ADAPTIVE AND FAULT-TOLERANT SCHEDULING FOR EFFECTIVE DATA STORING IN HEALTHCARE COMMUNITY USING CLOUD COMPUTING

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By

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Thesis submitted to the School of Graduate Studies Universiti Putra Malaysia in fulfilment of the requirements for the Master of Computer Science

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June 2019

Supervisor : AP Dr. Masnida Hussin
Faculty : Computer Science and Information Technology

Cloud computing is growing fast and spreading more into an aspect of our life. Apart from traditional web services such as searching, webmail and online education, many organizations, enterprise, personal developers and even individuals could make use of Cloud computing services. Healthcare community services are one of the vital aspects of our life. The volume of data the healthcare industries has to collect and manage are growing rapidly over the past decade. The Cloud infrastructure is helping healthcare organizations use large volumes of collected data to be effectively and efficiently managed, also to develop better clinical responses. Single Cloud Data Centers have a limitation of physical resources, thus, leveraging cloud confederation is a good approach to solve the limitation problems, but issues arise when it comes to selection for optimal CDC among the confederated CDC to complete a task. In this work, adaptive and fault-tolerant scheduling approach for securing healthcare information is

developed for a multi-Cloud Environment, where we use fuzzy logic for selection decision and square matrix multiplication for predictions of healthy/unhealthy resources. Cloudsim is used for the simulation system of our FT-FnF model and shows a better result in regards to users Qos, Providers profit, and resource utilization compared to the FnF model.

Abstrak tesis dikemukakan kepada senat University Putra Malaysia sebagai memenuhi keperluan untuk ijazah untuk Master Sains Komputer

JADUAL ADAPTIF DAN PENYELESAIAN TOLERAN FAIL UNTUK PENYIMPANAN DATA EFEK DALAM MASYARAKAT KESIHATAN MENGGUNAKAN KOMPLEK MUDA

Oleh

ALIYU MUHAMMAD

June 2019

Pengerusi : AP Dr. Masnida Hussin
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Pengkomputeran awan berkembang pesat dan menyebarkan lebih banyak ke dalam aspek kehidupan kita. Selain dari perkhidmatan web tradisional seperti carian, webmail dan pendidikan dalam talian, banyak organisasi, perusahaan, pemaju peribadi dan juga individu boleh menggunakan perkhidmatan pengkomputeran awan. Perkhidmatan komuniti penjagaan kesihatan adalah salah satu aspek penting dalam kehidupan kita. Jumlah data industri penjagaan kesihatan yang dikumpulkan dan dikelola berkembang pesat sepanjang dekad yang lalu. Infrastruktur Awan membantu organisasi penjagaan kesihatan menggunakan jumlah besar data yang dikumpul untuk dikendalikan dengan berkesan dan efisien, juga untuk membangunkan respons klinikal yang lebih baik. Pusat Data Awan Tunggal mempunyai batasan sumber fizikal, oleh itu, penggunaan konfederasi awan adalah pendekatan yang baik untuk menyelesaikan masalah batasan tetapi isu-isu timbul ketika memilih CDC optimum di antara CDC yang dikompilasi untuk mengira tugas. Dalam usaha ini, pendekatan

penjadualan adaptif dan kesalahan toleransi untuk mendapatkan maklumat penjagaan kesihatan dibangunkan di Persekitaran Berbilang Awan, di mana kita menggunakan logik kabur untuk keputusan pemilihan dan pendaraban matriks persegi untuk ramalan sumber yang sihat / tidak sihat. Cloudsim digunakan untuk sistem simulasi model FT-FNF kami dan menunjukkan hasil yang lebih baik dalam hal pengguna Qos, keuntungan pembekal dan penggunaan sumber berbanding dengan model FnF.

DEDICATIONS

This project is dedicated to my parents for their endless love and support in every journey of my life.

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All praise be to Allah the most gracious and most merciful for his bounty on to me of given me the health, strength, faith, endurance, and guidance, to mention but nothing, to be able to complete this work. I thank Allah for His immense grace and blessing every stage of my entire life. May His peace and blessings continue to shower on the best creature, the seal of prophet-hood, Muhammad *Sallallahu Alaihi Wasallam*, and on his descendants and disciples.

I would like to express my utmost gratitude to my parents Engr. Babangida Zango and Hajiya Maryam Goje on whose upbringing, continued support and prayers I am ascending up to this level.

