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Workflow Scheduling Strategies for Achieving Fault Tolerance in Cloud: A Review

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Abstract: Cloud computing is increasingly used amidst researchers for scientific workflows to perform high throughput computing and data analysis. cloud are realizing the vision of utility by delivering computing resources as services. There are many workflow scheduling algorithms focuses on makespan time, cost and reliability etc. Numerous research studies have investigated fault-tolerant aspect of the workflow management system in different distributed systems. In this study, we analyze these efforts and provide an in-depth taxonomy of them. We present the ontology of faults and fault-tolerant techniques then position the existing workflow management systems with respect to the taxonomies and the techniques.

Keywords: cloud computing, fault tolerance, workflow scheduling algorithm.

1. INTRODUCTION

Cloud computing is an emerging and innovative platform, which makes computing and storage available to the end users as a service. It has gained more popularity in the industry, still several research problems associated with various area like fault tolerance, workflow scheduling, load equalization, security etc are currently present. Its main objective is that it is used to allow customers to pay only for the amount of resources they efficiently consume. The option summarized by the term pay-as-you-go is permitted in cloud platform through the partitioning of their resource. It is increasingly used amidst researches for scientific workflow to perform high throughput computing and data analysis. numerous discipline use scientific workflow to perform large scale complex analysis. A process that maps tasks in a workflow to compute resources for execution (preserving dependencies between task) is called "scheduling of workflow". Cloud computing introduce more granular and specific meaning of the term "workflow" and "process" as used in different domain. Workflow are processed and completed as processes in a single domain for automation purpose.

II. ISSUES OF WORKFLOW MANAGEMENT

Workflow Management System (WMS) , is one of the issue in Cloud computing. Most of the business process can be represented in terms of workflow. So a workflow can be described as the set of tasks which is used to complete some business process. Task invocation, task synchronization, and information flow are done in a specific order which is described by workflow management. The tasks of workflows are varying in nature. Main issue in workflow management system is workflow scheduling because it is very difficult to identify the available resource from the central pool of resources at the time of execution of workflow.

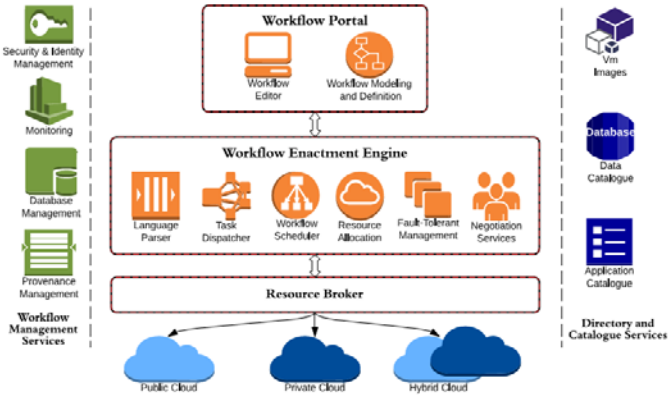

Figure 1.1: Architecture of cloud workflow management system.

Workflow scheduling is a problem of finding a correct execution sequence for the workflow tasks, i.e., execution that obeys the constraints which represents the business logic of the workflow. Mapping and management of workflow task's execution on shared resources is done with the help of workflow scheduling[1] .

III. FAULT TOLERANCE

Fault tolerance is related to handling the failure which can occur during the scheduling process due to several reasons such as resource unavailability/failure, task failure, overloaded resource, network fault, and lack of memory etc. Fault Tolerant WMS should be able to control these failures.

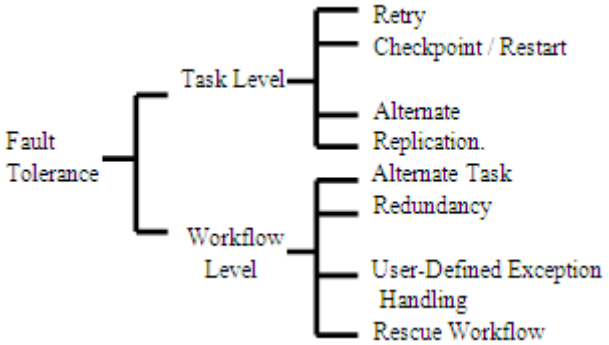

Figure1.2: Elements of fault tolerance

Fault tolerance is categorized into two main categories as task level and workflow level. In case of task level, failures occurred due to workflow task are handled and in case of workflow level, failure occurred due to the workflow structure is handled. Task level failure handling is further categorized into four aspects[2]:

- Retry technique is simplest method to handle the failure. In case of failure of a task or resource, Retry method simply tries to execute the same task on the same resource again.
- Checkpoint technique stores the state of the system when the failure occurred and then tries to execute the same task on some other resource and execution starts from the saved state after the failure occurrence.
- Alternate resource technique tries to execute the failed task on some other resource when there is a failure happened.
- Replication technique tries to execute the same task on the same resource again and again so that any one of the trial handles the failure.

Workflow level failure handling mechanism considers the whole workflow instead of the subtask or sub workflow. Workflow level failure handling is further categorized into four aspects[2]:

- Alternate task technique tries to execute another task of the workflow in place of previous failed task.
- The redundancy technique tries to execute multiple alternate tasks simultaneously instead of single alternate task in place of previous failed task.
- User defined exception handling provides a specific mechanism to handle the task failure in the workflow.

The rescue technique ignores the failed task once and tries to complete the execution of other task in the workflow until the execution is possible without handling the failed task till the completion of the workflow. If the whole workflow executes except the failed task then after the workflow execution completed, the rescue technique identify the failed tasks and allowed them to submit again for execution.

IV. CLOUD WORKFLOW ARCHITECTURE

Most of the sensible town applications is designed as cloud workflows[3]. A progress management system (WFMS) is developed for outlining, managing and corporal punishment workflows. Fig. a pair of shows the design of a cloud progress system in sensible town that relies on the progress reference model and a Cloud-based design for national Services in sensible City[4][5].

A. **Workflow Modeling & Definition components**

Workflow Modeling & Definition elements ought to abstract the essential characteristics of a method, and alter it within the kind of being understood and dead by a progress system. So, the progress Modeling &Definition is that the foundation of the WFMS, its performance decides the range of progress application and also the adaptive ability of WFMS the most modeling ways embody activity network-based modeling, formal based mostly modeling, dialogue based mostly modeling, object based mostly modeling etc. Results of progress modeling square measure descriptions and definitions of progress. At present, there square measure many various types of progress modeling tool, like open supply of JAWE and CIM Flow, that primarily will support most of typical organization method. With the recognition of the net, the net is presented straightforward to use, there are many progress modeling solutions supported internet, like Action technical school railroad, Ozweb and Dart flow[6].

B. **Workflow Engine**

Workflow Engine is that the core of a WFMS, it schedules the progress tasks through the middleware services and manages the execution of tasks on distributed resources. The key elements of the progress Engine square measures progress submission, progress language programme, resource discovery, dispatchers, knowledge movement and progress scheduler [7]. The progress Engine is intended to support Xwfl, (XML-based progress Language), this facilities user level coming up with at the submission time[8].The progress language programme converts progress description from XML format to things like tasks, parameters, knowledge constraint (workflow dependency),etc., that may be accessed by the progress hardware. The hardware makes cheap choices per the optimization objectives and sends the selections to Dispatchers. The resource discovery element queries the data services like Globus MDS, directory service, market directory, and reproduction catalogs, to find appropriate resources for executions of the tasks within the progress by coordinating with middleware technologies [9].

