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Usability of a cloud-based collaborative learning framework to improve learners' experience

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ABSTRACT

Computer-Supported Collaborative Learning (CSCL) is concerned with how Information and Communication Technology (ICT) might facilitate learning in groups which can be co-located or distributed over a network of computers such as Internet. CSCL supports effective learning by means of communication of ideas and information among learners, collaborative access of essential documents, and feedback from instructors and peers on learning activities. As the cloud technologies are increasingly becoming popular and collaborative learning is evolving, new directions for development of collaborative learning tools deployed on cloud are proposed. Development of such learning tools requires access to substantial data stored in the cloud. Ensuring efficient access to such data is hindered by the high latencies of wide-area networks underlying the cloud infrastructures. To improve learners' experience by accelerating data access, important files can be replicated so a group of learners can access data from nearby locations. Since a cloud environment is highly dynamic, resource availability, network latency, and learner requests may change. In this paper, we present the advantages of collaborative learning and focus on the importance of data replication in the design of such a dynamic cloud-based system that a collaborative learning portal uses. To this end, we introduce a highly distributed replication technique that determines optimal data locations to improve access performance by minimizing replication overhead (access and update). The problem is formulated using dynamic programming. Experimental results demonstrate the usefulness of the proposed collaborative learning system used by institutions in geographically distributed locations.

1. Introduction

The concept of collaboration is a fundamental form of human activity which fosters working in small groups to achieve some common goals. Collaborative learning (Bruffee, 1993; Dillenbourg, 1999) is a scenario where two or more people learn or attempt to learn something together. Individuals engaged in collaborative learning exploit one another's resources and skills (asking one another for information, evaluating one another's ideas, monitoring one another's work, etc.) (Chiu, 2000, 2008). Particularly, collaborative learning is based on the model that knowledge can be created within a group where members actively interact by sharing experience (Mitnik, Recabarren, Nussbaum, & Soto, 2009). In other words, learners engage in a common task in collaborative learning where each individual depends on and is accountable to each other. Initially, collaborative learning and its social aspects could not attract the attention of technological support. However, Computer-Supported Collaborative Learning (CSCL) is a comparatively new educational paradigm within collaborative learning which exploits technology in a learning environment to support group interactions in a collaborative learning context (Chen & Chiu, 2008; Mitnik et al., 2009). CSCL methods use technology to control and monitor interactions, to regulate tasks, rules, and roles, and to intervene the attainment of new knowledge (Pozzi & Persico, 2011).

Recently, CSCL has become the fastest growing area of research in the field of computer-aided education. In general, it articulates two essential concepts: first, the idea of learning in a group as already mentioned. Secondly, it stresses the role of the computer

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as an intervener in the whole process. Thus, CSCL helps the individuals learn to collaborate and collaborate in order to learn. Moreover, experimental study reveals that network-based collaboration may provide opportunities for more equality in group work than actual face-to-face group work (Dooly, 2008). Information and Communication Technology (ICT) tools such as sharing teaching and learning materials, using discussion forums, etc. can play a vital role in the learning process in where learners share their knowledge and experiences through the forum, get quick access to the essential materials and so on.

With advancement of cloud systems, more and more web-based applications are being developed using cloud technologies. These technologies offer ample compute and storage resources for cloud-enabled applications. More specifically, cloud computing offers datacenter computing power and storage. Hence, collaborative and e-Learning frameworks are being developed in a cloud based system (Huang & Liu, 2014; Yang, 2014). Cloud-enabled collaborative learning framework will thus have the advantage of resource elasticity offered by the cloud technology (Alexandru, Nicolae, & Loredana, 2013).

National Institute of Standards and Technology (NIST) (Mell & Grance, 2013) defines cloud computing "as a computing model which offers network access to a configurable resource pool, the access being location transparent, convenient and on-demand". These resource pools consist of compute cycles, storages, applications and services which can be used by the end user with a minimum maintenance and interaction with the cloud provider. There are primarily three models for services delivery in cloud computing: Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS). The authors in Kundu, Barnejee, and Priya (2010) proposes another model for service delivery in cloud computing known as Learning as a Service (LaaS) which could be considered for cloud based collaborative and e-learning tools.

