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A Conceptual Paper on Multi-Scale Applications in Cloud Environment with Reference to Variety of Data

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***Abstract**: Developments in Cloud Computing has opened up new avenues for cutting – edge technology applications. It is the conventional technology that deploys the applications and services on internet servers instead of traditional servers. Software-as-a-Service (SaaS) allows access to a variety of applications on the cloud commonly known as Multi-scale applications. Social and Professional media like Whatsapp, Facebook, Twitter, Instagram, LinkedIn, ResearchGate etc. have migrated to cloud. The terms scale and scalability in cloud environment has been used in different contexts. The applications can be scaled up or down based on the network traffic scenario, and has thus opened up a Pandora's Box in new research and development of multi–scale cloud based applications. This conceptual paper attempts to review literature across various domains where the term multi-scale, scaling, cloud based application have been used and arrive at a reasonable, crisp, concise yet accurate definition of the term multi – scale and multi–scale cloud application. The term "Multi – Scale" is used in various fields referring to multiple scales applied to arrive at solutions to spatio-temporal problems. This conceptual paper attempts to associate a formal definition to the term "multi-scale cloud application" in the cloud computing world. The proposed definition of the said term is extremely relevant in the context of multi–scale applications developed in recent times.*

***Keywords**: Cloud Computing, MSA, Multi-Scale application, Multi–Scale Modeling, multi-scale, SAAS.*

I. INTRODUCTION

Gaining world-wide acceptance and unprecedented demand and popularity, cloud computing and cloud technology has become a de-facto way applications are hosted and made available to end users. Standalone and COTS (Commercial-off-the-shelf) products were traditional which had a high risk of data loss and high cost of resources was incurred as the application resided on the local machine. However, with cloud, it was possible to have a lite version of the application on the local machine and core of the application residing on a cloud based internet server. Resources are made available to the user on the go, meaning ass per need, both applications based as well as user based. Thus eliminating the need for investment in resources, above minimum requirements, many times went as unutilized. This has been made possible with the advent of *SCALABILITY*. We can understand scalability by visiting the below references.

Wikipedia [22] defines scalability as a property of a system to adopt and adjust to handle increased amount of work by auto adding resources on the go. Rather than manual management of hardware and software resources the server system is made capable of assessing the resources available and resources needed by an application. A search engine, for example must be made capable of supporting unpredictable and increased user counts, and also the number of topics it indexes.

Multi–scale modeling is a type of advanced modeling in which multiple independent systems with their own modeling patterns are combined together to make a large and complex system comprising of these multiple models. It can be analogously understood like a human body, which is a complex system comprising of multiple independent systems which have their own rules and governance. It is used in almost all of the branches of Sciences such as Engineering, Mathematics, Physics, Chemistry, Bioinformatics, Computational Biology, Meteorology and even in Computer Science [1]. It can be used for investigating the problems that occur around time and space, also referred to as the space–time continuum. Multiple scales of such dependable attributes are studied in this modeling. Other than computer science, several important problems occur in disciplines such as fluids, solids, polymers, proteins and nucleic acids, adoption, chemical reactions and diffusion [3].

With reference to the software and information technology world, it is simply referred to as multiple components working together, which basically deals with High Performance Computing applications (HPC) or multi-processing or parallel-processing [6]. However, in cloud computing, these applications are referred with slight different approach. Lee, Kim et. al. explained it as: consumer invoked service deployed by its providers and service providers are liable to manage the quality of their services including scalability, availability and performance [8]. Furst et. al. referred to applications on the cloud as the next generation of Internet which will allow one to "buy" IT services from a web portal [9]. Cloud computing is an automated on demand self-serviced paradigm, allowing a pay – per – use model on shared resources [11]. Given the high costs of hardware and the maintenance of the same, the cloud infrastructure gained unprecedented exposure and growth. Today it is hard to imagine our computer and mobile systems as standalone systems.

