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Research paper

Comparative analysis of fault tolerance models and their challenges in cloud computing

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Abstract

Cloud Computing is a vital platform for viable and non-viable clients. It provides the reliable services to clients through data centers which contains servers, storage etc. One of the major challengein cloud computing environment is that services should be run without errors or faults. In cloud computing environment various computations are run on real time applications so that chances of errors becomes high, for these reasons applications running in cloud environment should be reliable and must have the ability of fault tolerance. In this paper, authors have discussed many fault tolerance techniques and compared various model of fault tolerance.

Keywords: *Cloud Computing; Fault Tolerance; Reliability; Virtualization.*

1. Introduction

Cloud Computing is described as a model of computing resources such as storages, Operating Systems etc.in which virtualization is provided as a service over the Internet. The benefits of Cloud Computing are low cost, pay-per-use on-demand-service, guaranteed QoS etc., but reliability is the major challenge among the users in Cloud Computing environment. Reliability means a particular task is accomplished within a particular time without failure. In a Cloud Computing environment, when a system does not perform well as it is designed, then the system becomes less reliable or there is an occurrence of failure. A failure is the condition when the hardware or software is unable to complete its functioning, so that fault tolerance capabilities are required to overcome the influence of system failures and perform the task rightly when fault occurs.

2. Types of faults

There are various types of faults which can be occurred:
Network Faults: - Faults which occur in network because of link failure, network partition, packet loss are known as network faults.
Physical Faults:-Such types of faults take place in hardware like fault in memory, CPU and storage device etc.
Processor Faults: - Such types of faults occur in processor because of Operating System clatter.
Process Faults:-These types of faults take place because of shortage of resources, software bugs etc.
Service Expiry Faults: - These faults occur when service time of a resource gets expire while using the application.

3. Existing fault tolerance methods

There are three types of fault tolerance methods:

1) Proactive Fault Tolerance Method:-Proactive Fault Tolerance means to predict the fault in advance and avoid recovery from errors, it proactively replaces the distrusted components and senses the problem before it actually happens.

Following are the techniques which come under the stated method:

i) Software Rejuvenation:- In this technique system is rebooted after a particular interval and every time system is started with a new state.
ii) Self-Healing:- In this technique when an instance of a particular application is running on various virtual machines and a failure occurs, it is controlled automatically.
iii) Preemptive Migration: - In this technique an application is repetitively pragmatic and evaluated, if any virtual machine is overloaded then some of its resources are migrated to another virtual machine.

2) Reactive Fault Tolerance Method:-This method is used to reduce or minimize the fault of a system when failure actually occurs.

Following techniques come under this method:

i) Checkpointing:- If failure occurs, then the task is not restarted from the initial point rather it starts from the recent checkpoint. Checkpoints are stored in the resource cache. This technique is applied for big applications.
ii) Task Resubmission:- In this technique, failed task is resubmitted to the same machine or the other machine to re-execute the task.
iii) S-Guard:- In this technique, the task is rollbacked if failure occurs, it is executed in HADOOP and Amazon EC2.
iv) Job Migration:- Sometimes a machine gets fail and unable to accomplish the work, then the job is migrated to another operational machine. There are some algorithms that repeatedly determines the failures and migrates batch applications within a cloud of multiple datacentres. This task is done through HAProxy.

v) User defined exception handling:-In this technique whenever a failure occurs, user defines the particular action for a task failure for workflows.

3) Adaptive Fault Tolerance Method:-In Adaptive Fault Tolerance Method, all procedures are done automatically, according to the situation. It assures the reliability of critical modules and the reliability of virtual machines changes after every computing cycle.

In adaptive fault tolerance method the techniques of proactive and reactive fault tolerance methods can be combined to remove the faults. Some of the techniques are check pointing, replication, fragmentation etc.

Fragmentation is a technique in which a single file is divided into multiple files in such a way that if these files are combined it forms the original file without any loss of data. This technique decreases the volume of unrelated data retrieved by the applications.

