Analysis - Validation of Public and Private Cloud Characteristics for Testing Using Fuzzy Model

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Abstract

The testing of software is an important means of assessing the software to determine its quality. Since testing typically consumes 40~50% of development efforts, and consumes more effort for systems that require higher levels of reliability, it is a significant part of the software engineering. Cost is, of course, a major advantage of moving testing to the cloud. It frees companies from large capital expenditures for creating test environments, and pay-as-you-go models mean need not to pay for idle test environments. Besides certain challenges cloud can attain its efficiency by taking care of parameters like network traffic, disk storage and RAM. In addition to this, types of clouds can be taken into consideration for effective testing. Taking certain characteristics such as performance, reliability & security, administrative control, market, capital benefits, TCO benefits, system availability and scalability as parameters along with their quality, this paper proposes an individual mathematical analysis for local computing, private cloud and public cloud under cartisian product for both parameter and quality, an combined analysis in partial ordering and computing based on quality alone , combined analysis through vendor diagram based on parameter alone. Finally, above is validated by a takagi sugeno fuzzy model which result testing in public cloud is more effective.

1. Introduction

Software testing is a very broad area, which involves many other technical and non-technical areas, such as specification, design and implementation, maintenance, process and management issues in software engineering[1]. With the development of Fourth generation languages (4GL), which speeds up the implementation process, the proportion of time devoted to testing increased. As the amount of maintenance and upgrade of existing systems grow, significant amount of testing will also be needed to verify systems after changes are made [12]. Despite advances in formal methods and verification techniques, a system still needs to be tested before it is used. Testing remains the truly effective means to assure the quality of a software system of non-trivial complexity [13], as well as one of the most intricate and least understood areas in software engineering [19].

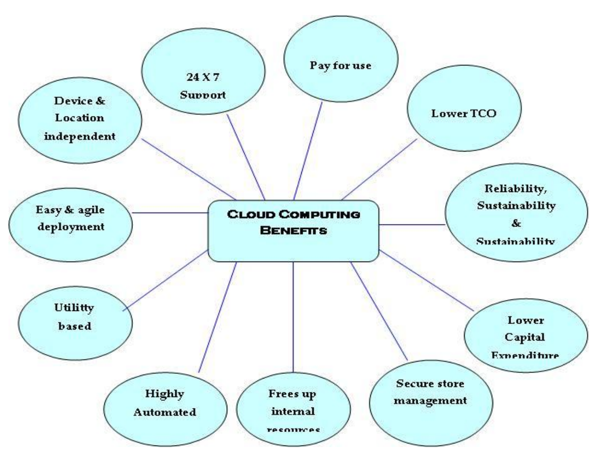

Figure 1 – Cloud Computing benefits

Cloud computing has opened up new opportunities for testing departments. Testing has traditionally required expensive dedicated infrastructure and resources that were only used sporadically. Compared to maintaining an in-house test environment cloud-based testing offers lower costs, more flexibility enhanced collaboration and several other benefits [2]. Figure 1 show the benefits of cloud computing [3].

With cloud-based testing, organizations no longer need to worry about finding servers, procuring licenses for programs and testing tools and installing them. Service providers give testers access to scalable and ready-to-use virtual labs with a library of operating systems, test management and execution tools, middleware and storage necessary for creating a test environment that closely mirrors the real environment. Testers can run existing applications and virtual machines with minimal or no rewriting and utilize pools of virtualized infrastructure to scale up the test environment within minutes [4].

There are some challenges associated with cloud testing such as security, lack of standards, infrastructure, usage, planning and test data[5][6]. As a part of infrastructure resource, cloud testing can attain its efficiency by taking care of the parameters like network traffic, Disk Storage and RAM speed[7]. Added to these parameters, limitations of different kinds of clouds also can be taken into consideration. Mainly public cloud and private cloud is taken into consideration. Thus a mathematical fuzzy model is used to test the limitations of public and private clouds which results testing in public clouds are more efficient. Takagi-sugeno fuzzy model is more realistic and reliable model for dynamic system than Malthus model, verhurst model and harvesting model[25]. In this work takagi-sugeno model is tested in statistical system.

The rest of the paper is organized as follows section 2 discusses about types of cloud computing. Section 3 provides the mathematical analysis using Cartesian product parameters and qualities. Section 4 combined analysis using partial ordering. Section 5 combined analysis using venn diagram. Section 6 validates the results using takagi sugeno model. The major contribution of this paper is to provide a mathematical model for testing the limitations of public and private clouds which results testing in public clouds are more efficient.

2. Types of Cloud Computing

Cloud Computing is one of the most hyped and publicized trends in IT. A cloud-based, 'virtualized' infrastructure can offer advantages over traditional datacenter build outs in the areas of performance, scalability, and even security. As they develop their strategies for implementing cloud computing, many organizations are facing a choice: to deploy a private cloud or leverage a public cloud[8]. Cloud computing can be classified into two ways first, location of the cloud computing and second, types of services offered. First one can be once again classified as public cloud and private cloud [9].