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Even so, Cloud Computing is by far one of the most studied and researched areas by most of the researchers in the current times. Most applications are now being executed on the cloud and those that are not are slowly either migrating towards the cloud or slowing phasing out. Challenges like rising costs of hardware, high maintenance costs, and unpredictable network traffic, time to scale up or make available additional resources, and is responsible for the widespread adoption and growth in the cloud infrastructure. Various types of applications defined according to their architecture or data volume are now available on the cloud. A whole new set of applications, which are gaining widespread popularity nowadays are somewhat distinct in their payload attributes are Facebook, WhatsApp, Twitter, Instagram, YouTube, LinkedIn, etc. These applications can be considered as true multi-scale applications as the transactions involved in these applications are a mix of text, image and multimedia oriented. When studying Cloud Computing, the term multiscale does not find a direct reference but the term scalability has been used alternatively. In the ensuing sections the paper will attempt to explore further literature to define and provide in greater detail, outlining the concept of a Multi Scale Cloud Based Application.

II. LITERATURE REVIEW

Traditional architecture of computer resources was mostly standalone in nature, or residing within local premises of the office. With the advent of networking and then internetworking, remote application hosting with application layer being provided as user interface gained popularity. With cloud computing and virtualization, even the resource management and availability shifted away from the local machine. These days, with advancements in cloud based systems and architecture there off, the concept of thin clients is back and even standalone systems have become nothing more than dummy terminals. The appropriate allotment of resources based on the application need is called scale architecture. This scale architecture of cloud application is of paramount interest to many researchers globally with numerous parallel studies and researches being carried out.

In 2007 there an important study conducted by Duboc, Rosenblum and Wicks [12] established that the term scalability was very loosely and poorly defined when referring to the cloud based systems and IT sector. The study also went on to establish that it was very difficult to evaluate claims of scalability and to compare claims from different sources. They initially attempted to define scalability by way of establishing that it is a technique which can be used as a multi – criteria optimization problem technique. Thus they arrived at a definition as "scalability is defined as a quality of software systems characterized by the causal impact that scaling aspects of the system environment and design have on certain measured system qualities as these aspects are varied over expected operational ranges". Further study reveals reference to multi scale modelling in the study published by Mark Horstemeyer [2] and its usage in various disciplines such as solid mechanics, fluid mechanics, materials science, physics, mathematics, biological, and chemistry. He refers to the roots in the works carried out by Da Vinci regarding different sizes of ropes to the power of multi computing and parallel computing in this modern age of technological advancements. He describes the modern 20th century references to multi – processing or parallel computing power of modern computer systems. His research also focuses on how multiscale modeling is used in different geographies and sectors around the world [2]. Mohamed Ben Belgacem [7] in his 2016 study titled MUSCLE HPC: A new high performance API to couple multiscale parallel application, defines Multiscale Coupling Library and Environment defines multiscale applications as the application that has multiple elements, processes and scale working techniques with each other and performing at different longitudinal and time – based measures. Though the paper focuses primarily on the multiscale concept and its applications in Physics, the underlying concepts are common to the world of computers and information technology also. In the study scales are defined or referenced to as size with respect to time and geographical locations. Tomasz Piontek et. al. 2016 presented a very detailed description study on multi scale modeling and high performance multi – scaling using extreme scaling and replica scaling. Also, he defines multiscale model as collection of attached single scale models that can be computed dependably with a devoted and uniform solver. It basically refers to the applications which are high performance and computing applications. Further it also depicts the difference between single scale and multiscale modeling of applications and their working on computing frameworks. The basic meaning of scale is referred as size inside the application [3]. Not unlike our literature review, numerous researchers have reviewed a lot of available research as well. They have intended to provide better definitions as well. In the handbook of cloud computing published by Furht et. al. scalability has been explained as skill of a system to fit a problem as the scope of that problem increases. The scope of problem referred scalability as ability to scale up to meet the increased demands of number of elements or objects, growing volumes of work and/or being susceptible to enlargement [9] . J Lee et. al. in the IEEE conference on e-business engineering in 2010 defined scalability as an ability to handle growing amounts of service loads without suffering substantial degradation in related valued features [8] .In an independent study in 2011, T. Chieu et.al demarcated scalability as the capacity of the application to be increased to meet requests – demand using copying and spreading of requests across servers [10]. Weinstock and Goodenough in 2006 studied the inability of a system to accommodate an increased workload. They mentioned that scalability is the ability of the system to handle increasing size (more lines of code, greater number of users, widened scope of demands, and the like) of U.S. Department of Defense systems [13].

