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Fault Tolerance in Cloud Computing

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Abstract:

In this modern era, Cloud computing provides many services to the users through cloud resources. In cloud environment the presence of large amount of data has resulted in increased number of errors. Hence the foremost provoking issue is to tolerate and handle the faults i.e. to achieve Fault Tolerance in Cloud Computing. Fault tolerance evaluates the capabilities of the system to respond graciously to an unforeseen hardware failure, software failure or any other kind of error. This paper has focused upon various types of faults, methods to achieve fault tolerance, Fault tolerance architecture and at last an analysis of existing fault tolerance methods is done.

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1. INTRODUCTION

Cloud computing denotes the diverse types of services and applications that are conveyed in the internet cloud and it is viewed that the devices do not require any special applications to access these services and applications. Cloud computing offers cloud resources which help in storing, processing and handling of data. Cloud computing is based upon sharing of resources in order to accomplish consistency and economies of scale.

In the late of 1960s, late professor John McCarthy Only until recently, with the latest advances in computer technologies such as virtualization, Internet connection and across network communications cloud computing concept has been realized Cloud computing services can be classified into three main categories:

• Software-as-a-Service (SaaS):

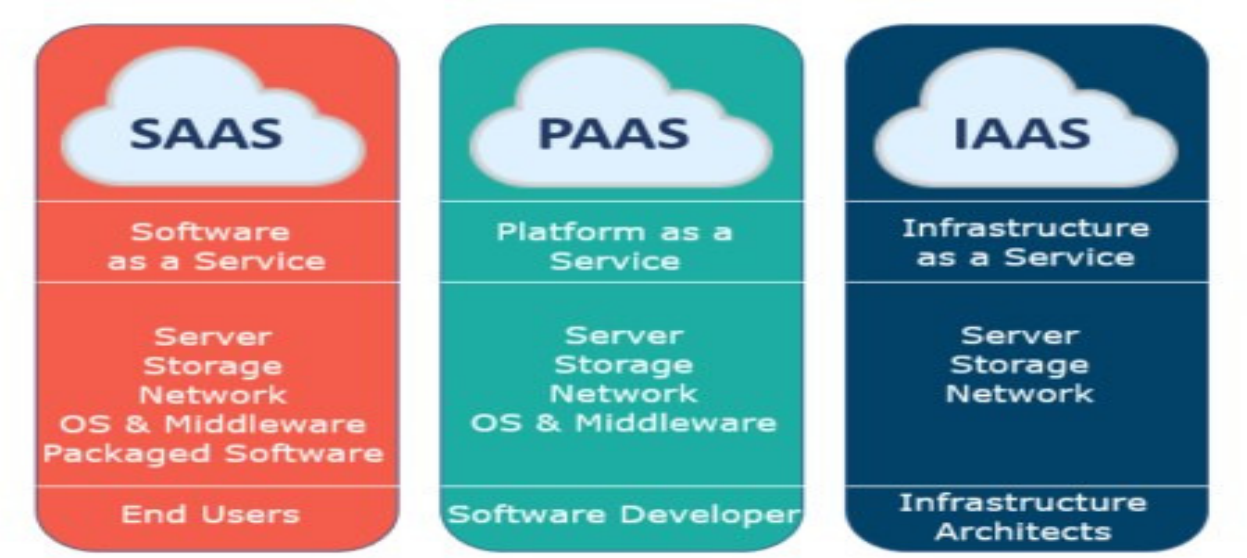
It allows users to access and use the applications hosted on the cloud via the Internet with various interfaces such as web browsers or web services. Furthermore, the users do not have to worry about the underlying cloud infrastructure including network architectures, servers, operating systems, storages, or even individual application capabilities. An example of SaaS is the web-based services offered by big companies such as Gmail of Google.

• Platform as a Service (PaaS):