Generally speaking, a public cloud consists of a service or set of services that are purchased by a business or organization and delivered via the Internet by a third-party provider. These services use storage capacity and processor power that is not owned by the business itself. Instead, this capacity (in the form of servers and datacenters) can be owned either by the primary vendor (e.g. an online storage/backup company) or by a cloud infrastructure vendor.

A public cloud service is provided "as a service" over the Internet and the customer's infrastructure or applications are hosted by a cloud service provider at the cloud provider's premises.

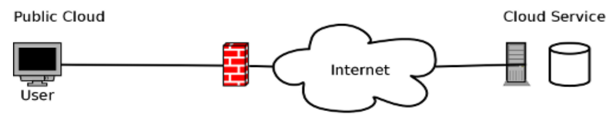

Figure 2 – Public cloud service

The customer has no visibility and control over where the cloud services are being hosted as shown in figure 2. The core infrastructure is shared between many organizations, but each organization's data & application usage is logically segregated so only authorized users are allowed access. Public cloud service is appealing to many decision-makers as it reduces complexity and long lead times in testing and deploying new applications. It is generally cheaper, too, as there is little or no capital expenditures needed[10].

A private cloud is essentially an extension of an enterprise's traditional datacenter that is optimized to provide storage capacity and processor power for a variety of functions. "Private" refers more to the fact that this type of platform is a non-shared resource than to any security advantage [8].

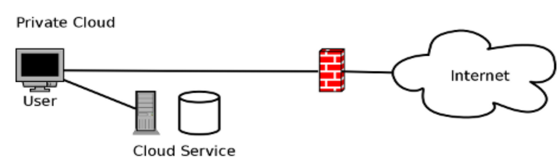

Figure 3 – Private Cloud service

A private cloud service, which can also be called an internal cloud or enterprise cloud, means that the computing infrastructure is hosted on a private platform in the customer data center as shown in figure 3. It is dedicated to a particular organization and not shared with other organizations. A key technology to help organizations enable a private cloud is virtualization. Virtualization helps organizations realize cost savings by letting them leverage their existing hardware infrastructure and not have to purchase additional equipment similar to a public cloud. The difference, of course, is that the private cloud resides at the customer's location and offers customers more control over the infrastructure. It's important to keep in mind that a private cloud also offers on-demand capability where more services can be added quickly as needed [10].

2.1 Public cloud Vs Private Cloud

In order to learn the difference between public cloud and private cloud advantages and disadvantages of both clouds are as follows.

2.1.1 Advantages and disadvantages of Public cloud.

Advantages of public cloud[10] are

Simplicity and efficiency are the overarching benefits of having a public cloud service. Public cloud services are offered as a service, usually over an Internet connection. An off-site third party providerhosts and manages the system. Users connect to the system via the web. Public clouds usually charge a monthly or yearly usage fee.

Low cost - Having a public cloud service in place, organizations can trim the IT budgets because there is no need to purchase physical hardware (which also saves on energy costs), as the servers are virtual - hosted at a third party. Organizations can customize the public cloud service with specific options such as the amount of users so that they only pay for what is needed (pay-as-yougo model). Since the public cloud is hosted by a third party, the organization doesn't need to spend money to have an IT employee monitor the system; it is taken care of by the host.

Reduced time – In-house servers take time to maintain. If hardware or software configurations need to be changed, or if a server crashes or needs to be restarted, the process can often take a couple of hours or couple of days depending on the situation. With a public cloud service, because everything is virtualized, reconfiguring the cloud can take minutes. Also - because the servers are hosted in the cloud, if one server fails, another can instantly be activated, reducing down time.

No maintenance - Due to the fact that the public cloud service is hosted off site, internal IT employees are not responsible for maintaining the system. The design lets users update or introduce technologies into the system at a much faster rate as everything is managed at the host company. Having a public cloud service means never having to deal with physical hardware; it can be maintained from a simple configuration screen.

No contracts – Along with the pay-as-you-go model, there are no long-term commitments. Once the monthly or yearly subscription is over, there is no obligation to continue the public cloud service.

Disadvantages of public cloud[10] are

Lack of control - Due to the fact that third party providers are in charge of the data systems, many organizations feel that not having enough control over the personal data with a public cloud service.

Slow speed - Public cloud services are based on Internet connections, meaning the data transfer rate is limited to that of the Internet Service Provider. If an organization is storing and transferring large amounts of data and needs, a public cloud service may not be the best bet. In addition, the public cloud service's servers must ensure fast access of information to customers' trying to access their data. For example, many customers won't tolerate slow page loading times.

Lack of investment - Although a great cost saving method by reducing the need to invest upfront, renting the service from an outside provider also means that there is little capital gained. Having items residing in-house such as servers and network equipment can pay off in the long run as assets and tax advantages.

Perceived weaker security – Perceived weaker security sometimes is viewed as the main disadvantage in public cloud service. This is not to say that the public cloud doesn't have any security - most of them have excellent measures in place - but for customers with sensitive personal information (e.g. financial institutions), the notion of trusting this information to a third party is often intolerable and considered a liability.

