Quality Based Cloud Simulators: State-of-the-art & Road Ahead

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***Abstract*—Cloud Computing is an emerging technology nowadays. It has been used by many leading organisations. They deploy their critical information onto the cloud. Several challenges are associated with it like quality issues, security, energy consumption etc. Continuous research is going on to cater these issues. It is not easy to setup a cloud for any researcher or group of researchers, it needs huge investment. Big organisations having huge budgets can only afford that. To address these issues cloud simulators are really helpful. Cloud simulator is a simulating environment through which one can realize actual cloud environment. Data centers, virtual machines, hosts and networks can be setup virtually. Numbers of cloud simulators are there in the literature each offering different scenario. Cloudsim, a well known cloud simulator calculates start time, finish time and total time for execution of cloudlet. Another cloud simulator GreenCloud calculates energy consumption by data centers, hosts, switches and other network equipments. In the present paper, we focus on quality metrics addressed by cloud simulators. With each simulator, we will enlist quality metrics discussed by them. At the end, we conclude that there is a need to develop simulator which will address relevant quality metrics.**

Keywords—Data centers; Virtual machines; CloudSim; GreenCloud.

I. INTRODUCTION

Simulators are software tools through which one can realize actual environment. Before the actual deployment, one can test and check the results. Simulators are also beneficial for organisations, before investing huge money into any project; they can also check feasibility of the project. Before this concept (simulators), history saw big failures, when organisations were putting money into projects without actually checking its outcomes. They were jolted with big losses.

Cloud system deployment needs huge investment too. Hardware and software involve in its deployment incur considerable budget. To overcome the situation of failure, cloud simulators are really helpful. After successful implementation of experiment on cloud simulator, the same has been handed over to organisation for physical implementation. Cloud simulators have several advantages[1,2,3,4,5,6] like no capital expenditure involved, leads to better results, assessment of challenges associated with project at early stages, easy to use and learn and many more. Number of cloud simulators are available in the literature. All are having different capabilities and limits. Some major cloud simulators are:

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- CloudSim
- CloudAnalyst
- GreenCloud
- iCanCloud
- MDCSim
- DCSim
- NetworkCloudSim
- GroudSim
- EMUSIM

Importance

- Reduce deployment cost: Costly cloud infrastructure can be deployed with minimal/no cost.
- Quick performance check: Data centers, virtual machines and other cloud equipments can be checked rapidly.
- Provide scalability and flexibility: Virtual machines and hosts can be added or removed from cloud setup easily.
- Ease testing and implementation processes: Testing cloudlets and implementing them can be automated.

In the next section, we will discuss some standard cloud simulators in brief. With each simulator, we will also discuss quality metrics which they addressed.

II. CLOUD SIMULATORS

Following are popular cloud simulators. After giving brief introduction about these simulators, quality metrics addressed by them will be discussed. Snapshots of their output will also be shown.

A. CloudSim

It is very popular event driven Java based simulator for simulating cloud computing environment[7]. It was built on core engine of GridSim simulator. It was developed and refined in CLOUDS labs at Computer Science & Software Engineering Department of University of Melbourne, Australia[8]. Since it is Java based simulator, which is powerful object oriented language, modules can be easily extensible according to user requirements. Huge data centers, unlimited virtual machines, different brokering policies can be modeled with this simulator. Following are main features of Cloudsim[8][9]:

- It assists in modeling and simulation of data centers and virtualized server hosts.
- Simulation elements can be included dynamically.
- Simulation can be discontinue/restart at any point of time.

- User defined policies for allocation of hosts to virtual machines can be given.
- Space shared policy and time shared policy of virtual machines are available and one can easily toggle between the two policies.
- Virtualization engine feature supports development and management of independent and co-hosted virtual services.

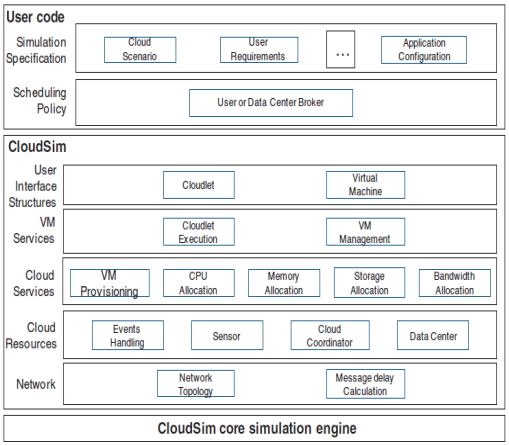

Figure 1: Overview of CloudSim[1]

CloudSim lacks GUI (Graphical User Interface) support[9,10,11]. Results of simulation are in plain text form, user has to interpret them and get a desired output. Despite of this limitation, CloudSim has been used in many universities and institution to carry out cloud based research.

