MULTI-AGENT FOG COMPUTING RESOURCE MANAGEMENT MODEL FOR CRITICAL HEALTHCARE APPLICATIONS

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DECLARATION

I declare that this thesis entitled "Multi-Agent Fog Computing Resource Management Model for Critical Healthcare Applications" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name : Ammar Awad Mutlag

Date : 04/04/2023

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APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Doctor of Philosophy.

Signature : ....

Supervisor Name : Professor Dr. Mohd Khanapi bin Abd Ghani

Date : 04/04/2023

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DEDICATION

To my beloved mother, wife and kids

ABSTRACT

Fog computing is a fairly new distributed computing technique which expands the capabilities of cloud computing to the edge of the network. Fog servers operate as an intermediary between cloud data centres and end-user devices. One of the aims of fog computing is to increase performance and reduce the amount of data being transferred to the cloud for processing, analyzing and storing. This approach allows the execution of a portion of a transaction at a fog server. However, cloud computing still suffers from resource management in healthcare application tasks. Critical healthcare application tasks require a quick response because it affects patients' life. Fog computing is the best solution to get a fast response and less energy consumption. To significantly implement Fog computing, it's paramount to manage the resources of Fog computing and develop interoperability among Fog and Cloud. Any modelling effort of Fog computing resource management, especially in healthcare applications, depends on scheduling the tasks which in turn involves three main factors; Load Balancing, Resource Availability, and Prioritization. Hence, the main contribution of this thesis is to develop a model of resource management that employ the aforementioned factors. From the literature, it is clear that the contribution of Multi-agent systems in scheduling is huge. In this thesis, the role of Multi-agent systems is to optimise critical healthcare tasks scheduling efficiently. The results have shown that the Multi-Agent Fog computing model (MAFCRMM) is very efficient in providing the fastest response for critical healthcare application tasks in terms of the number of energy consumption, instance cost, delay, and response time.

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MODEL PENGURUSAN SUMBER PENGKOMPUTERAN KABUS MULTI-AGEN UNTUK APLIKASI PENJAGAAN KESIHATAN KRITIKAL

ABSTRAK

Pengkomputeran kabus ialah teknik pengkomputeran teragih yang agak baharu yang memperluaskan keupayaan pengkomputeran awan ke pinggir rangkaian. Pelayan kabus beroperasi sebagai perantara antara pusat data awan dan peranti pengguna akhir. Salah satu tujuan pengkomputeran kabus adalah untuk meningkatkan prestasi dan mengurangkan jumlah data yang dipindahkan ke awan untuk diproses, dianalisis dan disimpan. Pendekatan ini membolehkan pelaksanaan sebahagian daripada transaksi di pelayan kabus. Walau bagaimanapun, pengkomputeran awan masih mengalami pengurusan sumber dalam tugas aplikasi penjagaan kesihatan. Tugas aplikasi penjagaan kesihatan kritikal memerlukan tindak balas yang cepat kerana ia mempengaruhi kehidupan pesakit. Pengkomputeran kabus adalah penyelesaian terbaik untuk mendapatkan tindak balas yang pantas dan penggunaan tenaga yang lebih sedikit. Untuk melaksanakan pengkomputeran Kabus dengan ketara, adalah penting untuk mengurus sumber pengkomputeran Kabus dan membangunkan kesalingoperasian antara Kabus dan Awan. Sebarang usaha pemodelan pengurusan sumber pengkomputeran Fog, terutamanya dalam aplikasi penjagaan kesihatan, bergantung pada penjadualan tugas yang seterusnya melibatkan tiga faktor utama; Pengimbangan Beban, Ketersediaan Sumber dan Keutamaan. Oleh itu, sumbangan utama tesis ini adalah untuk membangunkan model pengurusan sumber yang menggunakan faktor-faktor yang disebutkan di atas. Daripada literatur, jelas bahawa sumbangan sistem Multi-agen dalam penjadualan adalah besar. Dalam tesis ini, peranan sistem Multi-agen adalah untuk mengoptimumkan penjadualan tugas penjagaan kesihatan kritikal dengan cekap. Keputusan telah menunjukkan bahawa model pengkomputeran Multi-Agen Fog (MAFCRMM) adalah sangat cekap dalam menyediakan tindak balas terpantas untuk tugas aplikasi penjagaan kesihatan kritikal dari segi bilangan penggunaan tenaga, kos contoh, kelewatan dan masa tindak balas.