2.1.2 Advantages and disadvantages of Private cloud.

Advantages of private cloud[10] are

Greater control - Due to the fact that the hardware is on-site, organizations have more control over their data. The organization is in charge of monitoring and maintaining the data giving them complete oversight of their data.

More security – Because private cloud services are dedicated to a single organization, the hardware, data storage, and network can be designed to assure high levels of security that cannot be accessed by other clients in the same data center. To be clear, this is not said that public cloud service is not secure. It's just that certain companies will feel the data is more secure by having it reside in-house. Another reason that a private cloud would be desirable has to do with country regulatory issues. In certain countries, the data center hosting a public cloud service must reside within the local country where its users reside as well. When there is no public cloud option that can be provided from the local country, a private cloud is the only option that can be used.

Higher performance - The private cloud is deployed inside the firewall on an organization's intranet, meaning that transfer rates are dramatically increased versus using the Internet. In addition, there's no worry of slow page access times that may happen with using a public cloud service.

Deeper compliance – Sarbanes Oxley, PCI DSS and HIPAA compliance data may be delivered through a public cloud service deployment, but sometimes the data may not be as detailed or customizable. Because the hardware, storage and network configuration is dedicated to a single client, compliance data is much easier to attain.

Customizable – Hardware performance, network performance, and storage performance can be specified and customized in the private cloud since it is owned by the company.

Disadvantages of private cloud[10] are

Higher cost - Private cloud services are in general more expensive than public ones because they require both hardware and maintenance personnel. To build a private cloud service, an organization needs to invest in hardware or use already existing systems whereas a public cloud service is all handled off site. Private clouds also require system administrator's leads to higher administration costs.

On-site Maintenance - Since the private cloud is hosted at the company's site, the organization needs to provide adequate power, cooling, and general maintenance. The host organization also runs the risk of data loss due to physical damage of the unit (i.e. fire, power surge, water damage). Also, if a company has multiple data centers with each data center having a private cloud, the onsite maintenance and the associated costs go up significantly.

Capacity Ceiling – There will always be a capacity ceiling due to the limitations of the physical hardware in the organization's data center. There can only be so much space available within a company's environment to deploy a certain amount of hardware servers.

In overall, both public and private clouds provide a new level of convenience and computing power that was unheard of a few years ago and both have viable roles in the computing landscape. In general, in terms of scalability, versatility, simplicity of use, and price, public cloud service usually beats a private cloud service. The chance to make use of all services, including infrastructure, on a pay-per-use basis, and be free of the problems connected to their daily management represents what most enterprise customers denote as the most significant benefit of public cloud services. Possibly the greatest critique of a private cloud service is that it still requires the customer to purchase, configure and maintain the system or virtualized infrastructure. While the public cloud service user will be able to essentially buy a cheap, ready-made system to be employed right away.

2.1.3 Reasons for public cloud against private cloud.

For small businesses and startups, public cloud service makes all the sense in the world. These companies often do not have much capital and have less risk in losing information due to theft or security breaches. Reasons for public cloud better than private cloud are as follow [11]

1. Private clouds tend to use older technology than public clouds: It might require more money to be spent on new hardware and software every year.

2. Public clouds shift capital expenses to operational expenses: It is pay as you go, versus building an entire datacenter, no matter how virtualized it may be.

3. Public clouds have better utilization rates: With private cloud, the organization still has to build and maintain all kinds of servers to meet spikes in demand across various divisions or functions. Public cloud offers the same spare demand on a pay-as-you-need-it basis.

4. Public clouds keep infrastructure costs low for new projects: on-site resources for unplanned projects that may pop up suddenly might be scarce.

5. Public clouds offer greater elasticity: Not all the capacity of a public cloud is consumed but it is not so in private.

6. Public clouds get enterprises out of the "datacenter business": establishing private cloud probably gets one in deeper into the business than with traditional on-premises servers.

7. Public clouds have greater economies of scale: No private cloud can compete with the likes of Google and Amazon on price. And the public providers are constantly buying boatloads of the latest security technology.

8. Public clouds are hardened through continual hacking attempts: Thousands of hackers have been pounding Google and Amazon for years now. The public cloud providers are ready for anything at this point.

9. Public clouds attract the best security people available: Since security is challenging public cloud providers seek top security people than private.

10. Private clouds suffer from "perimeter complacency": feeling of contentment or self-satisfaction, often combined with a lack of awareness of pending trouble or controversy.

11. Private cloud staff competence is an unknown: The organization may have a lot of talented and knowledgeable people, but it is needed to check data security the main line of the business.

12. Private cloud penetration testing is insufficient: Even if testing the applications and networks on a regular basis these only inform things are secure at that exact moment.

The official Microsoft graph[14] figure 4 says with public clouds not only just amortizing costs across servers. It can also increase server utilization rates by aggregating demand from applications, and can lower application-management costs and server costs per user by serving myriad users across the same infrastructure.