III. MULTI – SCALE APPLICATIONS IN NON-CLOUD AND CLOUD ENVIRONMENT

Having established a standard definition for scalability and scalability of cloud based applications, further research is required to be conducted on the topic of multi scale modeling approaches and algorithms given its ever increasing importance.

However, for the research in this paper, it is required to study and arrive at an appropriate definition for a multi – scale application. With increased popularity and demand of larger and multi – functionality based applications in cloud, there is a necessity to model them for exploring, solving the issues faced by such applications in meeting unpredictable, anomalous and spikes with time. This would otherwise degrade the services; however, research in this field is important to arrive at solutions and algorithms which will allow handling of increased resource demand seamlessly without degrading the quality of services.

This concept presented is scoped around the following objectives-

- Contemporary definition of a multi–scale application.
- Contemporary definition of a multi–scale cloud based applications.
- Explore modern and existing multi–scale cloud based applications.

A)Multi-scale Applications in Non-Cloud Environment:

In lay man words, a multi–scale application is one which has the capability to handle multiple scales. Here, the keyword 'scales' requires further elaboration. Scale can be synonymously understood as the one which defines variety of individual details. They are attributes of the application. It can also be understood as the types of transactions or factors that can be performed or handled by the application. Factors represent characteristics of the application domain and the machine that will affect the system behavior, such as volume of input data, rate at which work arrives at the system, number of concurrent system users, maximum cache size, maximum thread pool size, number of nodes in a server cluster, algorithm selection and cost. These characteristics can be classified as scaling and non-scaling. Thus a multi–scale application can be alternately understood as one which can handle data of various types such as, text, image, streaming media, gif, etc. simultaneously.

With the above context, Multi-Scale Applications can be defined formally as**:**

"*The applications that contains mutable payload of itself characterized by data size with respect to data types.*"

B) Attributes of Multiscale applications in non-cloud environment:

- *Data Size* is referred to the amount of the data of each request. The minimum and maximum data size is specific to the application and type of the data.
- *Data Type* is referred to the type of data associated in the transaction, which can be text oriented, image based, audio encoded or video encoded, etc.

The figure-1 shows the conceptual representation of multi-scale applications.

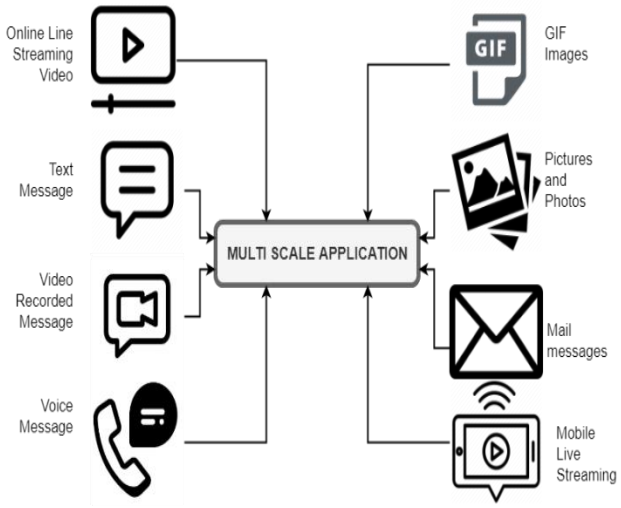

Fig. 1: Conceptual representation of a typical Multiscale Application

B)Multi-scale Applications in Cloud Environment:

The familiarity with the three tier architecture (figure-2) of an application can help explain the term multi-scale cloud applications. The end – user can connect to the backend database and application by way of a frontend or application client tier. The middle tier or business logic tier and the database or backend tier reside on a server which is capable of handling request from multiple operators simultaneously. This allows for multi – operation and eliminates the need for periodic reconciliation of the database by maintaining transaction files.

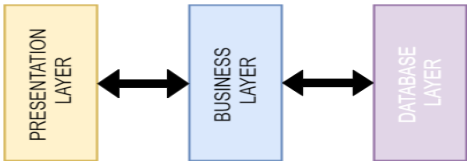

Fig. 2: Standard 3 – Tier Architecture

With the advent of the cloud based architecture and cloud technology, the server hardware which was traditionally available in a local environment or vicinity was now made available in a virtual environment. The applications reside on the virtual servers and the application interface or client is provided to the end users.

