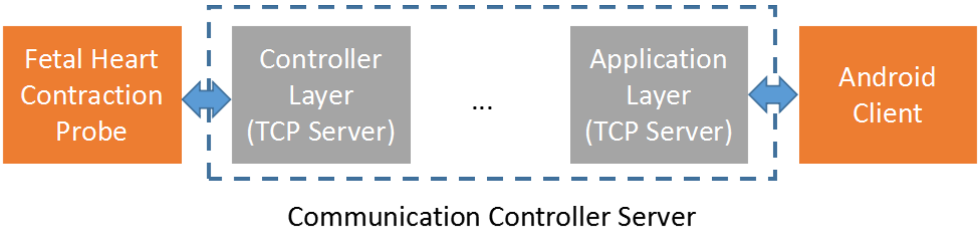

Figure 2. The basic workflow of the Android client

2.5.3 Web Client

As the core client, the web client implements all the service items of the application layer. The web client is implemented using HTTP protocol. The HTTP server on the web side directly obtains information such as EFM data, device list and device status from the local data storage. In addition,

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it has subscribed to three channels based on the Redis message list, and realized the cloud storage, cloud analysis and printing functions of the fetal monitoring report.

Figure 3. EFM monitoring data of the Android client

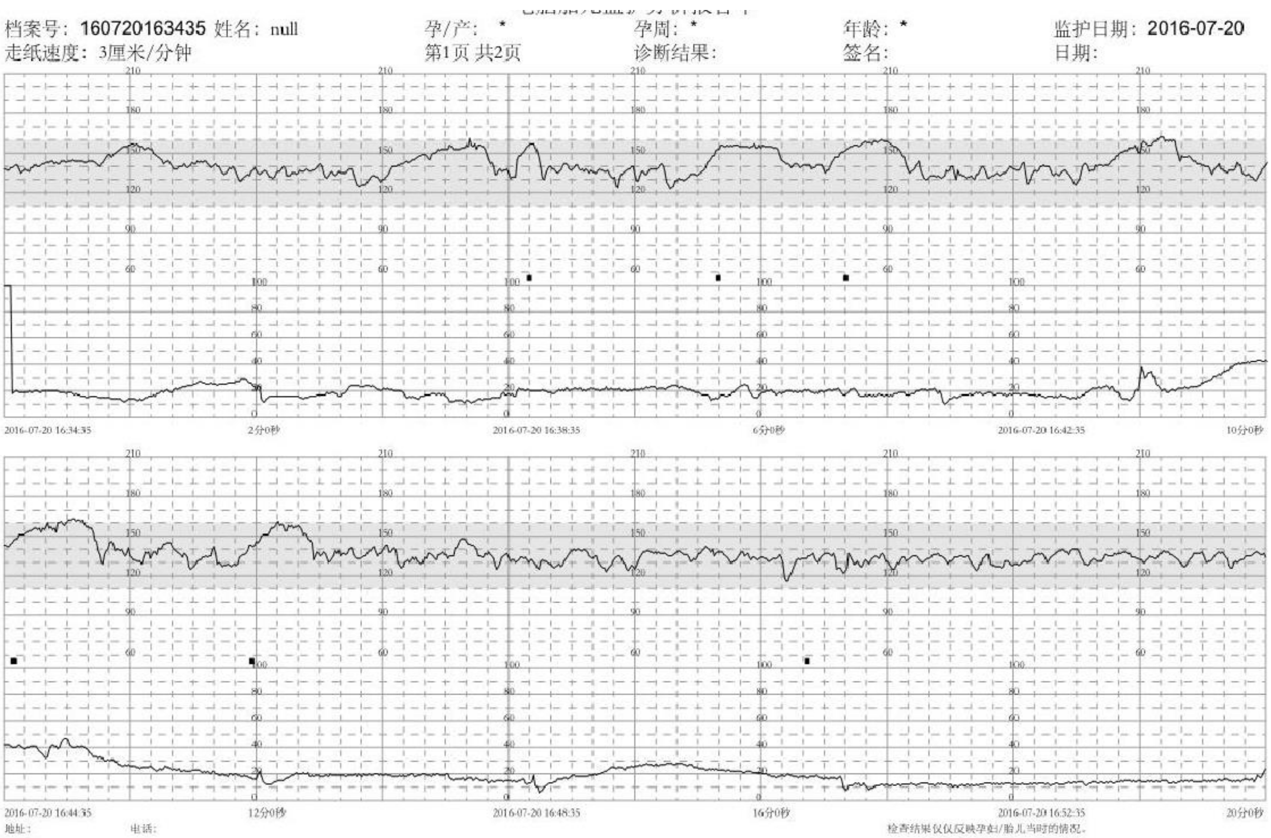

Figure 4. EFM fetal monitoring report of the web client

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3. System Performance

In the performance test phase, this study was connected to a wireless fetal heart contraction probe device for a long-term functional test. Figure 3 is a record of simulated EFM data obtained by the Android client in real time. Figure 4 is the actual EFM data report obtained by the Web client calling the print report interface. After 20 times of fetal heart rate monitoring tests and inspections, it was found that the coincidence rate of the internal fetal monitoring data of the EFM device and the synchronized fetal monitoring data of the server was as high as 99.7%. Among them, 0.3% of the loss is related to the abnormal data collected by the fetal monitoring probe.

The obstetric information system based on the IoT includes wireless fetal heart contraction probe, communication controller server (including control layer, management layer and application layer), upper client (Android and Web) and cloud server. In the entire structure, the wireless fetal contraction probe independently collects data from the EFM device, and performs data preprocessing in the probe. The communication controller server obtains EFM data, including fetal heart rate (FHR), uterus contraction (UC) and fetal movement graph. The wireless fetal heart contraction probe communicates with the control layer of the wireless communication server through a wireless network. As the core module of the system, the wireless communication server communicates with the wireless fetal heart contraction probe to obtain and record fetal heart rate monitoring data, including device number, device status, real-time fetal heart rate monitoring data, start and end of monitoring, etc. The wireless communication server communicates with the cloud server, and regularly uploads and downloads the device list, user information and fetal heart rate monitoring records.

4. Conclusion

Combining computer technology with medical treatment is one of the current research hotspots in interdisciplinary fields. With the development and maturity of wireless communication technology and computer technology, more and more medical data systems have successfully used cloud computing technology to improve medical efficiency and service quality. This article analyzes the shortcomings of traditional fetal monitoring, and combines the advantages of the IoT and cloud service technologies to design and implement a cross-platform obstetric information system. The main work of this paper are:

1. Designed the main protocol architecture and functions of the obstetrics information system based on the IoT, and gave a detailed hierarchical introduction to the basic composition and implementation of its protocol stack.

2. Designed the structure of the communication controller server, including the controller layer, management layer and application layer; introduced the functional realization of important modules in the communication controller server and the design of basic business logic. At the same time, it also introduces the basic implementation of Android client and web client based on the communication control server. Finally, the accuracy and stability of the communication controller server are tested through simulated data and measured data.

3. Designed an intelligent cloud analysis module. We introduced the basic process of obtaining reports for fetal heart rate and contractions data through cloud server interface for cloud analysis.

The design and implementation of the system in this article is an attempt to combine wireless communication technology, computer analysis technology, and cloud service technology with traditional electronic fetal heart rate monitoring systems. This combination not only improves the environment for fetal heart rate monitoring, and improves the comfort of pregnant women when performing fetal heart rate monitoring, but also improves the efficiency of the use of medical resources, reduces the waste of medical resources, and reduces the burden on medical staff.

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