Quality Metrics

Following metrics have been discussed in the simulator:

- Total execution time: It is time in milliseconds (ms) to execute a given cloudlet.
- Start time: Starting time of cloudlet.
- Finish time: Finish time of cloudlet.

Sample Output*

Start time: 0.1
Finish time: 700.1
Total Execution time: 700
Status: Success

*: This sample output is drawn from CloudSim simulator. Eclipse Java environment is used to implement CloudSim. In this simulation, there is only one datacenter with single host and single cloudlet. Various metrics like start time finish time and total execution time and status of a cloudlet have been shown. MIPS attribute of a VM is 1000 and length of a cloudlet is 700000. By varying number of data centers, hosts and cloudlets, different possibility can be derived.

B. CloudAnalyst

It is the simulation tool built on top of CloudSim[12]. It extends capability of CloudSim. It supports visual modeling of large scale applications. Different cloud metrics can be set like application workloads description, location of data centers, geographic location of users working on cloud environment, number of cloud users in each data center, number of resources in each data center (core, memory and other hardware equipments). Based on the above CloudAnalyst generates information like[13]:

- Response time of any request (Maximum, Average, Minimum)
- Processing time of request
- Cost incurred
- Usage pattern of an application

Basic objective of this tool is to provide abstraction level to cloud user meaning thereby user need not to bother about technicalities of programming language (as in case of CloudSim). User only needs to concentrate on the simulation experiments by varying different metrics. User can repeat simulation experiment in a quick and easy manner.

Features[12]

- Graphical User Interface: Easy to work and understand.
- Simulation can be defined with flexibility.
- Simulation experiments can be repeated n number of times.
- Results are shown graphically.
- Java, Java Swing, CloudSim and SimJava technologies are used to develop the simulator.
- Simulator can be easily extendable.

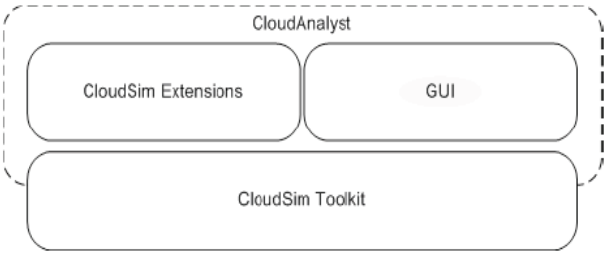

Figure 2: Components of CloudAnalyst[12]

Figure 3: Interface of CloudAnalyst[12]

Quality Metrics[13]

Following metrics have been discussed in the simulator:

- Response time: It is the time of sending a request (from user base) and getting back a response from data center.
- Processing time : It is total time to process a given request by a data center.
- Cost: Total cost incurred in the process (virtual machine cost and total data transfer cost).
- Usage pattern: How many users across the continents are using the application and what effect it will cause on the data centers?

Sample Output**

Response time (average): 300.06 ms
Data center processing time: 0.34 ms
Grand cost (VM cost plus Data transfer cost): $ 0.57
**: This sample output is drawn from CloudAnalyst simulator. Eclipse Java environment is used to implement CloudAnalyst. Above output shows average response time, data center processing time and grand cost. Depicted results are corresponding to one data center and one user base. Equally spread current execution load is used as load balancing policy across VM's.

C. GreenCloud

It is a packet level cloud simulator built on top of network simulator NS-2[14,15,16]. It is specifically designed for energy aware environment. Unlike its ancestor cloud simulators like CloudSim it calculates energy consumption by data centers and its constituent components such as switches, gateways, links, communication paths between packet levels. Part of energy consumed by data center is delivered to computing servers; rest of power is wasted in power distribution. To manage this power distribution, energy in GreenCloud has been divided into different categories[15,17].