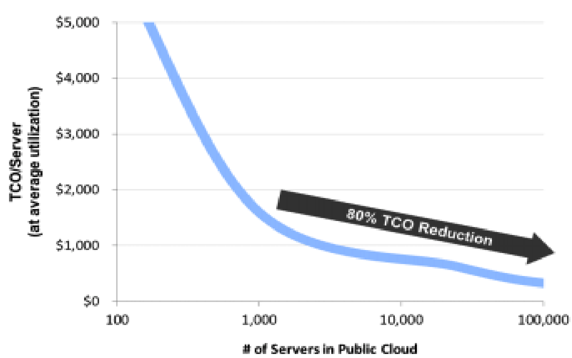

Figure 4 – Total Cost of Ownership (TCO) Vs Number of servers in cloud.

These added benefits are not found in private clouds, which attempt to mimic the public-cloud idea behind the firewall. "While the public cloud addresses all sources of variability, the private cloud can address only a subset," For example, industry variability cannot be addressed by a private cloud, while growth variability can be addressed only to a limited degree if an organization pools all its internal resources in a private cloud [14]. Thus a mathematical fuzzy model is developed using certain attributes such as performance, reliability & security, administrative control, market, capital benefits, TCO benefits, System availability and scalability[17] with which public cloud is preferred than that of private cloud. Computer performance is characterized by the amount of useful work accomplished by a computer system compared to the time and resources used. Depending on the context, good computer performance may involve one or more of the following: Short response time for a given piece of work High throughput (rate of processing work), Low utilization of computing resource(s), High availability of the computing system or application Fast (or highly compact), data compression and decompression, High bandwidth / short data transmission time. Reliability and security means trustworthy computing with data security. Apart from security, these managed service providers give you disaster recovery and data backup plans so that intense situations like cloud collapse or data crash could be handled or managed with ease and less efforts. Apart from security, these managed service providers give disaster recovery and data backup plans so that intense situations like cloud collapse or data crash could be handled or managed with ease and less efforts [23].

3. Individual mathematical analysis of cloud under Cartesian product

In mathematics, a Cartesian product is a mathematical operation which returns a set (or product set) from multiple sets. That is, for sets A and B, the Cartesian product A × B is the set of all ordered pairs (a, b) where a ∈ A and b ∈ B. The simplest case of a Cartesian product is the Cartesian square, which returns a set from two sets. A table can be created by taking the Cartesian product of a set of rows and a set of columns. If the Cartesian product rows × columns are taken, the cells of the table contain ordered pairs of the form (row value, column value). A Cartesian product of n sets can be represented by an array of n dimensions, where each element is an n-tuple. An ordered pair is a 2-tuple.

Consider the parameters performance (1), reliability & security (2), administrative control(3), market(4), capital benefits(5), TCO benefits(6), system availability(7) and scalability(8) as y co-ordinate which are the characteristics of local computing, private cloud and public cloud. The quality of above parameters are taken as No(1), yes(2), low(3), medium(4) and high(5) and considered to be x co-ordinate.

Given a universal set X, a fuzzy set is defined by a function of the $A : X \rightarrow [0,1]$ This kind of fuzzy sets are called ordinary fuzzy sets thus the quality no, yes, low, medium and high is represented in the form of probability as 0.1, 0.2, 0.4, 0.6 and 0.8 respectively.

Table 1 depicts the relationship between the x and y co-ordinates for local computing.

Table 1 – Local computing characteristics

y \ x	No	Yes	Low	Medium	High
Performance	0	0	0	0	0.8
Reliability & Security	0	0	0	0	0.8
Administrative Control	0	0	0.4	0	0
Market	0.1	0	0	0	0
Capital Benefits	0.1	0	0	0	0
TCO Benefits	0.1	0	0	0	0
System Availability	0	0.2	0	0	0
Scalability	0	0	0.4	0	0

Thus x and y coordinates are taken as follows

x= { No,Yes,Low,Medium,High}

y= {performance, reliability & security, administrtive control, market, capital benefits, TCO benefits, system availability,scalability}

In Table 1 the parameters are mapped with their corresponding quality. Performance and Reliability & security are found to be high in local computing whereas the administrative control and scalability is low. System availability is yes but does not mean sudden excess of requirement. Coming to capital benefits, TCO benefits and market it is nil in local computing since it is owned by a single user. Thus the relationship is given as follows

R(x,y) = { (1 4), (1 5), (1 6), (2 7), (3 3), (3 8), (5 1), (5 2) }

Relationship based on quality w.r.t its parameters are as follows. The first quality no is mapped with the parameters capital benefits, TCO benefits and market whose probability is given as 0.1. The weight vector for relationship R(1,y) is calculated as

R (1,y) = { (1 4), (1 5), (1 6) } = 0.1 + 0.1 + 0.1 = 0.3

The second quality yes is mapped with the parameter system availability whose probability is given as 0.2. The weight vector for relationship R(2,y) is calculated as

R (2,y) = { (2 7) } = 0.4

The third quality low is mapped with the parameters administrative control and scalability whose probability is given as 0.4. The weight vector for relationship R(3,y) is calculated as

R (3,y) = { (3 3), (3 8) } = 0.4 + 0.4 = 0.8

The fourth quality medium is not mapped with any of the parameters thus the corresponding relationship does not exist. .