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APPROVAL

This thesis was submitted to the Faculty of Computer Science and Information Technology of Universiti Putra Malaysia and has been accepted as partial fulfillment of the requirement for the award of the degree of Master of Computer Science.

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DECLARATION

I declare that the thesis is my original work except for quotation and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or other institution.

Signature: ___________________________ Date: _________________

Name and Matric No: Aliyu Muhammad GS51088

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LIST OF ABBREVIATIONS

CDC	Cloud Data Centre
STVM	Same type virtual machine
MLR	Multiple linear regression
CRM	Cloud resource manager
LCC	Local cloud confederation
GCC	Global cloud confederation
SLA	Service level agreement
VM	Virtual machine
QOS	Quality of service
FAM	Fuzzy association member
RFC	Resource provisioning in Federated cloud
MPA	Mathematical programming approach
FNF	Family and friends
FT-FNF	Fault Tolerant-Family and friends

CHAPTER ONE

INTRODUCTION

1.1 Background

Cloud computing has contributed towards transforming the delivery of information technology from product to a service. It makes platforms, infrastructural resources, and various software as scalable services on demand over the internet. Cloud computing has evolved virtually in all areas of computing, such as virtualization techniques, grid computing, distributed computing, and Service-oriented Architecture (SOA). It provides features such as pay as you go, connectivity, reliability, scalability, managing a large amount of data and ease programmability, also transform IT from a product to a service. Cloud computing has numerous advantages for easing difficulties of computing services but it still remains questionable when it comes to its reliability and availability of the services offered because of the Extensive use of the cloud-based services for hosting enterprise or business applications (Nazari Cheraghlou, Khadem-Zadeh, & Haghparast, 2016). Let’s now look at cloud computing in a different dimension. Cloud computing services are services that are divided into three major service models namely, Software as a service (SAAS): In this model, services are offered by the cloud service providers in a form to end users. Infrastructure as a service (IAAS): Provides a high-level API's used to dereference various low-level details of underlying networks infrastructure like data partitioning, location, scaling, backup, and security. Platform as a service (PAAS): This model allows a platform to be developed, run, test and manage applications in the cloud (Hasan & Goraya, 2018).

Most commonly used deployment model in a cloud (Nazari Cheraghlou et al., 2016): Public cloud: where the general public has access to the systems and services offered by an enterprise provider. It provides location independent, flexibility and scalability. Resources are provisioned dynamically on an on-demand basis from a remote third party provider that offer resources by using a multi-tenant approach.

Private cloud: The private cloud is used within a particular organization, all the services and resources can only be access with that organization. This model has high security and privacy of data because it is limited to a few numbers of users compared to other models.

Community cloud**:** various enterprise and organizations used this model and help a peculiar community/society that communal activities, this model can be owned, operate and managed by several organizations inside a community and a third party.

Hybrid cloud: this model is an alliance of both public and private cloud. Critical events that require much security in their operation are accomplished by the private cloud services, while non-critical events are accomplished by public cloud services.

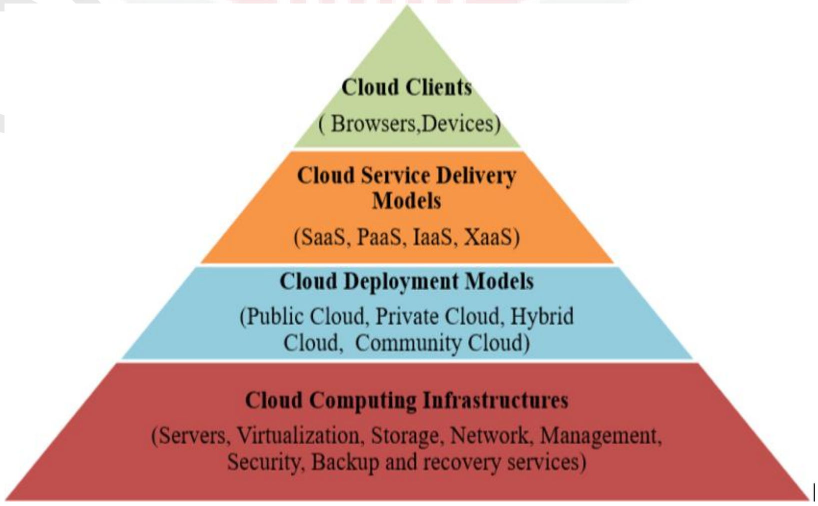

Figure 1. 1 Cloud computing models and their deployment (Firouzi et al., 2018)