4. Tools used for implementing fault tolerance

Assure:-ASSURE stands for Automatic Software Self-healing Using Rescue points. It works for rescue points which handles programmer's expected failures. When a fault occursat a particular location in the program, ASSURE reinstates execution to the nearest rescue point and persuades the program to recover execution by virtualization.

HAProxy:-HAProxy stands for High availability Proxy. The objective of this tool is to enhance the performance and consistency of a server cluster by distributing the load through various servers. It is an open source application developed for load balancing solutions for websites. It shows good performance in terms of CPU and memory usage. Also it is known for its stability and reliability. The websites like Twitter, Stack Overflow, GitHub etc. use this tool to overcome their problem of heavy traffic.

SHelp:-SHelp, is a runtime arrangement which works for virtual machines and applies rescue points and error virtualization techniques. It reduces the redundancy and rapidly recovers from future faults affected by similar bugs. SHelp can make server applications to recover from these bugs in few seconds.

AmazonEC2:-Amazon Elastic Compute Cloud (Amazon EC2) is a popular web service that provides space in the cloud depending upon the need of the user. This is efficient in handling the instances in terms of time, it provides tools to the developers to design applications which are failure resistant.

Hadoop:-Hadoop provides some of the cloud computing services. It is an open source Apache Software Foundation Project that allows the distributed processing of huge datasets across cluster of nodes. It provides services to public and private clouds like IaaS, PaaS and SaaS.

Table 1: Comparison of Various Fault Tolerance Techniques

Technique	Type	Tools	Implementation Environment	Fault Detected	Application Type
Software Rejuvenation	Proactive	Assure	Virtual Machine	Host, Network Failure	Fault tolerance
Self-Healing	Proactive/Reactive	HAProxy /Assure	Virtual Machine	Process/Node Failure/ Host, Network Failure	Load Balancing/ Fault Tolerance
Preemptive Migration	Proactive	HAProxy	Virtual Machine	Process/Node Failure	Load Balancing/ Fault Tolerance
Check pointing	Reactive/ Proactive	SHelp /Assure	Virtual Machine	Application Failure /Node Failure/ Host Network Failure	Fault tolerance
Replication	Reactive/Adaptive	HAProxy/AmazonEC2	Cloud Environment	Application Failure /Node Failure	Load Balancing/ Fault Tolerance/ Data Intensive
Task Resubmission	Reactive	AmazonEC2	Cloud Environment	Application Failure /Node Failure	Load Balancing/ Fault Tolerance
S-Guard	Reactive	AmazonEC2/ Hadoop	Cloud Environment	Application Failure /Node Failure	Load Balancing/ Fault Tolerance/Data Intensive
Job Migration	Reactive	HAProxy /Hadoop	Virtual Machine/Cloud Environment	Application Failure/ Process Failure/Node Failure	Load Balancing/ Fault Tolerance/ Data Intensive
Rescue Overflow	Reactive	Hadoop	Cloud Environment	Application Failure /Node Failure	Data Intensive
User defined exception handling	Reactive	Assure	Cloud Environment	Application Failure	Fault tolerance
Fragmentation	Adaptive	AmazonEC2	Virtual Machine/ Cloud Environment	Application Failure	Fault Tolerance

5. Related work

Several Models are employed constructed on the above technologies:

Zhao Wenbing et al.(2010) has introduced Low Latency Fault Tolerance (LLFT) model which is based on replication method and run on distributed applications for fault tolerance installed within a cloud computing environment. This model replicates applications by using various replication process to guard the applications from variety of faults.

SabahiFarzad (2011) has focusedon the issues and challenges of the cloud computing's reliability, availability and security (RAS). It investigates the intrusion detection methods and focuses on the procedures to improve RAS based on virtualization technology.

Srivaramangai P., Srinivasan R. (2012) has proposed a model to improve the reliability in Grid Computing. It is based on the fact that only reliable providers can provide the computing power and resources to make the cloud infrastructure reliable. It has also focused on various reliability factors to improve the inclusion of various constraints.

Jhawar Ravi (2012) has introduced fault tolerance Management (FTM) approach based on virtualized technology to investigate fault tolerance which evidently increases the reliability and availability of applications used in cloud computing.