The fifth quality high is mapped with the parameters performance and reliability & security whose probability is given as 0.8. The weight vector for relationship R(5,y) is calculated as

R (5,y) = { (5 1), (5 2) } = 0.8 + 0.8 = 1.6

Comparing all the weights of the above relations maximum is calculated among them which results as 1.6.

Thus max R(x,y) = { 0.3, 0.4, 0.8, 1.6 } = 1.6 ----- A
for local computing.

Figure 5 depicts the Cartesian product for the above for local computing based on both quality and parameters.

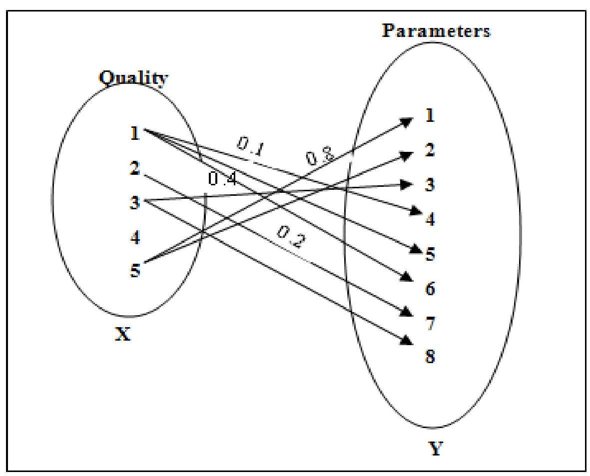

Figure 5 – Relationship between quality and parameters in Local computing

Now consider Cartesian product for private computing. Table 2 shows relationship between the x and y co-ordinates for private cloud computing.

Table 2 – private cloud computing characteristics

y \ x	No	Yes	Low	Medium	High
Performance	0	0	0	0	0.8
Reliability & Security	0	0	0	0	0.8
Administrative Control	0	0	0	0	0.8
Market	0	0	0	0.6	0
Capital Benefits	0	0	0.4	0	0
TCO Benefits	0	0	0.4	0	0
System Availability	0	0	0	0.6	0
Scalability	0	0	0	0	0.8

In Table 2 the parameters are mapped with their corresponding quality in private cloud computing. Performance, Reliability & security, administrative control and scalability are found to be high in private cloud computing whereas market and system availability is medium. Capital benefits and TCO benefits are low. Thus the relationship is given as follows

R(x,y) = { (3 5), (3 6), (4 4), (4 7), (5 1), (5 2), (5 3), (5 8) }

Relationship based on quality w.r.t its parameters are as follows. First three qualities such as no, yes and low does not exist since cloud computing ranges only between low and high. Thus relationships for qualities 1 and 2 does not exist.

The third quality low is mapped with the parameters Capital benefits and TCO benefits whose probability is given as 0.4. The weight vector for relationship R(3,y) is calculated as 0.8

R (3,y) = { (3 5), (3 6)} = 0.4 + 0.4 = 0.8

The fourth quality medium is mapped with the parameters market and system availability whose probability is given as 0.6. The weight vector for relationship R(4,y) is calculated as 1.2

R (4,y) = { (4 4), (4 7) } = 0.6 + 0.6 = 1.2

The fifth quality high is mapped with the parameters Performance, Reliability & security, administrative control and scalability whose probability is given as 0.8. The weight vector for relationship R(5,y) is calculated as

R (5,y) = { (5 1), (5 2), (5 3), (5 8) }

= 0.8 + 0.8 + 0.8 + 0.8 = 3.2

Comparing all the weights of the above relations maximum is calculated among them which results as 3.2.

Thus max R(x,y) = { 0.8, 1.2, 3.2 } = 3.2------(B) for private cloud computing.

Figure 6 depicts the Cartesian product for the above for private cloud computing based on both quality and parameters.

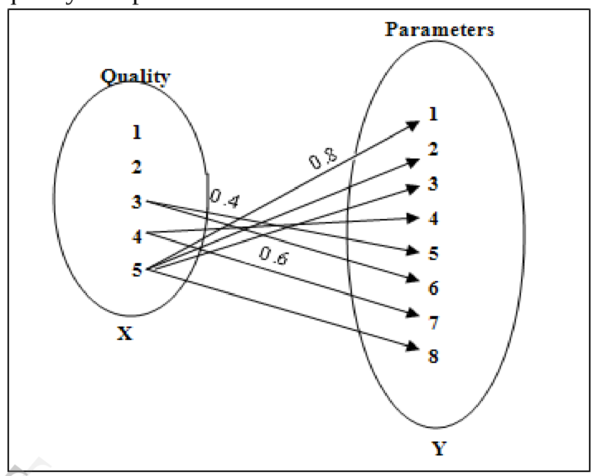

Figure 6 – Relationship between quality and parameters in private cloud computing

Now consider Cartesian product for public computing. Table 3 shows relationship between the x and y co-ordinates for public cloud computing.