1.1.1 Cloud Computing in Healthcare

Due to the rapid growth of the healthcare organization/industry, it is moving from a locally based business model to the cloud-based business model, such advancement enables it to fulfill resource demand of different types of applications in the healthcare industries. The tasks of the healthcare now vary from a common file retrieval of patient to complex biomedical images analytic, the cloud provides a huge amount of resources to the healthcare systems because of the cloud elasticity and flexibility the healthcare industries benefits from these characteristics of cloud, in which they carry out their medical operations without going through many difficulties.

Healthcare applications require large high-performance computational nodes and the cloud has the capacity to fulfilled such requirement, users can create a virtual version of physical resources, such as storage devices, servers, network components or even operating system by leveraging the virtualization technology of cloud facilities. It is essential to manage the large volume of resources while ascribing a huge number of a different healthcare related task to multi-computing nodes (Sahoo & Dehury, 2018). The major issues are data availability and load balancing or scheduling, providing an appropriate approach to the problems will help solve the stated problem by making the systems or application flexible and reliable. In this intent work, an adaptive approach will be provided to effectively and efficiently handle the problems facing the healthcare systems.

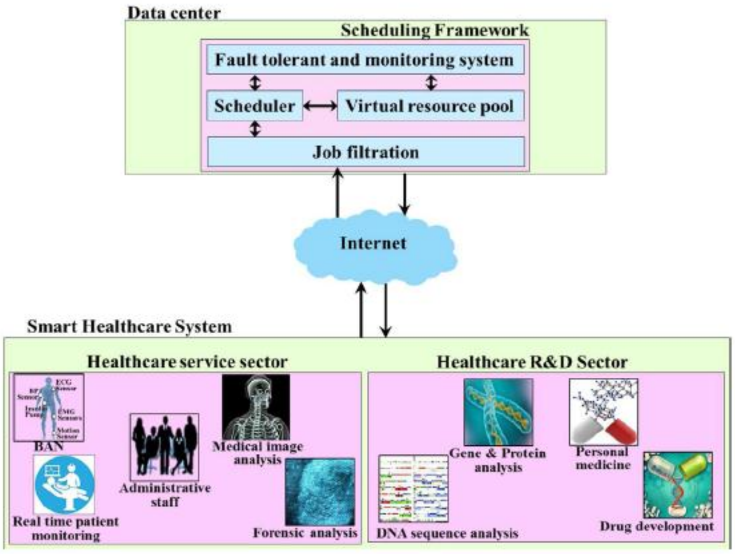

Figure 1. 2 Cloud computing and healthcare integration (Tawalbeh, Mehmood, Benkhlifa, & Song, 2016)

1.1.2 Electronic Medical Record

Electronic Medical Record (EMR), is a record that is created by the healthcare organizations using a computer, such as the patient, Doctors, and hospital information. Using EMR can improve healthcare efficiently because the traditional way of keeping medical data on papers creates many problems, including spending a lot of time to access and transmission, difficulty for backup, cost of space management, and increasing paper cost and waste, EMR is digital, paperless, and computerized for maintaining patient data, an example is where most hospital and radiography practices evolve from film-based management systems to a digital-based (paperless and filmless), although implementing EMR systems is expensive and complex. There are several advantages to electronic medical record even though the problem of storing medical images are more or less unsolved (Yang, Shih, Chen, & Kuo, 2015). In this proposed work maximum efforts are put to solve the problem by taking advantage of the EMR of a specific healthcare Centre/organization.