C. **Middleware and Cloud Service components**

Workflow management systems ought to be capable of interacting with many varieties of service bound architectures (e.g. Cloud Computing) in order that it will higher utilize the storage and reckon facilities provided for optimized knowledge delivery, storage and distributed access. The Middleware move progress with cloud resource, like Aneka platform [10]. The cloud resources supplier like Amazon will give virtual hardware by Infrastructure as a Service (IaaS) to user's workflow application victimization virtualization technique. within the same, Platform-as-a-Service (PaaS) provide a higher-level development and runtime surroundings for user to putting together and deploying progress applications on cloud infrastructures and Software-as-a-Service (SaaS) suppliers offers end-users with standardized computer code solutions that may be well integrated into existing workflows. There square measure 2 situations for user to leverage resource in clouds, i.e. entirely use cloud services or use cloud along side existing cluster-based solutions. as an example, Aneka platform (PaaS cloud) is used entirely to finish the progress. Aneka will give resources by accessing resources in different IaaS cloud to satisfy application demand. Conjointly a collection of internet services square measure delivered by this platform, wherever progress jobs in scheduled to Aneka internet service to execute the progress orchestration. the opposite cloud resources used used situations wherever Amazon EC2 (IaaS cloud) is employed to supplement. Cluster once there are light resources to satisfy the QOS needs [11], supported user nominative QOS needs, the WFMS schedules progress tasks to resources that square measure settled at the native cluster and within the Cloud. Technologies like Amazon S3 [12], Google Big Table [13] and also the Windows Azure Storage Services [14] can provide most scalable , reliable and secure storage resources for progress application. Cloud service supplier provide Apis for chase resource usage and investigating the

value. They charge fees for resources used, per the amount of VM instances running, user's QoS, and so on. Cloud services like Google App Engine and Windows Azure give platforms for building scalable interactive internet applications. We are able to port a progress management system to such platforms whereas taking advantage of their inherent measurability and reduced administration. as an example, deploying a progress into Google App Engine will utilize scalable systems that drive Google applications, together with technologies like Big Table and GFS [15].

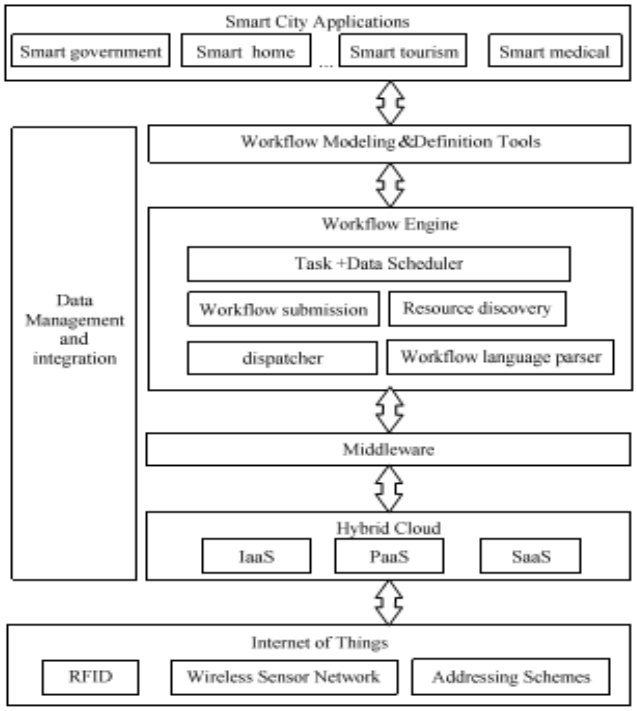

Figure 1.3.Cloud-based Workflow Architecture for Smart City

D. **The data management and integration component**

The data management and integration element ensures that processed outputs from one layer to a different square measure contextually connected and syntactically correct. And it will management the dataflow between layers. It connects every module of the system as an entire [15].

E. **The internet of things**

Internet of Things (IOT) is that the worldwide network of interconnected objects, which might move and communicate with business, data and social processes by exchanging knowledge and data, whereas reacting autonomously to the real/physical world events and influencing it by running processes that trigger actions and make services with or while not direct human intervention[16].The IOT components contains RFID, Wireless sensing element Networks(WSN), Addressing schemes, and so on. RFID technology could be a major breakthrough within the embedded communication paradigm that permits style of microchips for wireless electronic communication. they assist within the automatic identification of something they're connected to acting as an electronic barcode, and perceiving data from them. WSN contains plentiful nodes, that consist sensing element interfaces, process units, transceiver units and power provide. WSN is that the data network system together with distributed data assortment, data transmission and data process. It's a data-centric network, that aims to effectively understand, acquire and transmit knowledge detected by WSN nodes. Knowledge assortment is one among the essential functions of wireless sensing element networks, its perform is to gather knowledge for process, and transmittal the info to the sink nodes, together with knowledge acquisition, processing, and knowledge transmission. Addressing schemes modify to unambiguously determine "Things" that is crucial for the success of IOT. This may not solely permit North American country to unambiguously determine billions of devices however conjointly to regulate remote devices through the internet.