- Computing energy
- Communicational energy
- Energy consumed in physical infrastructure of data center

Further, simulator has different components:

- Servers
- Switches and links
- Workloads

Drawbacks

- Simulation procedure takes considerable time and memory to show the results.
- Because of the above reason, GreenCloud simulation is only used for small data centers.
- Simulation user must have expertise in dual languages C++ and Otcal.
- Specifically this tool is meant for calculating energy consumption by data centers ignoring other metrics.

Quality metrics

Following metrics have been discussed in the simulator:
Energy consumption by:

- Data Center
- Servers
- Switches
- Memories

Sample Output***

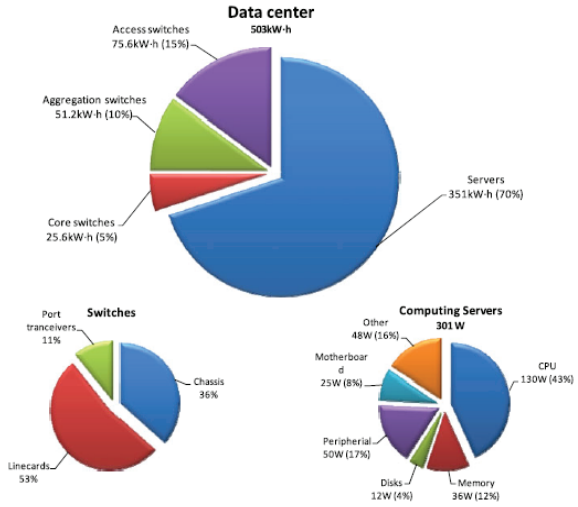

Figure 4: Sample output of GreenCloud[14]

***: VMware has been installed on a given machine. Next, operating system Ubuntu has been deployed on that VM. GreenCloud which is free open source software is downloaded and installed on Ubuntu. Simulation has been run on this setup. Above output shows total energy consumption by data center and its constituent parts Access switches (15%), Aggregation switches (10%), Core switches (5%) and Servers (70%).

D. iCanCloud

This simulator is an evolution of its previous simulators. It removes drawbacks of CloudSim, GreenCloud and MDCSim simulators. SIMCAN tool is the base of this simulator[18]. This novel simulator has some unique features like flexibility, scalability, performance and usability which add to its value. Primary objective of this simulator is to predict trade-offs between cost and performance of given core of applications on specific hardware. It gives useful information about the cost to carry the experiment.
iCanCloud is built on the following design principles[18,19]:

- Large experiment which involves large number of data centers, VMs, users can be conducted. This feature is the main drawback of previous simulators.
- Hypervisor class is flexible and fully customizable, which in turn a core class of iCanCloud. Any cloud brokering policy can be implemented with little or with no modification.
- Instances type can be reproduced that are provided by cloud infrastructure.
- The graphical interface is user friendly, which can manage a standalone machine to thousand of machines with ease.

- It uses POSIX based API and the adapted MPI library of simulating pool of applications.
- There is a provision in this simulator to add new functionalities and features with ease.

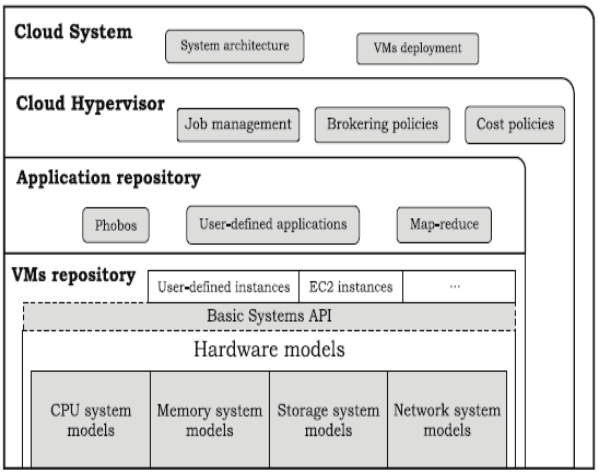

Figure 5 : iCanCloud Layout[18]

Quality Metric

Cost: It gives an estimate of total cost that will incur in the project by considering core applications on the specific hardware.

