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A dependable and economic service for long-life e-learning applications in grid environments

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Abstract

Developing highly available, reliable, scalable and mobile educational systems are so difficult or impossible in the client-server and web service architectures. On the other hand, a grid environment is such a large distributed system that it supports large numbers of distributed resources sharing. The grid environment can be used as a good platform for the long-life, online and mobile educational applications which need high availability, reliability and scalability. The possibility of failure occurrence on the educational resources during a running educational application on the grid environment is not negligible. This paper proposes a dependable and economic learning service in grid systems. The other focus in this paper is to minimize educational resource consumption and consequently decrease the cost of requested learning services by the learners in the economic grid. A hybrid and dynamic resource management method is used to improve the availability, reliability, scalability and stability of learning service with low resource consumption. An analytical approach, Markov model, is used to show the availability, reliability, stability improvement in the proposed method.

Keyword: Grid Environment; E-learning Service; Dependability; Resource Consumption;

1. Introduction

These days the e-leaning has become significant tool for modern educations without time and place restriction that is enabled by means of computer technologies like distributed technologies and web based application over the network. Many schools, universities and educational systems are using e-learning as their common training method [Tucker, 2002]. The e-learning resources are geographically distributed and system-dependent and thus cannot share and combine dependably and economically with other heterogeneous resources. Hence, the dependability and cost are the significant points in the e-learning and distance education systems. On the other the grid computing is an efficient distributed system with the large number of geographically distributed and heterogeneous resources which provides inexpensive access to various remote resources. It is a suitable framework for executing many applications like long mission oriented and distance learning applications [Foster,2002], [Globus website] and [Gannon, 2002]. The grid computing systems can be used to develop an efficient and economical e-learning platform. Service oriented concepts in the grid computing systems are the new platform-independent technique with open standards

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and protocols which have advantage over the web services [Gannon, 2002], [Chervenak, 2000] but some features of grid computing such as heterogeneity of remote resources, network details and geographical distribution can cause many transient and permanent faults. Therefore, failure occurrence in each component of grid environment is a rule not an exception. The resource in this paper refers to the educational resources. Hence, dependability and its related criteria such as availability, reliability, scalability and stability of educational resources must be considered in the grid resource management systems. The grid resource management is a complex process because the needed resources in the e-learning over the grid are dynamic, distributed and can enter and leave the grid at any time. The other significant feature from the learner's point of view is to minimize the cost of requested e-learning services. Delivering requested services by minimum number of resources leads to reduce the cost of services. Therefore, to attain a dependable and economic e-learning service the mentioned features must be considered.

2. Related Works

Dependability and cost of e-learning services are the significant drawback in the peer-to-peer, client-server and web service architecture [Pankratius, 2003], [Booth, 2003]. On the other hand, the grid services gather heterogeneous, dynamic and geographically distributed resources and achieve comprehensive and meaningful sharing of grid resources. Hence, it is a good choice to provide and share the distributed educational resources in the remote and e-learning applications. Some of the previously published researches like [Brusilovsky,2002], [Fuji,2002] proposed reusable distributed learning activities based on the CORBA technique. Several works have exploited the grid service technologies to attain dependable and economic e-learning systems [Pankratius, 2003], [Sun Microsystems, 2002]. Some of other works have proposed a framework based on Globus to develop a grid environment for e-Learning [Reklaitis, 2002], [Reklaitis, 2003] and [Towards, 2003]. This work proposes a resource management method to attain a dependable and economic learning service in grid systems. The other focus is to minimize educational resource consumption and consequently decrease the cost of requested learning services. The proposed hybrid and dynamic resource management method leads to improve the availability, reliability, scalability and stability of learning service with low resource consumption.

