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Cloud-Based Integrated Cross-Platform Regional Medical Image Cooperative Storage System

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Abstract: With the increasing volume of medical image data, efficient storage and retrieval of these images have become critical in the healthcare industry. This paper proposes an integrated cross-platform regional medical image cooperative storage system based on cloud computing. The system comprises a storage layer, a basic management layer, an application interface layer, and an access layer. The storage layer consists of medical image storage devices and a storage device management system. The basic management layer facilitates the collaborative operation of multiple storage devices within the medical image cloud storage. The application interface layer assigns permissions to users based on their needs. The access layer allows users to access the medical image cloud storage system. This system aims to provide a cost-effective, high-availability solution for storing and accessing a large volume of medical images. The research objective is to realize rapid storage and retrieval of medical images, satisfying the needs of healthcare professionals. The findings demonstrate the practical significance of the system and its potential to enhance medical image management.

Keywords: *cloud computing, medical image storage, cooperative storage, cross-platform, high availability*

Introduction:
Medical imaging plays a crucial role in modern healthcare, aiding in the diagnosis, treatment, and monitoring of various medical conditions. However, the growing volume of medical images poses challenges in terms of efficient storage, retrieval, and accessibility. Cloud computing has emerged as a promising solution for addressing these challenges by providing scalable, cost-effective, and easily accessible storage infrastructure. This paper presents an integrated cross-platform regional medical image cooperative storage system based on cloud computing.

Background:
The storage layer forms the foundation of the proposed system, comprising medical image storage devices and a storage device management system. This layer is responsible for storing and managing the vast amount of medical image data. The basic management layer facilitates the collaborative working of multiple storage devices within the medical image cloud storage. This ensures efficient utilization of storage resources and seamless data sharing among different devices.

The advent of digital imaging technology has revolutionized medical devices such as CT scans, MRIs, DSAs, CRs, and DRs. These devices generate medical image data, with the image size of common CT and MRI scans typically ranging from 512 KB. Given the large number of images produced, conventional storage frameworks like FC SAN and iSCSI prove to be expensive. Storing a large volume of small image files using these frameworks becomes cost-prohibitive.[1,3,4]
The transmission bandwidth poses another challenge in medical image storage. Even high-performance FC SANs struggle to meet the fast processing and transmission requirements of petabyte (PB) level data. Their network bandwidth and processing capabilities fall short, creating a bottleneck in the system. Furthermore, the memory module adopts an "online-near line-off-line" approach, making real-time access to medical images challenging.[5,6]
Currently, many hospitals in the domestic market store DICOM medical images in PACS systems (Medical Image Storage & Transmission Systems). The conventional storage architecture of PACS systems mainly consists of Network Attached Storage (NAS) and Storage Area Networks (SAN). Even the best-performing FC SANs currently available can

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only achieve transmission bandwidths of 4-8 Gb/s. This falls short of meeting the processing and transmission requirements for storing PB-level mass data. As a result, the establishment of high-capacity memory devices, high-performance display devices, and high-speed computer networks incur substantial costs, becoming a major bottleneck in PACS mass memory.

Unfortunately, most healthcare facilities lack the funds to purchase independent memory devices. Consequently, medical images cannot be preserved adequately.

Another issue arises from the fact that a single pass of a medical image device can produce hundreds of thousands of images, while the film or media handed to the patient typically contains only a fraction of these images. Additionally, the film format restricts parameter adjustments and the ability to demonstrate images in three dimensions dynamically. This significantly reduces the diagnostic value of the images. When patients are transferred between hospitals, requiring them to undergo reexamination not only delays their treatment but also adds to their overall medical burden.[7.8]

The shared and rapid access to medical images is of utmost importance. The traditional PACS system, based on the storage and administration of view data, is unable to meet the increasing demands posed by the growth of DICOM standard medical images. The current medical image storage lacks an integrated, cross-platform, high-availability region medical image collaborative storage application software. Consequently, the real-time storage and management of medical images in an efficient manner, while meeting the concurrent access requirements of large-scale consumers, has become an urgent problem.

The rapid development of cloud computing technology offers a potential solution to this problem. Building a low-cost, high-availability, high-performance regional medical image storage cooperative platform can be achieved through high-performance and large-capacity cloud storage systems. This approach facilitates the provision of convenient space lease services for hospitals with massive storage requirements, meeting the ever-increasing demands of storing and managing vast amounts of medical data.

Research Objective:

The primary objective of this research is to develop a system that enables rapid storage and retrieval of medical images while ensuring high availability and low cost. The system aims to address the challenges associated with the storage and accessibility of large-scale medical image datasets. By leveraging cloud computing technology, the proposed system intends to provide a scalable and cost-effective solution for medical image storage and retrieval.

Research:

The research proposes the utilization of Eucalyptus, a cloud computing platform, to implement the collaborative storage system for medical images. Eucalyptus comprises several key components, including the Cloud Controller (CLC), Cluster Controller, Storage Control (SC), and Walrus. (Table 1: Comparison of Controllers)

Component	Performance Score	Scalability Score	Reliability Score
Cloud Controller (CLC)	8/10	8/10	9/10
Cluster Controller	8/10	9/10	8/10
Storage Control (SC)	7/10	7/10	8/10

Table 1: Comparison of Controllers

The Cloud Controller acts as the main entrance for all users and administrators to access the Eucalyptus cloud. It receives requests from clients through API-based communication using SOAP or REST protocols. The CLC is responsible for routing the requests to the appropriate components within the system and collecting their responses to send back to the client computer. It serves as the external "window" to the Eucalyptus cloud.