Sample Output[20]

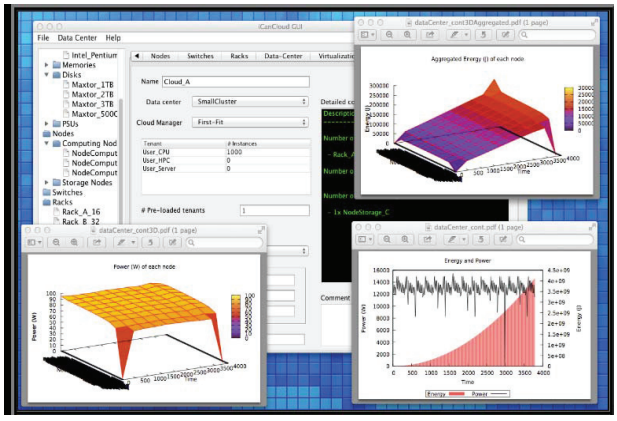

Figure 6: Sample output of iCanCloud[20]

Above output shows

- Power(w)
- Aggregate Energy

of nodes of data centers. Simulator provides facilities to set configuration for CPUs, disks, memories, PSUs, nodes, switches, racks, data centers, virtualization and users.

E. MDCSim

It is the Multi-tier data center simulation tool. Seung-Hwan Lim proposed this simulator in 2009 to design and analyse large scale multi tier data centers[21]. One has to know C++/Java to work on this simulator. Following important metrics can be estimated using this simulator

- Throughput
- Response time
- Power consumption

This platform has distinct features which add to its popularity like comprehensive, flexible and scalable. Multi-tier data center makes it more comprehensive. Different data center features can be manipulated and enhanced. Possible modifications can be change in number of tiers, change in existing scheduling algorithms and alternation in type of interconnection & communication procedures. Layers in multi tier architecture can be manipulated without affecting other layers. Any number of nodes can be added or removed during simulation experiment make it scalable.

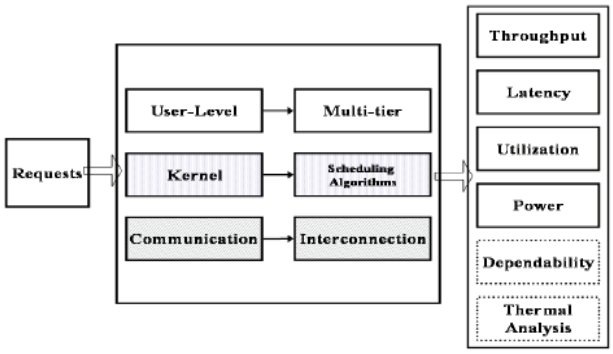

Figure 7: MDCSim overview[21]

To validate the simulator[21], three tier data center was created on IBA and 1GigE connected Linux cluster. Major constituent parts of this data center are: Web Server (WS) tier, Application server (AS) tier and Database server (DB) tier. RUBiS workload was generated to test the web traffic; this workload was distributed using a simple round robin web switch.

Drawback

Simulator is commercial. User has to buy complete package to enjoy full functionality of simulator.

Quality Metrics

- Throughput
- Response time
- Power consumption

After introduction of each cloud simulator with their quality metrics, next we are going to present a comparison between these simulators. We will consider five parameters for evaluating them namely platform they are working on, their availability in the market (open source, commercial), programming language they are based upon, graphical user interface and quality metrics they are addressing.

TABLE I: QUALITY BASED COMPARISON OF CLOUD SIMULATORS

Parameters / *Simulators*	*Platform*	*Availability*	*Programming Language based*	*Graphical User Interface*	*Quality Metrics Addressed*
CloudSim[10,11]	SIMJAVA	Open Source	Java	No	Total Execution time, Start time and Finish time
CloudAnalyst[12,13]	CloudSim	Open Source	Java	Yes	Response time, Processing time, Cost, Usage pattern
GreenCloud [14,15,16,17]	NS-2	Open Source	C++, Octel	Limited	Energy consumption by Data Center, Servers Switches and Memories
iCanCloud[18,19,20]	SIMCAN	Open Source	C++	Yes	Trade-off between Cost and performance
MDCSim[21]	CSIM	Commercial	Java/C++	No	Throughput, Response time, Power consumption