1.1.3 Cloud Confederation

Cloud confederation (federation) known as a paradigm that is used to increase the profit of service providers via the sharing of additional available virtual and physical resources. It allows providers to carry out federation principles while dealing with their resources. In this essence, providers aim to overcome resource constraints in their own infrastructures by outsourcing the request to other cloud providers that are in the confederation, thus increasing their revenue and user satisfaction. In addition to that cloud confederation allow other members of the cloud to leasehold portion of the resources owned by the underutilized providers generally at a lower cost in order to avoid underutilizing the capital that can't be stored. Confederated cloud data centers, which can be exploited for executing users request need to satisfy both the providers revenue and user Qos Requirement. The Confederating cloud also solves the problem of resource heterogeneity where a CDS receive a vast number of diverse big application request with varying durations, resource demands, performance objectives and priorities. (Hassan et al., 2014). Profit for host CDS will be minimized when it is driven to a confederated state for serving a particular job because the payment of the client will be bifurcated among the host CDS and the federated CDS, while on the other hand when a request is served only by the host CDS, its profit is maximized. But in some cases whereby the host resources is fully utilized or not powerful enough to compute the request, then it becomes unable to guarantee Qos requirements, therefore, a good member of the federation may perform task maintaining the Qos. However, the research challenge for this is to find the optimal CDS that maximize the profit of the host as well as ensuring the user Qos. In cloud confederation, we face the problem of multi-constrained optimization, where we need to make a trade-off between user's Qos and Providers profit, while considering resource heterogeneities and big data application making the problem difficult to solve(Das et al., 2017).

Digital Imaging and Communication in Medicine (DICOM), it's a standard in the field of medical informatics for exchanging of information between medical imaging equipment and other relevant systems, ensuring interoperability. Sets of protocols is specified by the standard for devices communicating through a network the syntax and semantics of commands and other related information that can be exchanged using these protocols using these protocols a set of devices and media storage services claiming conformance to the standard, as well as medical directory structure to facilitate access to the images and file format and related information stored on media that share information. This standard was developed in collaboration by the National Electrical Manufacturers Association (NEMA) and the American College of radiography (ACR) and as an extension of the earlier standard for exchanging medical imaging information that did not include provisions for offline media formats or Networking (http://medical.nema.org/). DICOM provides integration for workstations, printers, scanners, servers, and hardware from multiple manufacturers into a picture archiving and communication system (PACS). These devices come with the DICOM conformance statements that clearly state the classes they support. DICOM been widely adopted by hospitals and making inroads in dentists and doctors offices. Some DICOM differs from some, but not all, it groups information into datasets. Meaning a file of an x-ray contain both the x-ray information plus the patient ID with the file, in this case, the image can never be separated from the information by mistake. This is alike to the way that image formats such as jpeg that have embedded tags to identify and otherwise describe the image.

Data object in DICOM consists of a number of attributes, such as ID, name, and one special attribute containing the image pixel data (i.e., rationally, the main object has no header, such as merely a list of attributes, including the pixel data). Also, the same basic format is used for all the applications, including file usage and network. But when written to a file, usually a true header (containing copies of few key attributes and details of the application that wrote it) is added. In a single DICOM, an object can only contain one attribute containing pixel data. For many modalities, this resembles a single image. However, the attribute may contain multiple 'frames', which allow storing of cine loops or other multi-frame data possible. (Yang et al., 2015).

1.1.4 Fault Tolerance in Cloud Computing.

One of the hottest issue in the cloud to when it comes to reliable and desirable delivery of services is Fault tolerance. Implementing fault tolerance is difficult due to the dynamic service infrastructure and complex configurations. Researchers have put extensive efforts to implements mechanisms to be deployed in the cloud. Implementations of the fault tolerance mechanisms have to do with the analysis of the background, and several methods and knowledge of the application domain (Hasan & Goraya, 2018). A fault is a condition where one or more parts of the system malfunctioned, which makes the system to perform undesired and unintended functions, the fault causes error, error which is a deterioration in one or more component lead to systems failure. The effect of fault is so critical in the sense that it can bankrupt the economy of a service provider. In 2013 a failure for 45m cost amazon cloud a loss of $5m.

The ability of the system to keep executing its intended tasks in spite of fault occurred is called fault tolerance. No matter how a system is designed without having fault tolerance mechanism it is considered vulnerable. One of the important factors of the cloud is reliability because a large number of applications are to be executed, therefore service reliability is important. Fault can be classified into two Byzantine faults and crash fault (Jhawar & Piuri, 2013). Byzantine fault is faults which creates unclearness in the outcomes that results to non- deterministic condition while crash fault occurs as a result of failure in one or multiple system components, however certain fault exhibit both crash and Byzantine fault.