The architecture of cloud based applications can be understood in figure-3.

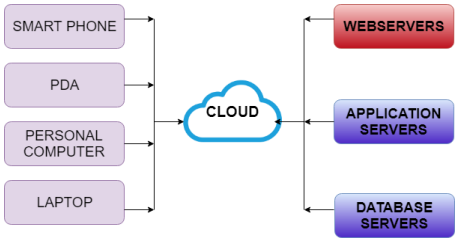

Fig. 3: Cloud Based Application Architecture

With the above context, *Multi-Scale Cloud Application* can be defined formally as-

Multi-Scale Cloud Applications -

"The cloud-based or cloud-native applications that comprises mutable payload of itself characterized by data size, data type and mutable payload of requests &/or users characterized by numbers of requests per user and number of concurrent users."

- *Data Size* and *Data Type* mentioned in above section is having same context here.
- *Number of Requests per User* is mentioned as the total number of requests sent by each user per unit time.
- *Concurrent Users* is stated as all the users who are actively accessing the application at that time and are sending or receiving requests simultaneously.

Hence extended model of multi – scale applications with cloud environment context can be pictorially shown in Fig.4.

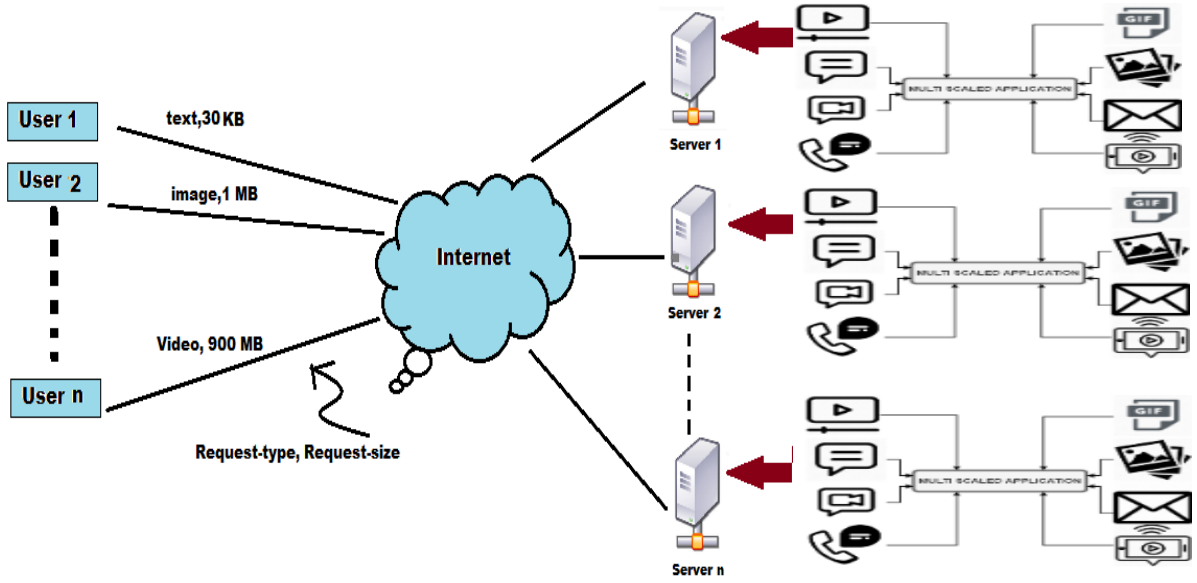

Fig. 4: Extended Multi – Scale Cloud Application Model

Now that we have defined a typical multi – scale application on the cloud, it is apt to also outline the characteristics of a multi – scale application. Following are few of the characteristics of a *typical multi – scale cloud application:*

- Application database and business layer resides on the cloud on a virtual server.
- Hardware and software web resources are allocated on need basis to handle the unpredictable spikes and increments in requests or traffic.
- Multimedia can be processed simultaneously by the application by assigning appropriate resources.
- Load balancer ensures optimized allocation of system resources.
- Applications can be simultaneously accessed across various devices like hand held tablets, smart phones, laptops, PC's, etc.
- Multiple users can access the same application thread and send similar request concurrently.