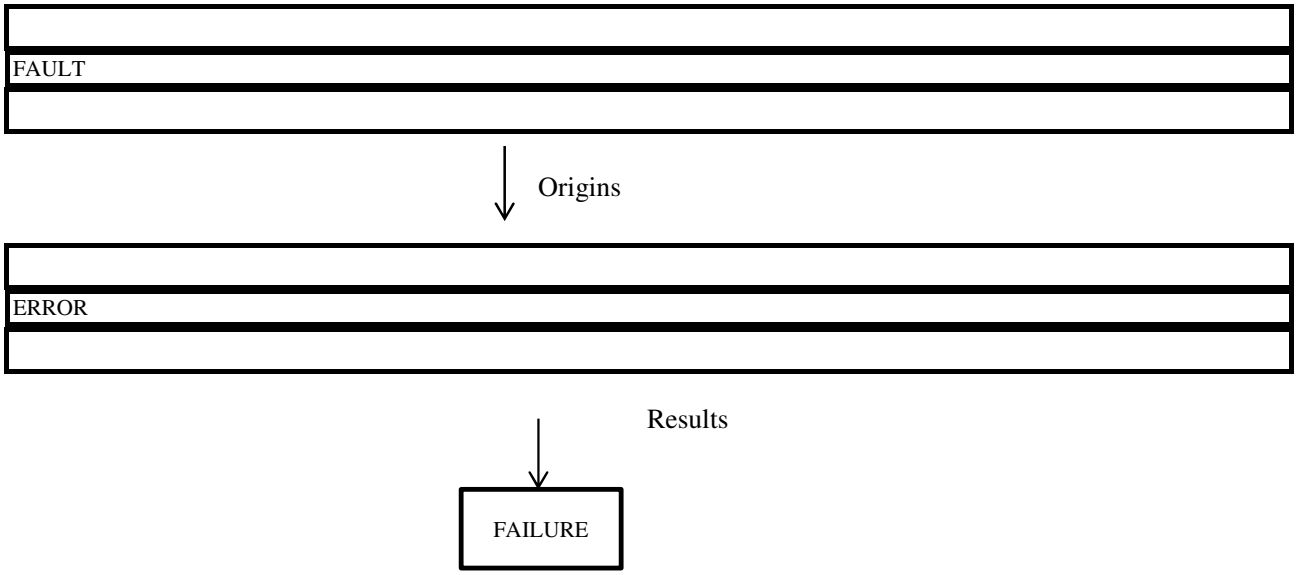
It provides users a platform for the deployment of their applications. Furthermore, it allows the users to control their applications setting and configuration. In PaaS, the user controls expand more than that in SaaS because the users handle the deployment of the applications and the configuration settings.

• Infrastructure as a Service (IaaS):

It not only allocates to the users the deployment of the applications and software onto cloud infrastructure, but also manages and maintains the operating system and storage. Nevertheless, it limits the control of selecting network components such as host firewalls.



Fault Tolerance may be defined as the ability of the system which prevents a network or device from failure, errors(hardware, software or system errors) and takes appropriate steps for this. Whenever any fault occurs in the system, it causes occurrence of errors and all these errors results in Failure. The following diagram also depicts that how a failure is generated due to presence of faults in the system.



TYPES OF FAULTS

a.) **Network fault:** A Fault that occurs in a network due to network partition, Packet Loss, Packet corruption, destination failure, link failure, etc.

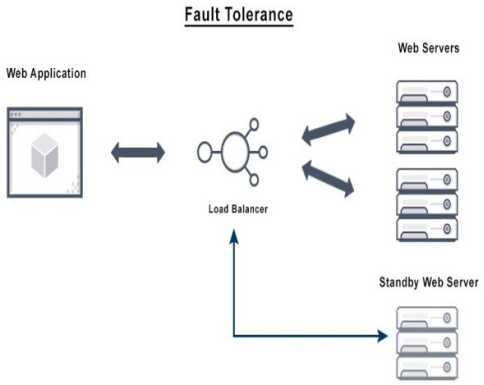
b.) **Physical faults:**These type of faults occur in the hardware e.g. fault in CPUs, memory, storage etc.

c.) **Media faults:**Fault that are caused due to the media head crashes components automatically. FT Cloud having abundant cloud resource can be employed by designers of cloud applications to design more reliable and robust cloud applications efficiently and effectively.

d.) **Processor faults:**Fault occurs in processor due to operating system crashes etc.

e.) **Service expiry fault:**While an application is using a resource it is possible that its service time expires, this is called as Service expiry fault. A fault can be categorized on the basis of computing resources and time. A failure occurs during computation on system resources can be classified as: omission failure, timing failure, response failure, and crash failure.