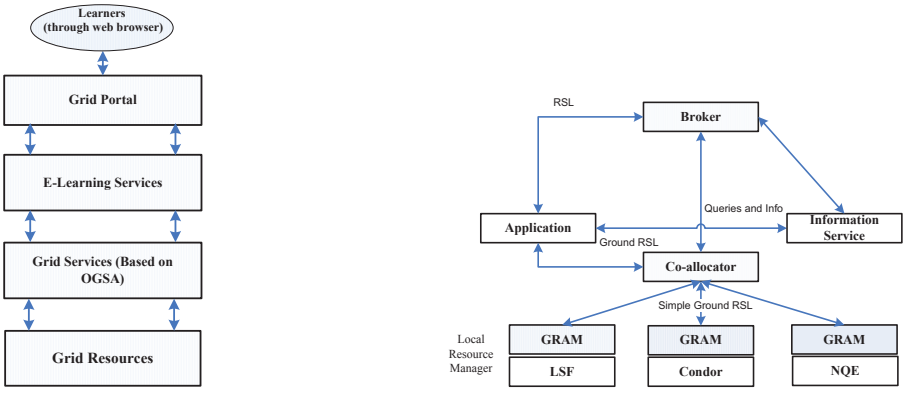
3. Background and system Architecture

This work exploits the grid service technologies to gather the distributed educational resources. A Grid can be defined as a layer of networked services that allow users access to a distributed collection of computing, data, communication and application resources from any location. The service oriented and grid based e-learning platform includes three components: Grid Infrastructure, learning management system (LMS) and user interface system.

3.1. Grid Infrastructure and Globus Toolkit

Service oriented concepts in the grid computing as a platform-independent technique are used in the e-learning systems. Grid infrastructure offers Grid services for computational and collaboration tasks needed by Learning process and the needed resources are managed and shared as a Virtual (VO) Organization by means of Grid publish-discovery mechanisms. The grid infrastructure consists of layered software components deployed in different nodes. In order to develop an e-learning system over the grid computing this work focuses on Globus Toolkit which is an open-architecture and software libraries that support Grid applications. The toolkit includes software for resource management, communication, security and reliability. Grid resource allocation management (GRAM), Monitoring and Discovery System (MDS) and Grid Security Infrastructure (GSI) are the main components of Globus toolkit. GRAM is responsible for managing local resources and comprises a set of Web services to locate, submit, monitor, and cancel jobs on Grid computing resources. The MDS is the information services component of the Globus toolkit and provides information about the available resources on the Grid and their status. GSI is a set of tools, libraries and protocols used in Globus to allow users and applications to securely access resources. Management of needed educational resources is one of the grid middleware roles which has significant impact on the dependability of delivered services. The discovery, selection and scheduling of needed resources in the e-learning applications are the main functions of resource management service. Figure1 shows an overview of e-learning architecture and the resource management component with respect Globus [Gannon, 2002]

In the e-learning system over the grid infrastructure the learner uses a PC and interacts directly with LMS. The LMS services coordinate all learning activities in the grid system. Learning object (LO), courses and tests management are the important functions of LMS. The user interface and grid portal are the next part of grid based e-learning. Grid portal as effective tool which provides simple and browser-based interfaces for accessing grid resources. The integration between Grid infrastructure, LMS and Grid Portal leads to hide the grid and network details and complexities.



Figurer1. a) An Overview of grid based e-learning architecture, b) An Overview of Resource manager in the Globus

3.2. Dependability of E-learning Systems

The needed resources of e-learning over the grid are dynamic, distributed and can enter and leave the grid at any time and thus the probability of failure occurrence in the grid resource during e-learning process must be considered in the resource management. Despite of theses features of grid resources the e-learning system must be dependable enough to deliver reliable and available services to the thousands of learners simultaneously. The dependability of a service is defined as a function of availability, reliability and stability of this service. The Ability of an e-learning service to perform its agreed Function when required is defined its availability. The reliability of an e-learning service is defined as a measure of how long this service can perform its agreed function without interruption. The learners wants to have uninterrupted and stable learning services over desired duration which is called service stability. The parameter λ in the following equations is the average failure rate of corresponding resources of a learning service.

$$\textit{Reliability of a Service} = e^{-\lambda t} \qquad \textit{and Availability of a Service} = \frac{servicetime - downtime}{servicetime} \times 100$$