Hence it is also true to say that, Multi – Scale Cloud Applications (MSCA) are capable of demonstrating further characteristics rather than restricted to just the ones mentioned above and can be further treated as a topic for further research and study.

IV. MULTI–SCALE APPLICATIONS USED IN CLOUD

Technological and systemic innovations in the world of information technology are so rapid that in the blink of an eye lid there are new software applications and solutions being made available on various platforms for end users globally. Also, with the world, now a global village with the advent on internetworking and World Wide Web offering unlimited resources and options, there are various cloud based multi scale applications found a dollar, a dime on the various software download platforms. However, to treat them individually will definitely not lead to a fruitful study outcome due to the sheer number of applications available to the end user. It is thus imperative to categorize these software applications in the following categories to study them better.

a) Social Media Applications (Social Networking Applications)

Collaboration between people globally and between different races is an age old need of man – kind. With internet as a medium to connect between people globally it was only a matter of time before social collaboration / networking applications mushroomed and engulfed our lives. There are hundreds of such social media / networking applications present for people to collaborate amongst each other.

Social media can be elaborated as an interactive real – cum – virtual time computer – mediated technological software solutions / applications, facilitating creation and sharing of information, ideas, interests and anything that individuals hold in social interest as a preference of liking.

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The most common social networking applications that have surpassed the one billion user mark, and most popularly in use today are Facebook, which boasts of being the world's first social media application to have achieved this feat, YouTube, Tencent QQ, WeChat, Tumblr, Viber, Snapchat, Telegram, WhatsApp, Instagram, Twitter, etc. can be considered as multi-scale cloud based applications.

b) Professional Media Applications (Professional Networking Applications)

While some only consider this to be a sub set of the social media collaboration or just a sub-category of social media, this is gaining a lot of traction in the professional arena and is commonly also being referred to as Professional Networking or Collaboration Platform. Applications which are allowing for businesses and individual users to pursue job search and business – networking related activities fall in this category. Best examples of these applications are LinkedIn, Skype for business, job portals like Naukri, Monster, Shine, Zoom, WebEx, etc.

c) E-Commerce Applications

Cloud based applications are not restricted to just social and professional collaborations, but also allow for businesses to be carried out over the internet. In simple words, the buying or selling of products and services over the internet is categorized in this division. These are termed as E-Commerce Applications. Many of the prominent and popular E – Commerce Applications in use today is Amazon, Flipkart, IndiaMart, Shop Clues, Parts Direct from Sears, Kmart, Walmart, Alibaba, etc. These can be considered as multiscale applications as the transactions involves different images as well as the price, description in terms of text in it, in addition to video descriptions of the products for marketing purposes. Also, they allow for users to post text, image as well as video reviews of the products received by them.

d) Educational Cloud Based Applications

Education is no more restricted to the physical classroom now. E-Learning and virtual education is slowly and steadily replacing traditional educational methodologies. While it has its pro's and con's which need further treatment in a separate forum, we can only talk about the availability of these academic options which are cloud based in nature. Many educational systems have their own ERP systems these days allowing learners to study at their own pace and time and availability of resources and time. The concept of MOOC or Millions of Open Online Courses has gained unprecedented popularity in recent times. Education effectiveness has been said to be enhanced by interactive tutorials and video based learning approaches. Learning effectiveness can be measured in real time by way of online assessment portals. The feedback can also be collected to assess effectiveness of course content and delivery system by executing online surveys. Various examples of online learning platforms are NPTEL, Edx, Collabera, Coursera, Simplilearn, Knowledgehut,Udemy etc. Various assessment services are provided by applications like Metrittrac, Meritnation, Pearson's Prometric Assessment Centers, Zoho Challenge, Question Mark Tool, SABA, etc. Popular online applications for carrying out and conducting surveys are surveymonkey, freeonlinesurvey, zoho, hotjar, typeform, survicate, surveygizmo, qualtrics, etc.

e) Business Productivity Applications

Another vast category of cloud based applications gaining popularity in the current business and corporate world are office automation applications. Applications like email clients, word processers, spreadsheets, presentation applications, image and video editors and creators. Microsoft has launched its MS Office 365 suite of applications which are cloud based providing mail, word processors and other office productivity applications. Applications like remove.bg, draw.io are great online image editors. GIMP, magisto, adobe spark and luminous, wevideo, etc. are popular cloud based video editors on the cloud. Zamzar, file-convertor-online, smallpdf, online-convert, etc. are popular file convertor cloud based applications. Outlooks 365, 1on1, emailtray, cloudwards, are popular email clients and services available online.