Fault Tolerance Methods:



A number of methods are available so as to tolerate the faults. These methods are essential for the smooth running of applications after the fault has been detected in the system. Some of the methods are described below:

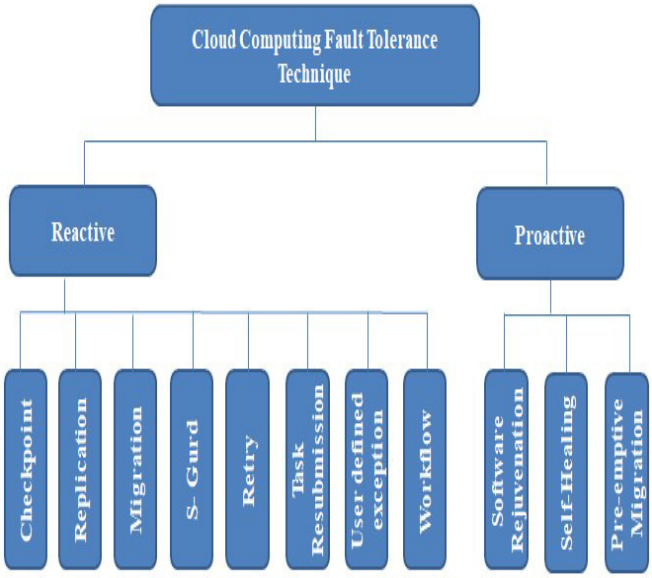
- **Based on strategies**: Reactive and Proactive
- **Load Balancing Fault Tolerance:**Hardware, Software and Network based **Redundancy**:Hardware, Software and Time redundancy

Based on Strategy:

- **Reactive Strategy:** Whenever failure occurs, this strategy reduces the influence of failures on the effective execution of the application. Various techniques are available under this strategy like check-pointing, Job Migration,

Retry, Replication, Task resubmission, Alternate resource, S guard etc.

- **Proactive Strategy:** This strategy aims on forecasting the failures and moving the running applications away from nodes that have been expected to fail. Several techniques are based on this strategy like Preemptive Migration, Software Rejuvenation and Self-Healing.



Load Balancing: Load balancing is principally working on traffic Shaping. It has the potential to handle the inbound or outbound traffic in any type of network and it is further divided into following categories:

- **Hardware Based:** Hardware based load balancing simply directs the requests of the client for a single IP address to several hosts within the cloud network. Hardware load balancers make use of a procedure named as network address translation (NAT), that discloses one or more virtual IP addresses to the clients and it forwards the data to the designated hosts by simply transforming IP addresses and resending the network packets. This technique presents only a single point of failure, i.e. in the computer that performs rerouting of packets, between the clients and the cloud network. In order to achieve high availability, there is requirement of backup load balancer.

- **Dispatcher Software Based:** In this load balancing there is essential requirement of a dispatch server that handles all the incoming connection requests and retransmits these requests to the other servers present in the network. This load balancing solution confines the throughput and also limits the performance since the cluster's throughput is restricted by the speed and processing capabilities of the dispatch server. The presence of a single dispatch server indicates only a single point of failure. Whenever the failure occurs, it should be eradicated by simply moving the dispatching function to another computer.

- **Network based:** This load balancing is entirely based upon distributed software based solution and it does not involve any particular hardware or network mechanisms. In this load balancing there is no need of centralized dispatcher as all the hosts receive their inbound packets. Depending upon the number of hosts present in the cloud, network load balancing provides redundancy accordingly. Packet handling is done by the filtering algorithm which is quite efficient as compared to centralized load balancing programs.

Redundancy:

- **Hardware:** Within the set of redundant modules, hardware redundancy technique masks the faults entirely. Various similar type of modules perform the equivalent functions and finally in order to remove

errors that have been created by the faulty module; all the outputs produced by the modules are compared and voted [12]. Commonly used fault masking hardware redundancy technique is Triple modular redundancy (TMR). TMR system can result in failure when the two modules in the redundant triplet generate errors simultaneously then the principle of voting is no longer valid and as a result TMR system can result in failure. To overcome this, Hybrid redundancy is employed that provides efficient fault tolerance by replacing the faulty modules.

- **Time:** In this redundancy scheme the task is recomputed and then results produced are compared . The hardware and software used for therecomputations can be same or different. This redundancy technique is using additional time in order to achieve both fault detection and fault tolerance. Time redundancy is exploited by the systems by reexecuting the same program on the same hardware.

- **Software:** In this redundancy scheme two diverse programs or algorithms are used that are required to detect and tolerate the faults. It autonomously yields two or more forms of software in the expectation that various versions cannot fail on the same input. This diversity ensures that all the copies will never fail on same type of input.