Table 3 – public cloud computing characteristics

y \ x	No	Yes	Low	Medium	High
Performance	0	0	0	0.6	0
Reliability & Security	0	0	0	0.6	0
Administrative Control	0	0	0	0	0.8
Market	0	0	0	0	0.8
Capital Benefits	0	0	0	0	0.8
TCO Benefits	0	0	0	0	0.8
System Availability	0	0	0	0	0.8
Scalability	0	0	0	0	0.8

In Table 3 the parameters are mapped with their corresponding quality in public cloud computing. Except Performance and Reliability & security. All

other parameters are found to be high in public cloud.
Thus the relationship is given as follows

R(x,y) = { (4 1), (4 2), (5 3), (5 4), (5 5), (5 6), (5 7), (5 8)}

Relationship based on quality w.r.t its parameters are as follows. First three qualities such as no, yes and low does not exist since cloud computing ranges only between low and high. Thus relationships for qualities 1,2 and 3 does not exist.

The fourth quality medium is mapped with the parameters performance and reliability & security whose probability is given as 0.6. The weight vector for relationship R(4,y) is calculated as 1.2

R (4,y) = { (4 1), (4 2) } = 0.6 + 0.6 = 1.2

The fifth quality high is mapped with the parameters administrative control, market, capital benefits, TCO benefits, System availability and scalability whose probability is given as 0.8. The weight vector for relationship R(5,y) is calculated as

R (5,y) = { (5 3), (5 4), (5 5), (5 6), (5 7), (5 8) }
= 0.8 + 0.8 + 0.8 + 0.8 + 0.8 + 0.8
= 4.8

Comparing all the weights of the above relations maximum is calculated among them which results as 4.8.

Thus max R(x,y) = { 1.2, 4.8 } = 4.8------Ⓒ
for public cloud computing.

Figure 7 depicts the Cartesian product for the above for public cloud computing based on both quality and parameters.

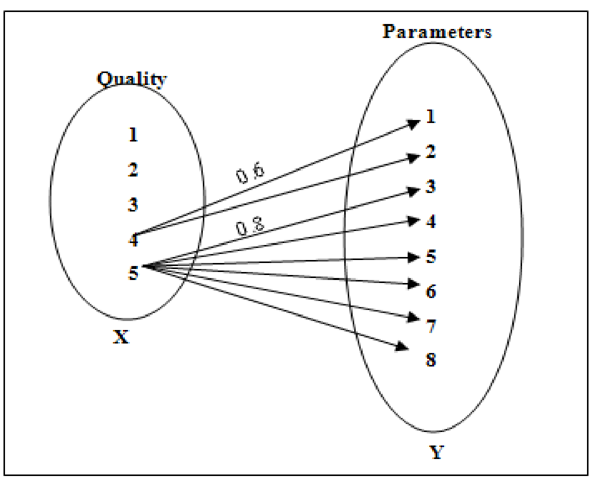

Figure 7 – Relationship between quality and parameters in public cloud computing

According to Cartesian product result maximum value obtained from local computing, private cloud computing and public cloud computing are 1.6, 3.2 and 4.8 by equations A, B and C respectively. Analyzing these results the weight of public computing is high.

Thus by this combined analysis of the parameters and quality of individual analysis of three computing public computing is best suitable for testing.

4. Combined analysis using partial ordering.

In mathematics, especially order theory, a partially ordered set (or poset) formalizes and generalizes the intuitive concept of an ordering, sequencing, or arrangement of the elements of a set. A poset consists of a set together with a binary relation that indicates that, for certain pairs of elements in the set, one of the elements precede the other. Such a relation is called a partial order to reflect the fact that not every pair of elements need be related: for some pairs, it may be that neither element precedes the other in the poset. Thus, partial orders generalize the more familiar total orders, in which every pair is related. A finite poset can be visualized through its Hasse diagram, which depicts the ordering relation [16]. Partial orders have applications to temporal reasoning, planning and scheduling, configuration, process algebras, partially ordered constraint optimization[15].

A fuzzy binary relation R on a set X is a fuzzy partial ordering iff it is reflexive, antisymmetric, and transitive under some form of fuzzy transitivity. When a fuzzy partial ordering is defined on a set X, two fuzzy sets are associated with each element x in X. The first is called the dominating class of x. It is denoted by $R_{\geq[x]}$ and defined by $R_{\geq[x]}$ = R (x,y).where yεX[18].

Thus considering the parameters performance, reliability & security, administrative control, market, capital benefits, TCO benefits, System availability and scalability as set elements the set X = { a / performance, b / reliability & security, c / administrative control, d / market, e / capital benefits, f / TCO benefits, g / System availability, h / scalability }

Figure 8 is the membership matrix that defines a fuzzy partial ordering R on the set for quality and parameters.