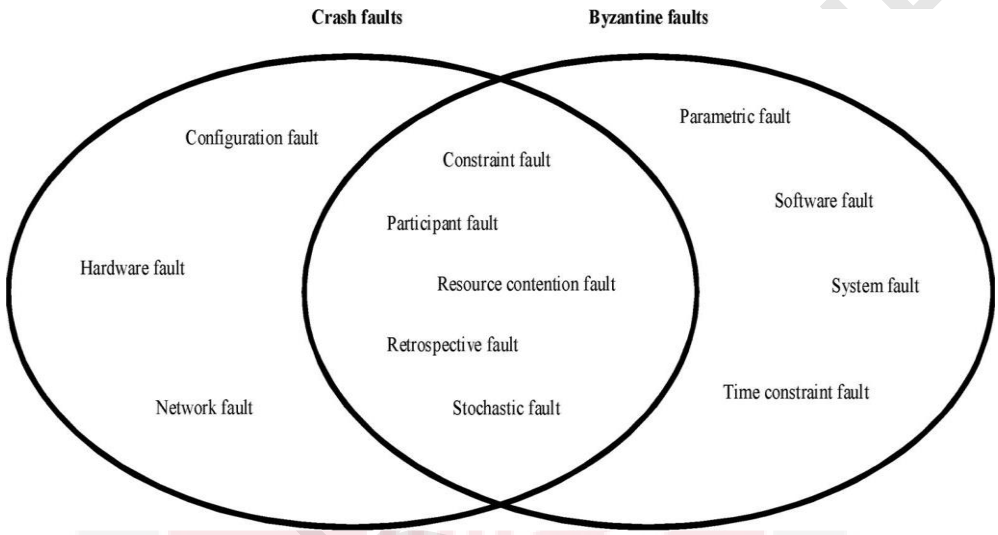

Figure 1. 3 Fault categorization in cloud (Kail, An, Eter, & Os, 2016)

However, this work only focused on network and hardware fault. Network fault: is a type of fault that occur as a result of failure in either of the network component (router, switch, etc.). Hardware fault: This type of fault that occurs at the infrastructure level as a result of a failure in any hardware component.

1.2 Problem Statement

- Effective optimization of cloud VM resources support various medical services such as storing, pre-processing, prioritizing, sharing, visualizing, and analysis of monitored data has been a challenging issue(Das et al., 2017).

- A model FnF (Das et al., 2017) leverage the cloud confederation approach which maximize profit and resource utilization for cloud service provider and maintains the Qos. Nevertheless, the prediction doesn't cover resources that are prone to failures, which means there is no fault tolerant capability on the systems, which makes it difficult to discover failing component, as a results causes violation of users Qos and loss of profit for service providers.

1.3 Research Question

This research work will provide answers to the following questions:

- How will the confederated cloud be more efficient when it comes to the selection of which Cloud to run various requests by the users with the appropriate prediction of CDC resources as well as predicting their condition (healthy or unhealthy)?
- How will overprovisioning and under-provisioning that leads to loss of revenue (provider) and violates the user SLA respectively be solved?

1.4 Research Objectives

The objective of this work is to provide a fault tolerant system in a cloud computing environment for healthcare services, where various requests are sent by the users to the cloud for computations and the cloud service providers have to effectively and efficiently manage those requests.

An FnF model is developed by uniting local and global cloud for all types of VM resources, namely; on demand, spot and reserved, the first work to introduce a model for all types of VM resources, the work was done in regard to composite schema brokerage (single broker), fuzzy logic policy for decision on cloud selection was used, as well as leveraging multiple linear regression (MLR) for resource prediction to solve provisioning issues (Das et al., 2017). In our work, we implement a model FT-FNF. We introduced a distributed schema, which has more advantages over composite (Khanna & Jain, 2014), where we have a broker on each cloud Data center to disseminate resources and allocate Virtual Machine to each request. We used Square Matrix Multiplication, which is ideal for the complex scientific application for predicting resources of service providers with their conditions, healthy or unhealthy and fuzzy logic for cloud data center selection.

Having studied the cloud confederations and the FNF model strength and weakness, we considered achieving our objective by;

- Design of fault-tolerant FNF.
- Using fuzzy logic for CDC selection and square matrix multiplication for resource prediction with fault detection and migrator.