V. **RELATED WORK:-**

In this section most of the workflow scheduling strategies exists in the grid and cloud environment has been reviewed briefly with respect to the technique/algorithm description, scheduling parameter considered and tools/platform used for the implementation for result analysis. These existing scheduling algorithms are classified in the following categories:

a) **Genetic Algorithms (GA):** This category mainly includes [17,18,19] in which various different parameters are considered for scheduling such as makespan, time, cost and reliability etc. A genetic algorithm uses the mutations and crossover functions to optimize a parameter by considering the other parameters.

b) **Critical Path based Scheduling:** This category mainly includes [20,21,22] , these algorithms focuses on makespan and schedules the task by dynamically identifying the critical path which gives the lowest execution time for the workflow. Some variation of critical path algorithm focuses on identifying the predecessors of a task for critical path creation.

c) **Multiple QoS with Multiple workflows:** M. Xu [23] focused on makespan and cost. These algorithms calculates the mean execution time and mean execution cost of all the workflows and schedules the task first having minimum covariance of time and cost to optimize both the makespan and cost.

d) **Ant Colony Optimization (ACO) based scheduling algorithms:** There are various version based on ACO such as [24,25]. The basic ACO algorithm is based on the foraging behaviour of ants. Whenever any ant searched a food, then it spread the chemical known as pheromone to make the shortest path from the food to their destination. Others ants follow this path with the help of pheromone and reached to the food as soon as possible by following the shortest path. The algorithm based on ACO considers many QoS and objective of these algorithms is to find a best optimized solution by considering the user preferred QoS parameter.

e) **Particle Swarm Optimization (PSO) based Scheduling Algorithms:** S. Pandey [26] proposed a PSO based heuristic which consider the computational and transmission cost as the scheduling parameters. The algorithm calculates the average computational and average transmission cost of each task and schedules tasks to the resource with minimized cost.

f) **Priority based scheduling algorithms:** S. Ghanbari [27] proposed a priority based job scheduling algorithm by

considering makespan as the scheduling parameter in the cloud environment by considering three levels of Analytical Hierarchy Process which are represented with three types of job priority which are objective level, scheduling level and job level.

g) Hierarchical scheduling strategy: Z. Wu [28] includes GA, ACO and PSO heuristics for the job level and resource level scheduling known as the assignment of task-to-service scheduling by considering makespan, cost and resource utilization as the scheduling parameters.

h) Trust based Scheduling algorithm: Y. Yang [29] schedules the task by verifying resource failure probability during the transmission of task with security and reliability constraint.

Table 1.1: Workflow scheduling strategies exists in the grid and cloud environment

Author & Year	Algorithm/ Technique	Scheduling Parameter	Description	Tools/ Platform	Environment
Jia Yu (2006)	Genetic Algorithm	Time &Cost	Time & Cost is Optimized	GridSim	Grid
Bogdan Simion (2007)	Improved Critical path using Descendant Prediction	Makespan and Load balancing	(i)As Late As Possible(ALAP) time for each task is calculated. (ii)Scheduled the task having minimum ALAP.	Mon-Alisa farms and ApMon	Grid
Meng Xu (2009)	Multiple QOS with Multiple Workflow	Makespan & Cost	Schedules first the task having minimum covariance of time and cost.	Simulation environment with 20 services and 5-25 users.	Cloud
Wei Neng Chen (2009)	Ant Colony Optimization	Deadline, Cost, Budget, Makespan and Reliability	ACO finds the schedule that meets all user imposed QoS constraints. It calculates the pheromone values based on heuristics and experiments are done on ten workflow applications.	Grid Environment	
Rajkumar Buyya (2010)	Particle Swarm Optimization (PSO)	Resource utilization, Time	A particle swarm optimization (PSO) based heuristic to schedule applications to cloud resources that takes into account both computation cost and data transmission cost. It is used for workflow application by varying its computation and communication costs.	Amazon EC2	Hybrid Cloud
Shamsollah Ghanbari (2012)	Priority Job Scheduling Creteria	Makespan	Based on three levels of Analytical Hierarchy Process which are represented with three types of job priority which are objective level, scheduling level and job level.	Cloud environment consists of 3 resources.	Cloud
Zhangjun Wu (2013)	Hierarchical scheduling strategy	Makespan,Cost and Resource utilization	Includes GA, ACO and PSO heuristics for the job level and resource level scheduling known as the assignment of task to service scheduling.	SwinDeW-C	Cloud
Yuli Yang (2013)	Trust based Scheduling algorithm	Reliability and Security	Schedules the task by verifying resource failure probability during the transmission of task with security and reliability constraint.	Cloudsim	Cloud