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	a	b	c	d	e
a	0	0	0	1	1
b	0	0	0	1	1
c	0	0	1	0	1
d	1	0	0	1	1
e	1	0	1	0	1
f	1	0	1	0	1
g	0	1	0	1	1
h	0	0	1	0	1

Figure 8 – Membership matrix

From the membership matrix it is found that the element e the capital benefit which is dominating class of c and d the administrative control and market. Where c is a dominating class of f and h the TCO benefits and scalability. Also d is a dominating class of a and b the performance and Reliability & security. a is once again dominating class of f TCO benefits and b is dominating class for g system availability. Thus figure 9 depicts partial ordering of membership matrix in figure 8.

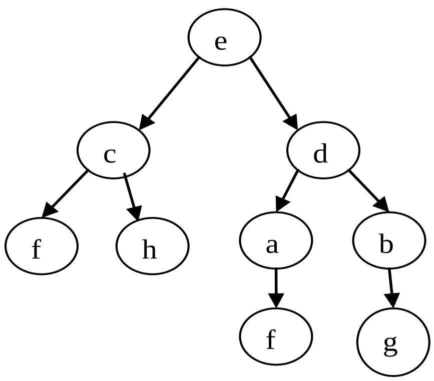

Figure 9 – Fuzzy partial ordering

From the above fuzzy partial ordering it is found that f and g are minimal elements and e is the maximal element. Thus by analyzing it TCO benefits will be obtained only when performance of the computing is good. Similarly system availability requires reliability. Now market is attained when performance and reliability & security is high. On the other hand TCO benefits and scalability relies in administrative control. Finally the maximal element capital benefits are attained. Thus all the parameters is dominated by the capital benefits. Public computing is the one preferred for its capital benefits. Thus comparing to local computing and private cloud computing, public cloud computing attains the capital benefits.

Class for hasse diagram figure 9 is as follows

{ (f) (g) } C { (a) (b) } C { (c) (d) } C { **(e)** }

Thus by partial ordering in fuzzy it is found that public cloud computing is best suitable for cloud testing.

5. Combined analysis using Venn diagram.

A Venn diagram or set diagram is a diagram that shows all possible logical relations between a finite collection of sets. A Venn diagram is a type of graphic organiser. Graphic organisers are a way of organising complex relationships visually. They allow abstract ideas to be more visible. Although Venn diagrams are primarily a thinking tool, they can also be used for assessment. Venn diagrams are used to compare and contrast groups of things[24].

Consider Parameters of private computing which has high performance as
set A = { performance, reliability & security, administrative control, scalability }

Considering the parameters of local computing which has high performance as
set B = { performance, reliability & security }

Parameters of public computing which has high performance as
set C = { administrative control, market, capital benefits, TCO benefits, System availability, scalability }

Venn diagram for the above sets is found in figure 10.

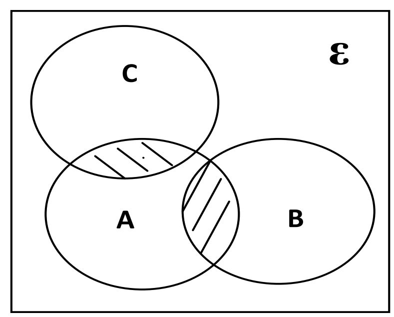

Figure 10 – Venn diagram

From the above figure it is found that common parameters to A and B (i.e) private computing and local computing are performance and reliability & security. Thus the intersection of two sets are given as

$A \cap B$ = { performance, reliability & security }

Similarly common parameters of A and C (i.e) private computing and public cloud computing are administrative control and scalability. Thus the intersection of two sets are given as

$A \cap C$ = { administrative control, scalability }

It is found that there are no common parameters between B and C (i.e) local computing and public cloud computing. Main difference in cloud computing is that there is no need to understand the infrastructure behind it, it becomes "a cloud" where applications and services can easily grow (scale), run fast and almost never fail, without knowing details of how this "cloud." But local computing is fully infrastructure base.

In figure 10 the union set is taken as follows
AUB = { performance, reliability & security, administrative control, scalability }

They are the combined parameters of private computing and local computing. Local computing has dedicated infrastructure but private Cloud on the other hand has dedicated resources that can be managed by the customer and provide greater reliability and higher security.

(AUB)' = {market, capital benefits, TCO benefits, System availability}

When looking into the union set of A and B and their corresponding inverse we find maximum parameters in them forms public cloud computing parameters. Such as

(AUB)U(AUB)' = {performance, reliability & security, administrative control, market, capital benefits, TCO benefits, System availability, scalability} = ε

Thus public computing dominates local computing and private computing by their characteristics.