CHALLENGES OF FAULT TOLERANCE IN CLOUD COMPUTING:

The reliability of the cloud resources is still far from perfect in reality. Nowadays, the demand for highly reliable cloud resources is becoming extremely strong. If we want to build highly reliable clouds, it becomes a critical, challenging, and urgently required research problem. As compared to traditional software systems, there are a lot of redundant resources in the cloud environment, making software fault tolerance a possible approach for building highly reliable cloud applications. Some of the challenges of fault tolerance are:

- Fault tolerance techniques cannot function efficiently when several instances of an application are executing on different Virtual Machines.
- A new fault tolerant approach should be constructed by integrating the current fault tolerance techniques and approaches.
- For ensuring reliability and availability a benchmark based method should be developed so as to assess the fault tolerance performance in comparison with similar ones.
- Fault tolerance for real time applications in cloud environment fails when there is no backup virtual machine present to execute the task when primary copy fails to execute due to the presence of faults, errors or any network related issues.
- Whenever there is presence of heavy load, Cloud computing observes severe performance instability. The expected behaviour cannot be predicted as the cloud resources are shared among different users with variable process load and hence fault tolerance is of key concern.

2. REVIEW OF LITERATURE

A number of fault tolerance methods, strategies, frameworks and models have been developed. In this paper a survey and analysis of all the fault tolerance models have been done. The first fault tolerant computer was developed in 1975 i.e. Tandem- 16 which aimed at online transaction processing. Later on in 1999, Felix C. Gartner explored the area of fault tolerant distributed computing. He surveyed the fault tolerance methodologies, discussed relationship among them,

specified their advantages and limitations and also analysed that how these methodologies interact with the system. A major feature of this paper was that they have focused upon reliability feature of fault tolerance.

In 2011, Arvind Kumar explored several fault detection and fault tolerance methods based upon reliability. The major emphasis was on various kinds of faults that occur in the system, several fault detection and recovery techniques. This paper has focused on the fact that how these methods can be used to detect and tolerate the faults even in the presence of hardware faults in real time distributed systems. It described two important hardware fault tolerance techniques i.e. load sharing and redundancy. In order to tolerate the fault that occurs in the system foremost requirement is to detect the fault and then to isolate it to a separate unit. The key detection mechanisms described in this paper include: protocol faults, In Service diagnostics, Watchdog monitoring and Transient Leaky Bucket counters.

In order to address the reliability and fault tolerance issues, J. Deng in proposed a decomposition matrix multiplication scheme. This technique helps to analyse various tasks and their corresponding behavior in different clouds. The idea primarily focused upon scientific computations in cloud environment. This scheme also helps to find faulty clouds in the network can also find out faulty clouds in an intellectual way.

After the fault has been detected in the system there is requirement of analysing it and then removing it . For this purpose several fault tolerance models have been developed. Some of them are described below:

- AFTRC i.e. Adaptive Fault Tolerance in Real Time Cloud Computing is based upon the principle that real time applications can be implemented in the cloud environment by making use of virtual nodes in the cloud. In this model, fault tolerance is based upon reliability of the processing node and makes a decision according to node's reliability that it is to be included or not.
- LLFT i.e. Low Latency Fault Tolerance model that contains (LLFT) middleware which provides fault tolerance support for distributed applications organized within the cloud computing environment. In order to provide protection against several types of faults, this middleware repeats the application by using various replication techniques. It provides protection against crash cost and trimming fault.
- FTM i.e. Fault Tolerance Model was developed to accomplish the reliability and hence helps to manage the fault tolerance. This mechanism permits the user to apply desired level of fault tolerance without any requirement of prior knowledge about its implementation. FTM architecture can be viewed as collection of various web services components, each having its particular functionality. In short it focuses on reliability, availability and on demand service.
- Candy is a component based availability fault tolerance model. This model focused on the fact that high availability is not only an important feature of cloud service but also serious and stimulating issues for the cloud service provider.
- Magi-Cube is extremely reliable and low redundancy storage architecture developed in cloud computing. This fault tolerance model describes that high reliability, performance and low cost (in terms of space requirements) are the major inconsistent components in a storage system. To facilitate these services to a specific model Magi cube framework was proposed. It focuses on Performance, reliability and low cost storage.

3. PROBLEM DEFINITION

OBJECTIVE: In this modern era, Cloud computing provides many services to the users through cloud resources. In cloud environment the presence of large amount of data has resulted in increased number of errors. Hence the foremost provoking issue is to tolerate and handle the faults i.e. to achieve Fault Tolerance in Cloud Computing. Fault tolerance evaluates the capabilities of the system to respond graciously to an unforeseen hardware failure, software failure or any other kind of error. This paper has focused upon various types of faults, methods to achieve fault tolerance, Fault tolerance architecture and at last an analysis of existing fault tolerance methods is done.