3. OPPORTUNITIES AND CHALLENGES

Inspired by scientific work flow systems been antecedently with success applied over variety of execution environments like clusters, grids, and supercomputers, there square measure additional notably appealing for work flow applying in cloud computing, which offer surprising size of datacenter-level resource pool and modify work flow solutions capable of addressing peta-scale sensible town application. we are able to profit a lot for the large-scale resource in cloud computing,

however we tend to still ought to face some challenges to run workflows on the Clouds[30,31].

A. Opportunities:

•As cloud computing might give extraordinary computing resources and knowledge resource to end-users, the issues processed by workflow management system are additional in depth after we apply workflow applications on cloud. The cloud surroundings makes the workflow applications be solved additional timely for the tremendous resources. The unexampled resources conjointly enable some very difficult sc ientific workflow applications to be enforced in a very massive scale.

• Cloud computing is business-oriented, and supported pay-per-use. The on-demand mechanism in Cloud will improve resource utilization and is additional in line with the interests of the users. Cloud-based workflow applications is dynamically allotted needed resources, meantime the resources price is diminished.

•Transparency of resource is additionally an enormous advantage of cloud computing. The non uniformity of assorted resources (computing, storage, networking, etc.) square measure disguised, all resources is managed and regular uniformly; for users, these resources square measure clear, and don't ought to perceive the inner structure, which can build the work flow programming easier.

B. Challenges:

In order to create the work flow application running in a very cloud platform, we want to unravel many issues as follows

•Integrated architecture: the primary challenge of running workflow on cloud is that the integration of workflow of workflow management systems with cloud (infrastructure and resources). because the resource in cloud is tremendous, we should always obtain a more robust approach for a work flow management system to accumulate resources, dispatch tasks, monitors method, track origin data, and traumatize faults. Associate in Nursing engine ought to be designed as its perform is powerful enough to traumatize large-scale tasks. A easy and climbable Middleware tool that move workflow with cloud resources must be found because it will facilitate within the preparation, scaling, execution and watching of workflow systems [32].

•Large scale knowledge management and workflow scheduling: As in cloud surroundings, the dimensions of knowledge is big, and scientific work flow applications are getting additional knowledge intensive, the management of knowledge resources and dataflow between the storage and work out resources is turning into the most bottleneck. Finding Associate in Nursing economical thanks to manage the information required by the workflow is incredibly vital, like addressing knowledge occupation and out of the cloud, chase of knowledge origin and therefore the exploration of knowledge vicinity, knowledge and computation co-location, they're useful to know and use workflows. Cloud workflow programming plays a significant role within the workflow management and programming algorithms ought to contemplate a few numerous of criteria to satisfy QOS necessities of workflow application.

•Service composition and orchestration: for several workflow applications, services offered by one cloud square measures aloof from enough. sanctioning any growing and complicated complicated wants of workflow application, service of various freelance cloud supplier ought to be composed to deliver uniform QOS as one request. This composition and orchestration of services in inter-cloud ought to be meted out in a very dynamic and automatic manner to promptly win client necessities. Moreover, Associate in Nursing economical cloud service composition methodology ought to choose the foremost high level QOS and therefore the least expensive services. Its difficult to with efficiency notice a composition resolution in response cloud, for the rationale of it involves not solely service composition. However Conjointly optimization below the constraint of price and point

VI. CONCLUSION

Cloud computing is one of the user oriented technology in which user faces hundreds of thousands of virtualized resources for each task. In this paper we survey various existing scheduling algorithms in cloud, grid and workflows.

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