6. Validation using Takagi-Sugeno fuzzy model.

A fuzzy logic is a precise logic of imprecision and approximate reasoning. More specifically, fuzzy logic may be viewed as an attempt at formalization/mechanization of two remarkable human capabilities[26]. Fuzzy logic is much more than a logical system. It has many facets. The principal facets are: logical, fuzzy-set-theoretic, epistemic and relational. Most of the practical applications of fuzzy logic are associated with its relational facet[20]. Fuzzy inference system also known as fuzzy rule-based systems of fuzzy models are schematically[21]. Two major types of fuzzy rules exist, namely, Mamdani fuzzy rules and Takagi-Sugeno fuzzy rules.

The fuzzy model proposed by Takagi and Sugeno is described by fuzzy IF-THEN rules which represents local input-output relations of a nonlinear system. The main feature of a Takagi-Sugeno fuzzy model is to express the local dynamics of each fuzzy implication (rule) by a linear system model. The overall fuzzy model of the system is achieved by fuzzy "blending" of the linear system models. The input for the model is taken as the parameters of local, private and cloud computing and the input membership function is seen in the table 4.

Table 4 – Takagi-sugeno model inputs and output member functions.

Outputmf / Input	Local Computing	Private Cloud	Public cloud
Performance	High	High	High
Reliability & Security	High	High	Medium
Administrative Control	Low	High	High
Market	Low	Medium	High
Capital Benefits	Low	Medium	High
TCO Benefits	Low	Low	High
System Availability	Low	Medium	High
Scalability	Low	Medium	High

For a zero-order Sugeno model, the output level z is a constant *(a=b =0)*. The output level zi of each rule is weighted by the firing strength wi of the rule. For example, for an AND rule with Inputs as parameters of the local, private and public computing. $F(X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8)$ as inputs the firing strength is

$$wi = AndMethod\ (F(X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8))$$

where low, medium and high in table 4 are the membership functions for inputs.

The final output Z of the system is the weighted average of all rule outputs W, computed as

$$\text{Final Output} = \frac{\sum_{i=1}^{8} WiZi}{\sum_{i=1}^{8} Wi}$$

Sugeno rule operates as shown in figure 1.

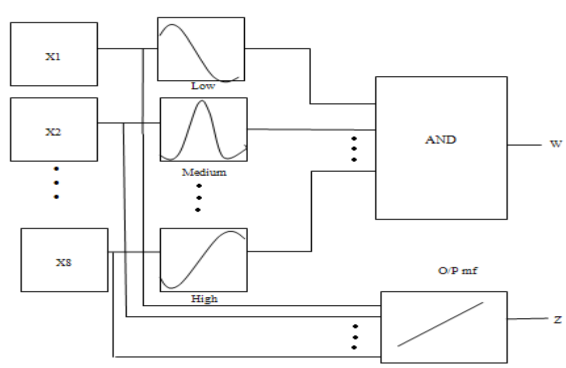

Figure 11 – Sugeno system

The modeling approach used by ANFIS editor. The ANFIS Editor GUI in the Fuzzy Logic Toolbox is the tool that apply fuzzy inference techniques to data modeling. Here zeroth order Sugeno-type systems is used which have a single output Z as public, obtained using weighted average defuzzification. All output membership functions W are as local, private and public. The ANFIS editor model structure is shown in figure 12.

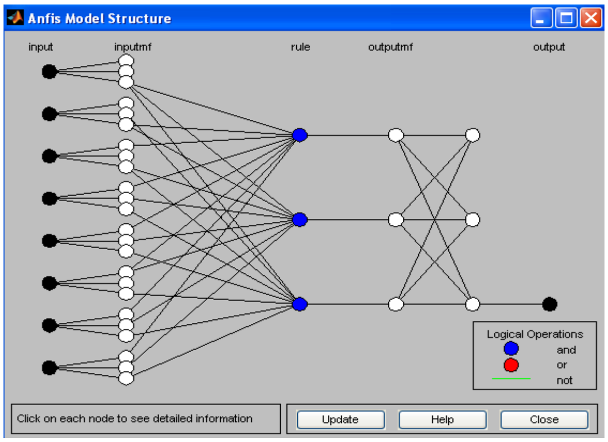

Figure 12 – Anfis Model structure

In the anfis model structure in figure 12 there are 8 input parameters. Each and every membership function is member shipped by low, medium and high as shown in table 4.

After applying AND rule to input membership functions 3 of output membership functions is got such as local, private and public.

From output membership function the weighted average results as public.

Thus from this structural analysis by takagi sugeno fuzzy model it has been proved that based on the characteristics public cloud perform better than testing in local computing and private computing.

7. Conclusion.

A new mathematical model has been framed to analyse the characteristics of local computing, private cloud computing and public cloud computing and have been validated using takagi-sugeno fuzzy model. Though public cloud has many benefits it is argued to be lack in security. Although in public cloud security concerns are handled by the cloud provider yet is has been always a matter for consideration for IT professionals and researchers. Whatever the security risks might be, security breaches will always be part of the computing landscape, but technology will evolve to address each new security risk that emerges so this parameter is nbot taken as major consideration. With all these analyze public clouds provide far more value to users than harm based on its characteristics. Thus public cloud is more suitable for testing in cloud. As future work anfis training in sugeno method might be used for analysis.

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