Our fault-tolerant FNF (FT-FNF) provide the following outcomes:

1. Maximize providers profit.
2. Reduced tasks execution time.
3. Maximizes Resource Utilization.

1.5 Research Scope

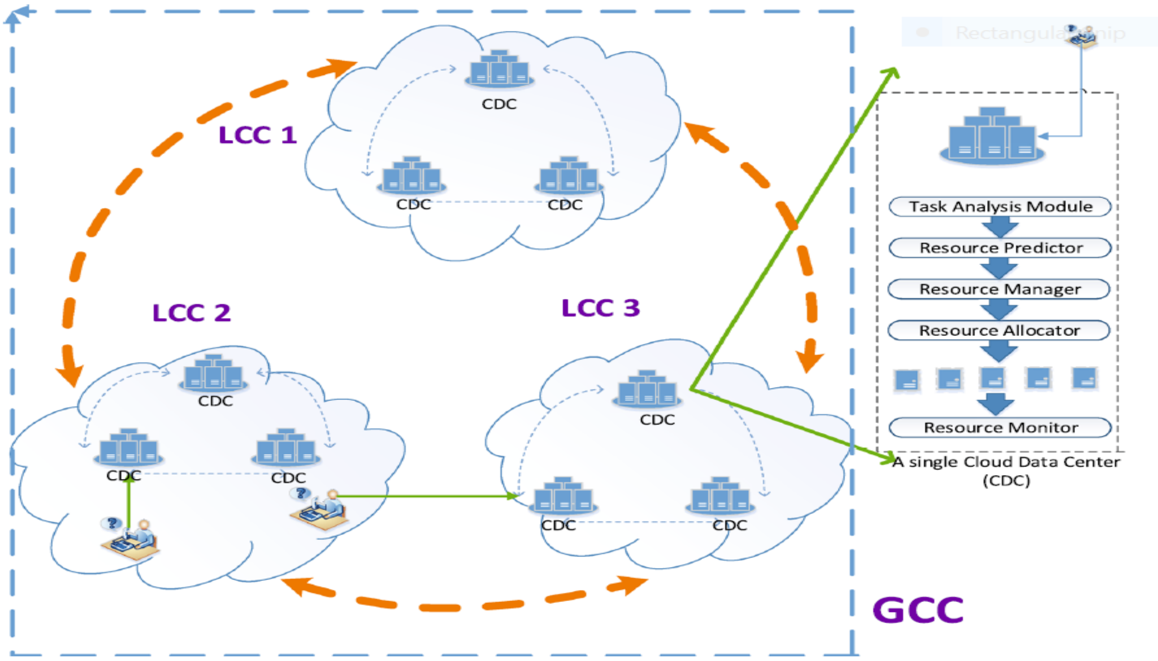

Figure 1. 4 Global and local cloud confederation (Das et al., 2017)

Functional components:

The arrangement of the local cloud confederation (LCC) and Global cloud confederation (GCC) is shown in the above diagram. We observe the collocated CDCs form an LCC and several such LCCs might form a GCC as well. At the right-hand side, functional components are shown from the Figure, where a CDC contains Task analysis Module, Resource Manager, Resource predictor, Resource monitor, and resource Allocator. The task analysis module monitors the arrival of every task and identifies the type it belongs to and also selects a task location (Shpiner, Keslassy, Arad, Mizrahi, & Revah, 2014). The resource predictor, which estimate the resource requirement for processing a request. The resource manager checks for the availability of resources on the CDC and decides whether it will serve a new request or not. While the resource Allocator serves VM to the client for processing client requests and the Resource monitor constantly observes the resource utilization of the servers and the clusters.

1.6 Research Contribution

A novel Qos and profit aware Local and Global confederation model, FT-FNF, has been adopted for processing big data requests. A fuzzy logic based system is used for decision making to choose from the local and global confederation CDC optimally, by trading off between the users Qos and Providers Profit base on some parameters such as the distance, cost and, type of virtual machine, etc. Efficient resource prediction using the Square Matrix Multiplication technique have been constructed that ensures to predict user resource requests more optimally.

1.7 Organization of the Paper

The remaining sections of the paper are organized and presented as follows. **Chapter 2** gives an explanation on related works that match with our area of interest and **Chapter 3** explained how the implementations are conducted. **Chapter 4** explained on the FnF model with validation and result analysis. **Chapter 5** our proposed work on FT-FnF is explained and finally **Chapter 6** Conclude the paper together with the future work.

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