4. Proposed Model

In order to deliver a dependable learning service the failure of learning resources must be handled during a session which is the main focus of this work. The proposed dependable model to mange the learning resources consists of two main components. The first is finding the learning resources with higher dependability and the next is failure handling service during a session. The *resource search*, *resource selection* and allocation as scheduling process are the main functions of resource manager in the grid systems. The figure 2 shows an overview of proposed model. Based on needed learning resources the MDS in the Globus toolkit is invoked and it finds the set of candidate resources. The needed degree of dependability is important to discover the candidate learning resources. In the learning resource discovery and resource selection algorithm the following parameters must be considered: Dependability of the resources (availability, Reliability and stability), performance of the resources (this criteria is considered for the computing resources), Locality of the resources (The resources with high degree of locality impose low communication and performance overhead) and the cost of the required resources is other measure in the economic grid. The important of the following parameters in the following equation can vary for different type of learning session like long-life and real-time learning session. It leads to attain a trade-off between the dependability and cost because the resources with higher dependability have higher price in the economic grid.

$$Resource\ Selection\ Criteria = \frac{Depenability * Locality}{Workload}$$

The optimal scheduling algorithm selects learning resources with hopes that the session will be completed with timely and without interruption. Some genetic and heuristic methods are proposed to estimate the dependability and performance of the resource before using it . The focus of this paper is on the failure detection and recovery during learning session through the dynamic redundancy technique and the resource manager uses resource redundancy to improve dependability of learning services.

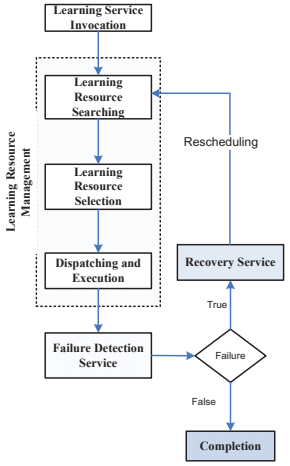


Figure2. An Overview of Proposed Model

4.1. Resource Failure Detection during a Learning Session

The failure handling services consists of failure detection and recovery services. The selected resources by the selection service are used to deliver the requested e-learning services. In this model the resource manager selects K version of each needed resources as spares and just allocate one of them to exploit in the learning application.

The allocated learning resources are used to start the learning session. The failure detection service monitors the status of the resources during a session. In order to detect failure of an active resource during a learning session the following point must be considered: Is the delivered results and service by the resources, correct? Are the time thresholds considered? Has the resource failed? Resource failures in the grid systems can be categorized into two types: *timing failure* and *content failure*. In the timing failure the determined deadline for delivery of the requested service is not met. Checking deadline constraints is an important factor in timing failure detection mechanisms especially in the real time learning applications. The resource management service can monitor the deadline constraints in the session by timing tests to detect halt and timing failures. Timing tests typically use absolute or interval timers to invoke the detection mechanisms. For example, when the selected resources is brought to halt during a session, the resource manager detects it by timing tests and immediately selects the other available and ready resource to continue the session by means of this resource.

When the second type of failure, content failure, occurs, the content of information delivered at the service interface is deviated from the specified functions [Avizienis, 2004], [lyu, 1996]. Comparison techniques, voting techniques and acceptance tests (AT) can be applied to deal with that problem. The proposed model like heartbeat mechanism (Jain, 2004) detects timing and content failure during a learning session. The detection service determines a time interval based on the remaining deadline of the learning session as a heartbeat signals period. Hence, the resource manager invokes the AT periodically to detect resource failure during the learning process. In this step, if the AT passes the delivered service then the status will be stored as a last checkpoint. By saving at each checkpoint the state of the session, the need to repeat some learning activity again is avoided. It leads to reduce the interruption during a session. If the the AT returns false, the system is in the faulty state and must be recovered.