SCOPE: In this modern technological world, cloud computing is gaining tremendous popularity day by day. More is data present in the cloud; more are chances of error occurrence. Considering this fact, in this paper we have glanced upon various types of faults that can occur in the cloud, different methods to tolerate the faults, challenges of fault tolerance in cloud computing and analysis of existing fault tolerance techniques is done. With more efforts and technological research in this area, the drawbacks of the existing techniques can be eliminated and new techniques cheaper than the existing ones should be developed to cope up with the current issues.

4. RESEARCH METHODOLOGY

Scope of Literature Search

The primary source of literature for the review was electronic database searches as this practice has become apparent among information systems (IS) research (Hwang & Thorn, 1999; Petter& McLean, 2009). Therefore, the choice of electronic databases was deemed appropriate. The search for literature was conducted in two phases. First, a senior basket of IS journals (Association for Information Systems, 2011) were searched individually to ascertain the extent to which cloud computing research has been accorded credence in these journals. Since, this practice is evident in other studies (e.g., Duncombe & Boateng, 2009; Ngai & Wat, 2002; Yang & Tate, 2012). However, it became evident that the senior basket of information systems journals did not have many studies on cloud computing. A possible reason for less research on cloud computing in these senior basket of IS journals is the relative newness and technicality of cloud computing. Second, a wider search was conducted in electronic databases such as Ebscohost, ScienceDirect, Emerald, Sage, JStor, ACM Digital Library and Google Scholar. According to Levy and Ellis (2006), these sources cover an extensive size of the top fifty information systems journals. Therefore a fair representation is assumed to be achieved. The search was conducted with the phrase "cloud computing" and keyword "cloud" on the abstracts, keywords and titles across the databases. However, the search was limited to peer reviewed scholarly journal articles from 2009 and till 2015. The articles were subjected to manual filtering where editorials, review articles, and reports were eliminated. Because, the study set out to include only peer reviewed articles in the review. Conference papers, dissertations, books, working papers, and reviews of books were also excluded. Further checks were conducted to remove duplicates and articles from other disciplines such as computer engineering. In all, 285 articles from 67 journals were considered for classification and analysis.

Related Technologies

The paradigm of cloud computing has contribution of many technologies such as parallel computing, grid computing, utility computing, virtualization, Autonomic computing, Software as a Service, web 2.0 and distributed computing. Various technologies related to cloud computing are:

- **Parallel computing:** The concept is to divide the computing problem which is scientific into many small tasks and run them at same time.

- **Grid:** It is used to shift the workload to place which requires computing resources that are remote and immediately available to use.
- **Utility Computation:** It has resources based on clients demands and charging them according to use.
- **Virtualization:** It separates the underlying physical hardware and provide virtualized resources to the applications.

Cloud computing technologies

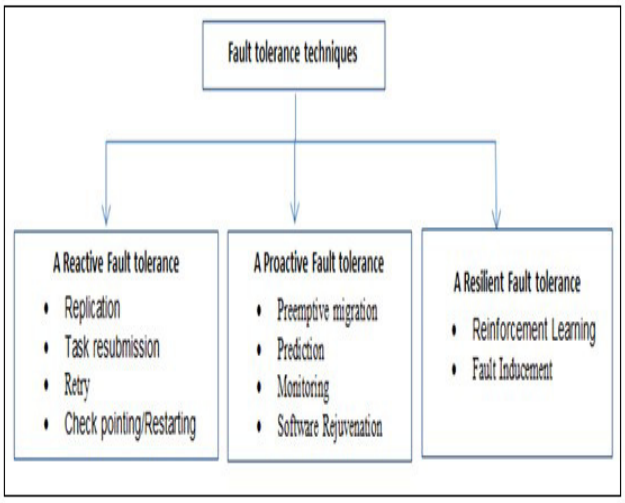
There are 5 main categories:

- On-Demand Self Service
- Broad network access
- Resource pooling
- Elasticity
- Measural service

5. DATA ANALYSIS & FINDINGS

Now let us consider the following existing fault tolerance techniques :

1.) **Retrying**: The failed task is retried on the same resource.
2.) **Alternate resource:** The failed task is retried on another resource.
3.) **Check-pointing:** The failed task resumes processing from the last saved checkpoint instead of from the beginning.
4.) **Replication**:Different replicas of the same task are processed on different resources simultaneously.