III. RESEARCH METHODOLOGY

Systematic approach has been used for state-of-the-art survey of existing cloud simulators. There are several tools available to conduct this survey viz Narrative Review, Descriptive Review, Vote Counting, Meta Analysis. Out of these methods descriptive review is most appropriate in current scenario. In this review systematic approach in every process (searching, filtering, and classifying) is followed. In the first instance, reviewer collects as many papers as he/she can in the research domain. Then reviewer treats individual study as one data record and identifies trends and patterns among the papers surveyed. Outcome is generally representative of the current state of a research domain. The first step in literature survey is to collect relevant materials of research domain from online as well as from offline sources like library collections. Since our broad area of research was Cloud Simulators(latest technology), so we had to rely mainly on online sources. We searched various renowned online databases like IEEE Xplore, Springer, ScienceDirect (Elsevier). We conducted our search with various keywords like Cloud Simulators, Quality issues of Cloud Simulators, core cloud simulators etc. Next step in the survey was filtering process, for this we used Mendeley Desktop[22] utility (free open source software for managing research materials). Using this utility, we removed duplicate papers from the collection, papers without author names or written by anonymous authors. After performing preliminary investigation, next task was to manually scanning of titles for evidently irrelevant articles. This round of filtering excluded those articles that did not address the Cloud Simulators. Search engine wrongly included those articles. At last level, abstracts were manually scanned and reading full texts were carried out. This round was to exclude those articles that did not address Quality issues of Cloud Simulators as a central theme of discussion, but instead merely mentioning cloud simulators with other technology phenomena for a general coverage. This round was the most comprehensive and time-consuming phase, as in-depth reading of the articles were required to perform the filtering task.

IV. DISCUSSION

We have surveyed five core cloud simulators viz. CloudSim, CloudAnalyst, GreenCloud, iCanCloud and MDCSim. Their basic working, architecture, output and quality metrics have been enlisted. In the present paper, we are focusing on quality issues. CloudSim simulator focused on total execution time, start time and finish time of cloudlet. Next, CloudAnalyst which was built on top of CloudSim discussed response time (maximum, average and minimum), cost, usage patterns of the application and time taken by data centers to service a user request quality metrics. GreenCloud simulator whose main objective is to calculate energy consumption discussed energy consumption by data centers, servers, switches and memories. iCanCloud simulator discussed cost of deploying an application by taking care of trade-off between performance and cost. MDCSim which is a commercial simulator calculates throughput, response time and power consumption.

After a thorough literature survey we conclude that following are core quality metrics which every company who is providing cloud services must include:

- Availability
- Reliability
- Cost
- Response time
- Throughput

None of the above simulator includes all the core metrics. So, there is need to devise a cloud simulator which will focus on quality metrics of cloud service. These metrics are basic issues which every company who is using cloud services needs to be address.

V. CONCLUSION

Cloud Computing is an emerging technology of 21st century. It is not an easy to setup a cloud and start experimenting because it needs handsome investment and huge setup. Cloud simulators are really helpful to cloud researchers because they can virtually visualize a cloud environment (data centers, virtual machines, hosts etc.) and carry out their research work. In this paper, we started our discussion by mentioning the importance of cloud simulators. How these cloud simulators assisted in setting up a cloud environment. After that we listed some popular cloud simulators. These cloud simulators were covered in detail. Since our main focus of this paper was to consider quality metrics, so we listed various quality metrics which these cloud simulators discussed. We have also listed core quality metrics. For a future direction, we can say there is a need of cloud simulator, which will cover all the necessary quality metrics which any cloud service must include.

REFERENCES

[1] P. Kumar, A.K. Rai, "An Overview and Survey of Various Cloud Simulation Tools", Journal of Global Research in Computer Science, ISSN: 2229-371X, vol 5, no. 1, p.p. 24-26, January 2014.

[2] W. Zhao, Y. Peng, F. Xie, Z. Dai, "Modeling and Simulation of Cloud Computing: A Review", IEEE Asia Pacific Cloud Computing Conference (APCloud CC), ISBN: 978-1-4673-2904-0, p.p.20-24, 2012.

[3] A. Nunez, J. L. Vazquez-Poletti, A. C. Caminero, J. Carretero, and I. M. Llorente, "Design of a new cloud computing simulation platform," The International Conference on Computational Science and Its pplications, LNCS 6784, pp.582-593, 2011.

[4] Q. Wang, L. Ren, and L. Zhang, "Design and implementation of virtualization-based middleware for cloud simulation platform," 4th International conference on Computer Science and Information Technology, 2011.