Sun Dawel et al. (2013) has given a dynamic adaptive fault tolerance (DAFT) model which is based on the ethics and semantics of

clod fault tolerance. In this model checkpointing and replication methods are used for fault tolerance to increase the serviceability.
BalaAnju(2014) has given a model on intelligent task failure detection which is based on proactive fault tolerance technique which predicts the failure task for scientific workflow applications.
Lee Hwamin (2009) has given fault tolerance and recovery system (FRAS) model which is based on agent based system. In this method recovery agent accomplishes on rollback technique when failure occurs. In this strategy agent recovery algorithm is proposed to retain a constant state of a system.
Joshi Sagar(2014) has given the concept of virtual data centres (VDC) which is based on the migration technique. In this methodology if a virtual machine is overloaded then some of its resources are migrated to another virtual machine to handle the server failure.
Meshram Anjali (2013) has given fault tolerance model for cloud (FTMC). In this model reliability of computing nodes is measured and nodes are selected on the bases of reliability. The node which is producing constantly incorrect results is removed.
NagpalShivam (2013) has introduced a fault tolerance model based on decisions. In this model reliability of a node is measured on accuracy and time. This is based on adaptive technique. If any node does not perform well then backward recovery is performed and removal and addition of the nodes is decided on the bases of reliability.
Padmakumari P. (2015) has provided the idea for diverse fault tolerance and monitoring mechanism to enhance the reliability in cloud computing environment. In has given the data about various techniques and methods which are used for fault tolerance and also focused on future research direction in cloud fault tolerance.
Jean Rahme (2015) has proposed a software reliability model for cloud based software rejuvenation using dynamic fault trees. In this model the problem of software aging is focused where system performance may continuously tainted because of enervation of system resources, fragmentation and accretion of faults.
Saika Lakshmi (2015) Prasad has proposed an algorithm for fault tolerance technique in cloud computing. In this model author has described that major problems arises because of the occurrence of faults. In this model various fault tolerance techniques are predict these faults and take an appropriate actions before or after failure occurs.
ZibinZheng(2012) has given the concept of FT- Cloud. It is a component which is determined on the bases of ranking for building cloud applications. In this module there is an algorithm which inevitably direct fault tolerance.
Malik Sheheryar (2011) has proposed an Adaptive fault tolerance model in real time cloud computing (AFTRC). This model is based on real time computing on cloud infrastructure. It has the benefits of forward recovery. This model is highly fault tolerant. This model also focuses on backward recovery through checkpointing.

Table 2: Comparison of Various Fault Tolerance Models

Model Name	Procedure for Fault Tolerance	Type of Fault	Challenges
LLFT	It runs for distributed applications using replication technique.	Reactive Fault Tolerant Method	Cost and overhead of maintaining replicas.
RAS	Based on intrusion detection method.	Proactive Fault Tolerant Method	Performance problems can be occurred due to limited CPU cycles.
Model to provide reliable infrastructure	Improve the reliability in grid computing and checks the reliability of cloud providers.	Reactive Fault Tolerant Method	Relative ordering of the accuracy will remain unaltered.
FTM	Based on reliability, availability and on-demand service through virtualization technology.	Reactive Fault Tolerant Method	Lack of in-depth analysis of fault tolerance services.
DAFT	Check pointing and replication techniques are used to increase serviceability.	Adaptive Fault Tolerant Method	Less focused on backward recovery.
Model for intelligent task failure detection	Predicts the failure task for scientific workflow applications.	Proactive Fault Tolerant Method	A standard method can be developed in cloud environment for estimating the routines of fault tolerance segment in assessment with parallel ones.
FRAS	Agent based system based on recovery of the system.	Reactive Fault Tolerant Method	It does not apply on practical applications.
VDC	Based on Migration Technique.	Reactive Fault Tolerant Method	More server utilization can be there.
FTMC	Accesses the reliability of computing nodes.	Adaptive Fault Tolerant Method	More parameters can be used for decision making to enhance the reliability.
Decision based fault tolerance model	Reliability is estimated on time and accuracy.	Adaptive Fault Tolerant Method	More reliability factors can be included to make the reliability more effective.
Diverse Fault Tolerance	Based on diverse fault tolerance and monitoring mechanism to enhance reliability.	Adaptive Fault Tolerant Method	Needs to reduce the waiting time of users and data availability can be increased.
Software Reliability Model for Software Rejuvenation	Focused on software aging phenomenon.	Proactive Fault Tolerant Method	It does not work for non-constant failure rates.
Fault Tolerance Techniques and Algorithms in Cloud Computing	Proactive techniques are used to predict fault in advance.	Proactive Fault Tolerant Method	Need to make a compact model which will cover maximum fault tolerance aspects.
FT- Cloud	Substantial component is measured based on the ranking.	Proactive Fault Tolerant Method	It does not contain latency.
AFTRC	Focuses on backward recovery through check pointing.	Adaptive Fault Tolerant Method	Removes the nodes which does not complete the task within the time frame even though it produces the correct results