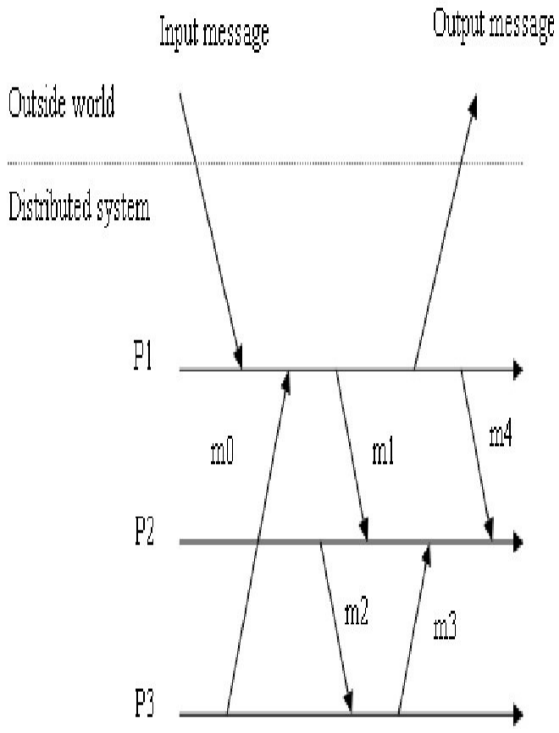
Each technique has its own advantages and disadvantages.

The retrying technique is the simplest technique being used. Both the retrying and alternate resource techniques are not time-efficient as when a task fails, it has to be restarted from the beginning as a result it consumes more time.

The replication technique is resource demanding since replication means duplication. For the achievement of desired results and successful execution various tasks are duplicated and permitted to use different resources.

As compared to above techniques, the check-pointing technique consumes more storage space as it needs to store lots of checkpoints. Whenever any failure is encountered the job is permitted to start from the point where last checkpoint was placed rather than from the beginning. Hence it results in less time consumption. Certain fault tolerance models have also been developed that are based upon check-pointing technique.

external interactions with the outside world.



6. CONCLUSION

In this modern technological world, cloud computing is gaining tremendous popularity day by day. More is data present in the cloud; more are chances of error occurrence. Considering this fact, in this paper we have glanced upon various types of faults that can occur in the cloud, different methods to tolerate the faults, challenges of fault tolerance in cloud computing and analysis of existing fault tolerance techniques is done. With more efforts and technological research in this area, the drawbacks of the existing techniques can be eliminated and new techniques cheaper than the existing ones should be developed to cope up with the current issues.

The cloud-computing model has changed the IT industry as it brings several benefits to individuals, researchers, organizations, and even countries. Despite providing numerous advantages, the cloud system is still susceptible to failures. Failures are inevitable in cloud computing due to the scale of operation. Fault tolerance policies are commonly implemented to handle faults effectively in the cloud environment. Fault tolerance techniqueshelp in preventing as well as tolerating faults in the system, which may occur either due to hardware or software failure. The main motive to employ fault tolerance techniques in cloud computing is to achieve failure recovery, high reliability and enhance availability.

This survey paper has discussed cloud computing concepts, its components, service model, anddeployment models. The commonly useddata centernetwork topologies are also described since these affect the design of FT algorithms. Various fault tolerance techniques, models, and algorithms to improve the reliability issue of cloud services have been outlined. Techniques to enhance the performance of fault tolerance approaches, such as heuristics, meta-heuristics, clustering approaches etc. have been enumerated. Further, metrics and parameters to assess the effectiveness and efficiency of the proposed FT approaches have been discussed. Considering limitations of existing fault tolerance techniques and the emerging technologies in related domains, we have put forth some directions for future research initiatives.

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7. SCOPE FOR FUTURE RESEARCH

In this modern technological world, cloud computing is gaining tremendous popularity day by day. More is data present in the cloud; more are chances of error occurrence. Considering this fact, in this paper we have glanced upon various types of faults that can occur in the cloud, different methods to tolerate the faults, challenges of fault tolerance in cloud computing and analysis of existing fault tolerance techniques is done. With more efforts and technological research in this area, the drawbacks of the existing techniques can be eliminated and new techniques cheaper than the existing ones

should be developed to cope up with the current issues.

Fault tolerance approaches are required to improve the quality of service in the cloud environment. However, the existing or proposed approaches have considered, in general, only the reliability issue of the simple cloud workflows and evaluation has been done using some basic metrics, such as response time, availability, throughput and reliability. Some future directions for research in this domain are suggested as follows:

- Deep Learning
- Blockchain
- Distributed Deduplication Systems
- Emphasis on Performance issues

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