With this presentation of a quite number of latest multi scale cloud based applications available for users, it can only be assumed that by the time this concept paper will be published many of the mentioned applications would have become obsolete and replaced by more modern and revolutionary applications. There would also be numerous new applications available to the users on the whole.

V. RESULT & DISCUSSION

The research findings related to "Multi-Scale" concept and applications is summarized in table-1. The Multi-Scale concept had been an interested study of the researchers in almost all branches of sciences including Computer Science. In computer Science, it had been studied for network, server and hardware scalability. But Multi-Scale Applications had not been studied in computer science with the attributes such as data type or data size. The researchers work can be summarized for the term "scale" as size incurred in the system. Hence new definition of "multi-scale" applications is defined around data size.

Table-1: Summary of different views of "Scale" term

Key Terms	Paper	Domain	Significance	Case
Scalability	Wikipedia [22]	Computer Science	Adjustment of the system with increased workload.	Search Engine
	Duboc, Rosenblum and Wicks [12]	Computer Science	quality of software systems described by aspects are varied over expected operational ranges	multi – criteria optimization problems
	Furht et. al.[9]`	Computer Science	system to fit a problem as the scope of that problem increases	Hardware, software

	J Lee et. al.[8]	Computer Science	capacity of the application to be increased to meet requests – demand	Network components
	Weinstock and Goodenough [13]	Computer Science	ability of the system to handle increasing size	Hardware, software
Multi–scale modeling	Wikipedia [1]	almost all of the branches of Sciences	problems around time and space	fluids, solids, polymers, proteins and nucleic acids
	Mark Horstemeyer [2]	mechanics, materials science, physics, mathematics, biology and chemistry	different sizes of ropes to the power of multi computing and parallel computing	geographies and sectors
	Tomasz Piontek [3]	Computer Science	collection of attached single scale models that can be computed dependably with a devoted and uniform solver	High performance Computing Applications
multiscale applications	Mohamed Ben Belgacem [7]	Physics	multiple elements, processes and scale based on different longitudinal and time – based measures	Spatio-temporal problems

The data and usage of "Multi-Scale" applications in cloud environment is becoming extremely huge day by day and data are in the form of Scale Applications. With increased demand of such applications, traffic of incoming requests on the cloud servers is increasing exponentially. This load is in terms of number of users, huge data size per requests, variety of each request, etc. Hence to cope with this increasing load without changing the hardware configuration is a challenge which needs attention and further treatment in the form of load balancing algorithm. This is known as Load Balancing Problem in Multi-Scale Cloud Applications. Hence with this basic definition, the problem can be studied at deeper level for sighting the solution.

VI. CONCLUSION

This paper attempts to develop a formal definition with primary model of "Multi–Scale Applications" and "Multi–Scale Cloud Applications" with regards to type of transactions or data used in or by the applications. The engendered definition is reasonable, concise and effective. This study had considered the preliminary but important attributes such as data type, data size, number of requests and number of concurrent users. The study of recent applications reveals where the researchers can find the real cloud dataset of multiscale cloud applications. It can also be concluded that it is a vital and necessary study for present and future needs of the cloud users.

This resourceful definition forms the basis for the research in this context of cloud computing domain and opens up new door for study and further research and development in Multi-Scale Applications issues. Furthermore, additional experiments and a focused research in this area will help to formulate robust and meaningful mathematical models for solving the challenges in multi–scale cloud applications.

This definition can be extended to more novel attributes that can be associated with multi-scale applications with another conceptual framework as per the relevance of the respective study. This paper mentioned the exclusivity of the term which was of keen interest to the researchers in the past and will remain to do so in future.

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