In this table various challenges and types of faults of various fault tolerance models have been discussed. Some models are highly reliable whether some needs more server utilization. Some models focus on reliability of nodes of real time applications while some does not work for non-constant failures.

6. Challenges of various fault tolerance models

During the literature review various challenges are faced in fault tolerance in cloud computing which are:

i) There are huge chances of faults because processing is done through remote computers.

ii) There is a requirement to implement efficient methods to find the errors.
iii) Restricted data is given to the customers because of high system density.
iv) Fault prediction methods needs to be developed for more real time applications.
v) It is tough to understand the altering system state because cloud environment is active.
vi) Occurrence of faults in data centers are not the concern of customer's organization needs to implement fault tolerance techniques.

Table 3: Comparison among Various Models Based on the Metrics Element

Model Name	LLFT	RAS	Model to provide reliable infra-structure	FTM	DAFT	Model for intelli-gent task failure detec-tion	FRAS	VDC	FTMC	Deci-sion based fault toler-ance model	Di-verse Fault Toler-ance	Software Reliabil-ity Model for Soft-ware Rejuve-nation	Fault Toler-ance Tech-niques and Algo-rithms in Cloud Compu-ting	FT-Clou d	AF-TRC
Proactive	N	Y	N	N	N	Y	N	N	Y	Y	N	Y	Y	Y	Y
Reactive	Y	N	Y	Y	N	N	Y	Y	N	N	N	N	N	N	N
Adaptive	N	N	Y	N	Y	N	N	N	Y	Y	Y	Y	N	Y	Y
Perfor-mance	H	A	A	A	H	H	A	H	H	H	A	H	H	H	H
Response Time	A	A	A	A	H	A	A	H	A	A	L	H	H	A	A
Scalabil-ity	H	A	H	L	H	H	H	H	H	H	A	H	H	H	H
Through put	A	A	A	A	H	H	A	A	H	H	A	A	H	H	H
Reliabil-ity	H	L	H	A	H	A	H	H	H	H	H	H	H	H	H
Availabil-ity	H	L	H	H	H	A	H	H	H	H	A	H	H	A	H
Usability	A	A	H	A	H	H	H	H	H	H	A	H	A	H	H
Overhead Associat-ed Cost	L	H	L	L	A	A	A	H	A	A	L	L	A	A	A
Effec-tiveness	L	H	L	L	A	A	A	L	A	A	A	L	A	H	A

(Y=Yes, N= No, H=High, A=Average, L= Low)

7. Conclusion and future scope

The paper discusses various types of faults and need to cover the fault-tolerance with various implementation techniques. Different fault tolerance models are discussed and compared in terms of fault tolerance in cloud. These models have presented various fault tolerance mechanism that can improve the performance of a system, however there are challenges that needs to be considered. Based on the comparative analysis done, author needs to develop an algorithm to improve the reliability of cloud nodes using fault tolerance techniques through proper resource allocation of jobs by implementing the concept of adaptive reliability by identification and correction of failure nodes. It may reduce number of failure nodes (which are failed due to time constraint) by implementing load balancing techniques. It may enhance the processing speed of nodes to improve the reliability.

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