The coverage and latency are the major performance criteria in failure detection mechanisms. The coverage refers to the probability of detecting an arbitrary failure [Gehring, 1999]. It is difficult and more complex to have perfect coverage. This model has used AT for failure detections at the predefined time intervals. The discussion of test case

generation and test coverage is related to software development and test engineering. AT as a software module is used to verify the validity of learning service during a learning session. High coverage, short run-time and low development costs are the main criteria for selecting algorithms for AT. Developing a perfect AT for learning applications sometimes is complex. Then the satisfaction of requirements and the reasonableness test are regarded as the effective algorithm for AT. After a resource failure is detected and it is not tolerable by the learning system during a session the *recovery service* must be invoked. The checkpointing process as a recovery service saves status of services periodically. This model focuses on the system level checkpointing which is supported by Condor and Libckpt middleware. There needs to be a trade-off between the frequency of checkpoints and interruption as performance overhead. Hence, one of the main parameters that affect the dependability and performance is the granularity. Granularity is considered the time interval between checkpoints. To determine the graining size the following factors must be considered: *transparency*, *performance overhead consists of time and space* and *Failure detection latency.*

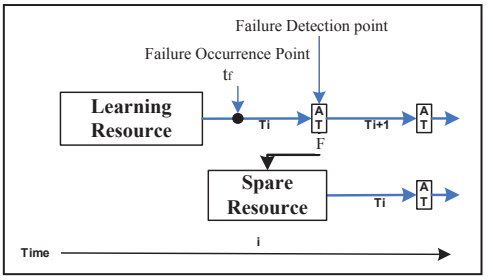


Figure3. The resource manger after an alarm from AT at a checkpoint selects the other ready candidate resource from spare resources by the selection algorithm

5. Dependability Evaluation of proposed model

In order to evaluate the dependability of e-learning model over the grid, we use an analytical approach. The results show that this model improves the dependability learning services. Markov model and fault tree have been using to dependability analysis of software and hardware systems [Lyu, 1996]. We have used the Markov approach to analysis of reliability and availability of proposed scheduling model. .

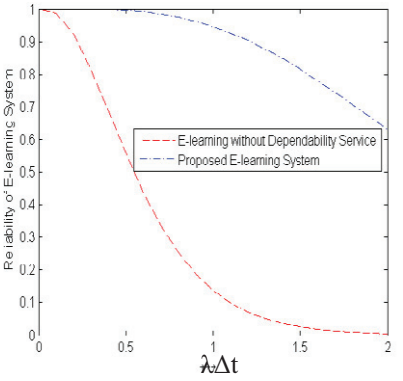


Figure4. Reliability of Proposed E-learning System

The Figure4 shows the dependability of proposed scheduling model. Using dynamic redundancy technique leads to reduce the number of resource consumption and consequently reduce the cost of requested learning service in the economic grid We assume λ_i is the constant rate of failure occurrence in the resource$_i$. $R_i(t) = e^{-\lambda t}$ is the reliability of resourcei during a learning session. We assume $\lambda_i = \lambda$ and $R_i(t)=R$. With respect the availability equations the availability and consequently stability of the the learning service are optimized by using this method. Attaining to higher mean time to failure (MTTF) in this model leads to improve the availability and safety. We assume k is the number of spare resources. MTTR refers the mean time to repair of a failed resource.

$$\textit{Reliability of a learning Service in this model} = \sum_{r}^{k-1} e^{-\lambda t}\frac{\lambda t^{r}}{r!} \quad > \quad e^{-\lambda t} \quad \textit{and} \quad MTTF = \int_0^{\infty} R(t)dt$$

$$\textit{Availability of a learning Service in this model} = \frac{servicetime - downtime}{servicetime} \times 100 = \frac{MTTF}{MTTF + MTTR} \times 100$$

6. Conclusion

The proposed service oriented model based on dynamic architecture and active redundancy has better dependability, resource consumption and consequently lower cost. Attaining to higher mean time to failure (MTTF) is the other characteristic of this model. In the proposed model an active and dynamic redundancy technique is used to tolerate resource failure during the learning session in the economic grid. The proposed fault tolerance service consists of failure detection and failure recovery. The failure detection service leads to improve failure coverage. The recovery service uses checkpointing techniques in the system or application level with an appropriate time interval to attain a trade-off between failure detection latency and service interruption and performance overhead. Low resource consumption leads to decrease the cost of requested learning services in the economic grid. Results of this study demonstrate the effectiveness of the proposed model. This model can be implemented and adopted for any Grid platform.

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