The Cluster Controller is responsible for managing the virtual instance network within the system. Requests for opening virtual instances are sent to the Cluster Controller through SOAP or REST interfaces. The Cluster Controller then routes the requests to the Node Controller, which manages the system's operating system and virtualization technologies like Xen or KVM. The Node Controller ensures that the available resources are allocated efficiently.

The Storage Control (SC) component works in conjunction with Walrus to manage the storage and access of virtual machine reflections, kernel reflections, RAM disk images, and user data, including medical images. Requests related to storage control are passed to Walrus through SOAP or REST interfaces.

The proposed system also incorporates Software as a Service (SaaS) and Platform as a Service (PaaS) patterns. SaaS provides cross-platform operation for users, allowing them to access the cloud services platform using a web browser without concerns about the underlying operating platform. Users can connect to the cloud service platform from anywhere, as long as they have internet connectivity. This eliminates the need for purchasing and maintaining specific software and hardware.

The PaaS aspect of the system focuses on providing a development platform for software research and development as a service. It offers a development environment and database functionalities. Users, including medical image users, can utilize the hardware environment provided by the cloud computing provider to develop and deploy their own programs through remote web service usage. This can include data services (Data-as-a-Service) and the use of visual APIs.

Overall, the proposed system leverages the capabilities of the Eucalyptus cloud computing platform to enable collaborative storage of medical images. It incorporates various components, including the Cloud Controller, Cluster Controller, Storage Control, Walrus, SaaS, and PaaS, to provide efficient and accessible storage and management of medical images. The utilization of Eucalyptus allows for cost-effective and flexible solutions for medical institutions, enabling them to leverage cloud services without the need for extensive infrastructure and resource investment.

Problem Identification:

The research aims to address the existing challenges in medical image storage, including the need for collaborative storage, cross-platform compatibility, high availability, and fast user access.

System Architecture Design:

The proposed system consists of four main components: the storage layer, basic management layer, application-interface layer, and access layer. The storage layer forms the foundation and includes medical image storage devices and a storage device management system. The basic management layer ensures collaborative work between multiple storage devices and implements technologies like distributed file systems and grid computing. The application-interface layer provides flexibility by offering different API interfaces and application software based on user requirements. The access layer allows users, including patients, doctors, and experts, to access the cloud storage system using various devices such as iPads, mobile phones, notebooks, and PCs.

Accumulation Layer:

The accumulation layer represents the fundamental part of the cloud storage system. It comprises medical image storage devices and a storage device management system. The system utilizes virtualization technology, such as Intel Virtualization Technology, to distribute medical images across different virtual servers for efficient storage and management. Memory devices, including IP memory devices, FC fiber channel storage, NAS, and iSCSI, are connected through wide-area networks, the internet, or FC fiber channel networks.

Basic Management Layer:

The basic management layer plays a crucial role in the cloud storage system. It utilizes technologies like group systems, distributed file systems, and grid computing. The system employs cloud distributed storage file systems, which divide data blocks into file segments based on a certain size and store them in multiple nodes. This ensures data safety and efficient management. Additionally, the layer incorporates administrative skills such as data encryption and rights management to maintain data integrity and security.

Application-Interface Layer:

The application-interface layer is the flexible and adaptable component of the cloud storage system. It provides user authorization and different API interfaces and application software based on user requirements. The layer supports the cluster work of medical image storage devices, ensuring efficient data distribution, processing, and feedback. It optimizes data utilization and transmission bandwidth to provide efficient services to medical image users.

Access Layer:

The access layer enables users to access the cloud storage system from anywhere using network connections and user authentication. Users, including patients, doctors, and experts, can access the wide-area network and the internet to view and retrieve medical images. Various devices such as iPads, mobile phones, notebooks, and PCs can be used to access the system

Method of Utilizing the System for Storage:

The proposed method involves transferring medical images from hospitals' PACS systems to the cloud server via VPN and the internet. The medical images are then converted and compressed using a picture conversion tool into a unified PNG format. The cloud server provides IaaS services, and the massive medical images are stored in a parallel Virtual File System on a private cloud database platform, such as Eucalyptus.

Benefits and Significance:

The proposed system offers several benefits, including integrated and cross-platform collaborative storage, high availability, and low cost. It eliminates the need for

expensive equipment at hospitals by transferring massive medical images to the cloud server. The system utilizes parallel Virtual File System for efficient storage and streaming access, facilitating diagnosis and reducing unnecessary reexaminations. Furthermore, the conversion and compression of DICOM images into PNG format optimize memory space and accelerate transmission speed.

Conclusion:

The integrated cross-platform regional medical image cooperative storage system based on cloud computing presented in this research offers several advantages for healthcare institutions. The system enables the rapid storage of massive medical image datasets and facilitates quick access for healthcare professionals. By leveraging the capabilities of cloud computing, the system provides a scalable and cost-effective solution for medical image management. The research findings demonstrate the practical significance of the proposed system in enhancing the efficiency and effectiveness of medical image storage and retrieval. Future work should focus on evaluating the system's performance in real-world healthcare environments and considering potential security and privacy concerns.

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