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LIST OF ABBREVIATIONS

CC	-	Cloud Computing
CHTM	-	Critical Healthcare Tasks Management
CW	-	Current Workload
DTA	-	Dynamic Tasks Allocation
EC	-	Edge Computing
FC	-	Fog Computing
FN	-	Fog Node
FNA	-	Fog Node Agent
HP	-	High Priority
IA	-	Intelligent Agent
IoT	-	Internet of Things
LBA	-	Load Balancing and Availability
LBD	-	Load Balancing Decision
LP	-	Low Priority
LW	-	Local Workload
MAFC	-	Multi-Agent Fog Computing Model
MAS	-	Multi-Agent Systems
MFN	-	Master Fog Node
MP	-	Moderate Priority
MPA	-	Master Personal Agent
NW	-	Neighbor Workload
P, L, R	-	Priority, Load Balancing, Resource Availability
PA	-	Personal Agent

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PD	-	Priority Decision
PHR	-	Patient Health Record
PTL	-	Priority Tasks List
PTS	-	Priority Tasks Scheduling
RAD	-	Resource Availability Decision

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LIST OF SYMBOLS

£ - Cost

ą - The set of fog node agents

C - Critical Task

ƈ - Mapping function from agents to cloud

L - Load Balancing

ɱ - Mapping function from agents to fog nodes

N - Normal Task

P - Priority

R - Resource Availability

T - Task

ţ - The set of tasks

ρ - The set of personal agents

χ - The cooperative model for multi-agents

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Healthcare is an essential part of life, providing a variety of services such as counseling, diagnosis, and disease prevention. The quality of people's lives is improving, and the need for medical resources is growing by the day, emphasizing the major drawbacks of the traditional medical model. Currently, the typical pattern's crucial distinction of healthcare services focuses on the following aspects: intensive healthcare resources, doctors' and patients' conflicts, inequality in the distribution of medical resources, and so on (Yang et al., 2021).

A health information system is a system designed to handle health information (HIS). HIS is a tool used to enhance services and reduce medical errors (Melin and Axelsson, 2014). A hospital's organisational structure, or a technology that supports healthcare policy choices are all included in HIS. HIS also included the systems that manage information about the operations of healthcare organizations and providers. These might be utilized in tandem to improve research, patient outcomes, and policy and decision-making. The HIS is normally related to commonly accessing, process, or maintaining large volumes of sensitive data related to patient lives, where many medical applications are developed. Previous research has recognized numerous reasons, such as, not restricted to, unjustified or inadequate HIS deployment, unsuitability in healthcare specifications, absence of appropriate input data as well as validation, and speeding up evolution of technology causing instability of patient solutions (Noran and Bernus, 2022).

The use of computer-aided technology nowadays in HIS is important to meet the needs for long-term care and remote medical monitoring, as well as to decrease the financial burden on patients, convenient and comprehensive. One of the important features of health information systems which has many applications to name few; Mobile Health (mHealth) (Zhu et al., 2021), and Electronic Health (eHealth) (Gerli et al., 2021).

The healthcare information system has three main steps, first is the generation of the data, then the processing, and lastly the outcomes and analytics of the data. Whereas, healthcare services have important metrics that are used to evaluate the system which are; accuracy, performance, time, cost, energy, interoperability, scalability, and reliability (Haghi et al., 2021).

One of the technologies used in healthcare is cloud computing. It is a way of providing a shared pool of readily provided and released configurable computer resources with ubiquitous, simple, on-demand network connectivity (for example, networks, servers, storage, applications, and services) (Botta et al., 2016). Researchers are attempting to merge healthcare systems with cloud computing to better fulfill healthcare application demands.

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A potential technology is cloud computing, that has the potential to change the healthcare information system infrastructure. Cloud computing technology is adaptable, energy-efficient, low-cost, and fast to implement, which can help healthcare systems cope with the many challenges (Kumar et al., 2021).

Although cloud computing has many benefits, there are some drawbacks, such as significant delays, ironing demands for applications that are sensitive to real-time or latency, and the constraint of network bandwidth, which can still not be overcome by using only cloud computing (Shukla et al., 2021).

According to Jamil et al. (2020), cloud data management and processing can lead to latency, network traffic management, computer processing, and power consumption inefficiencies. Cloud computing offers computing and storage resources for users and has brought massive economic benefits in many areas. The architecture of the cloud in healthcare is termed a sensors cloud. virtualization, automation, collaboration, scalability, and flexibility with better processing and storage capacity are all advantages of sensor-cloud. However, with the exponential growth of smart devices and sensors, artificial intelligence, and other items on the Internet, these networks have challenges in scheduling, load balancing, reliability resource optimization, and limited bandwidth (Alturki et al., 2021). Because the cloud data center is located distant from the end user, long-distance transmission reduces real-time efficiency, and a large number of applications such as healthcare information systems are processed in the cloud data-center, thus raising the cloud burden (Wang et al., 2020).

In response to the increase in low latency, mobility, and network capacity, fog computing can expands cloud features to the edge of the network and allows processing, connectivity and storage closer to HIS devices as well as HIS's end-users (Tuli et al., 2020).

Bonomi et al. (2012) revealed that the use of fog in three networking levels includes; i) Collecting data from the devices on the edge (medical sensors); ii) a Huge number of devices connecting to the network and sending data; iii) The collected data from the devices should be processed in less than a second along with decision making (You and Learn, 2015). Fog computing refers to the movement of cloud solutions closer to the users at the edge of the network and the provision of computation, communication, and storage to the devices at the edge, thereby facilitating and improving mobility, latency-sensitive, and network bandwidth. Fog computing can match perfectly low-latency or real-time applications (Hu et al., 2017). Fog computing offers an intermediary layer between remote and isolated conventional data centers and on-site equipment or sensors/devices to provide computational power, storage, and control to consumers (Amaxilatis et al., 2020). Fog computing will

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