[5] G. Kaur, Study of Comparison of Various Cloud Computing Simulators.

[6] K.Bahwaireth, L.Tawalbeh, E. Benkhelifa, Y. Jararweh and M. A. Tawalbeh, "Experimental comparison of simulation tools for efficient cloud and mobile cloud computing applications", SpringerOpen, EURASIP Journal on Information Security, DOI 10.1186/s13635-016-0039-y,p. 1-14, 2016.

[7] A. Ahmed, A.S. Sabyasachi, "Cloud Computing Simulators: A Detailed Survey and Future Directions", IEEE Internationl Advance Computing Conference, Print ISBN: 978-1-4799-2571-1, p.p.866-872, February 2014.

[8] http://www.cloudbus.org/cloudsim/[Accessed online on 21-06-2016]

[9] H. Marwaha, R. Singh, "A Comprehensive Review of Cloud Computing Simulators", Journal of Information Sciences and Computing Technologies, ISSN: 2394-9066, vol 4, issue 1, p.p. 281-286, June 2015.

[10] R. Buyya, R. Ranjan, and R. N. Calheiros, "Modeling and simulation of scalable cloud computing environments and the CloudSim toolkit: challenges and opportunities," The International Conference on Hign Performance Computing and Simulation, pp.1-11, 2009.

[11] R. N. Calheiros, R. Ranjan, A. Beloglazov, C. A. F. De Rose, and R. Buyya, "CloudSim: a toolkit for modelsing and simulation of cloud computing environments and evaluation of resource provisioning algorithms," Software: Practice and Experience, Vol.41, No.1, pp.23-50, 2011.

[12] B. Wickremasinghe, R.N. Calheiros, R. Buyya, "CloudAnalyst: A CloudSim-based Visual Modeller for Analysing Cloud Computing Environments and Applications", IEEE Internationl Conference on Advanced Information Networking and Applications, Print ISBN: 978-1-4244-6695-5, p.p.446-452, April 2010.

[13] B. Wickremasinghe, R. Buyya, "CloudAnalyst: A CloudSim-based Tool for Modelling and Analysis of Large Scale Cloud Computing Environments", MEDC Project Report, 433-659 Distributed Computing Project, CSSE Dept., University of Melbourne.

[14] D. Kliazovich, P. Bouvry, Y. Audzevich, S.U. Khan, "GreenCloud: A Packet-level Simulator of Energy-aware Cloud Computing Data Centers", IEEE Global Telecommunications Conference – 2010, Print ISBN: 978-1-4244-5636-9, p.p.1-5, December 2010.

[15] D. Kliazovich, P. Bouvry, S.U. Khan, "GreenCloud: A Packet-level Simulator of Energy-aware Cloud Computing Data Centers", SpringerLink, The Journal of SuperComputing, vol 62, issue 3, Print ISSN: 0920-8542, p.p.1263-1283, November 2010.

[16] GreenCloud (2012), The green cloud simulator, http://greenCloud. gforge. uni.lu/. [Accessed online on 25-06-2016]

[17] Ns2 Networking simulator, http://www.isi.edu/nsnam/ns/.[Accessed online on 05-07-2016]

[18] A. Nunez, J.L. Vazquez- Poletti, A.C.Caminero, G.G. Castane, J. Carretero, I.M. Llorente, "iCanCloud: A Flexible and Scalable Cloud Infrastructure Simulator", SpringerLink, Journal of Grid Computing, vol 10, issue 1, Print ISSN: 1570-7873, p.p.185-209, April 2012.

[19] A. N. Covarrubias, G. G. Castane, 'iCanCloud: Quick guide'. Version 0.9 (Beta) (2011), www.iCanCloudSim.org. [Accessed online on 05-07-2016]

[20] http://www.arcos.inf.uc3m.es/~icancloud/screenshots.html [Accessed online on 10-7-2016].

[21] S.H. Lim, B. Sharma, G. Nam, E.K. Kim, C. R. Das, "MDCSim: A Multi-tier Data Center Simulation", IEEE Internationl Conference on Cluster Computing and Workshops, Print ISBN: 978-1-4244-5011-4, p.p.1-9, September 2009.

[22] https://www.mendeley.com/[Accessed online on 10-3-2016]