In a cloud-based collaborative learning scenario, group of learners and the educator can be located in geographically dispersed locations. Due to this distributed nature, learners' need of immediate access to resources is important. To this end, this paper studies the feasibility and applicability of a cloud-based learning tool, identifies the major requirements in respect of effective access to learning resources and proposes a development framework. Accordingly, we designed a collaborative learning platform prototype and we devised an efficient replication technique for proper dissemination of learning resources among the learners and conducted simulation experiments in order to evaluate the end-user experience, utility and satisfaction.

Given the characteristics of wide-area networks underlying cloud systems and the need to access and manage large amount of data, scalability, data availability, and access speed are challenges that must be met. One way to speed up access in clouds is to replicate datasets at multiple locations so a learner can access the data from a nearby site (Venugopal, Buyya, & Ramamohanarao, 2006). The benefits of replication are multitude such as system availability, access performance, and scalability. Replication removes single points of failure by replicating data so that they are accessible from multiple sites. Even when some sites are down, data may be accessible from other sites thus system availability is ensured. Replication also enables learners to locate the data closer to their sites, which contributes to a response time reduction and thus improves access performance. Furthermore, as systems grow geographically and in terms of the number of sites (which increases the number of access requests), replication handles this growth with reasonable response times (Iacob, 2011; Ranganathan, Iamnitchi, & Foster, 2002). Creating replicas also allows the routing of learners' data requests to different replicas thereby also distributing the workload across the replica servers. The network load is also distributed across multiple network paths thereby decreasing the probability of congestion-related performance degradation. However, to maximize the possible gains from data replication, strategic placement of the replicas is important (Kalpakis, Dasgupta, & Wolfson, 2001; Tu, Li, Ma, Yen, & Bastani, 2005; Wolfson & Milo, 1991).

In clouds, where control is decentralized, placing replicas using a centralized algorithm is unattractive. Distributed placement offers potential benefits in terms of both scalability and reliability. In this paper, we describe a distributed replication technique to determine optimal locations for replicas to minimize overall replication overhead (access and update) for a given data access pattern. The use of dynamic programming is natural in distributed systems. We show that the replication problem described in this paper can be formulated as a dynamic programming problem and its solution can be obtained for hierarchical clouds in a distributed fashion. To evaluate the performance of our cloud-based collaborative learning framework, we performed simulation experiments within a hierarchical cloud structure reflecting the characteristics of a real-world learning environment in institutions in geographically distributed locations. Overall, the main contributions of this paper are summarized as follows:

- Unlike most of the previous cloud-based collaborative learning framework, this paper considers the importance of data replication in designing such a framework.
- A distributed replication technique to improve learners' data access performance.
- For optimally solving the replication problem in a collaborative learning framework, we present how to formulate the replication problem as a dynamic programming formulation.

The rest of this paper is organized as follows. Section 2 presents some relevant approaches from the existing literature. Section 3 describes the system model assumed. We present our framework and specific methodology for development in Section 4. Our simulation methods and results are described in Sections 5 and 6, respectively. Section 7 concludes the paper and suggests directions for future work.

2. Related work

There are a quite a bit of work done in the area of computer supported collaborative learning. Among relatively earlier efforts, the authors in Barros and Verdejo (1999) have proposed an asynchronous newsgroup-style environment where students can have structured and computer supported discussion online to foster learning experience. The performance evaluation is done based on the interaction among the learners. This involves the analysis of the conversation that takes place among the learners and the performance metrics consists of some important values having a number of attributes: initiative, creativity, elaboration, and conformity. Katz (1999) proposes two rule learning systems: String Rule Learner and Grammar Learner. These systems allow learners to learn from patterns of conversation targeting some particular pedagogical goals. Inaba and Okamoto (1997) present a collaborative learning model that uses the concept of finite state machines and utility functions. They make use of a finite state machine to control the flow of conversation and to identify proposals. Then they apply utility functions to measure learners' beliefs with regard to the group conversation.

Muhlenbrock and Hoppe (1999) develop a framework for computer-supported cooperative learning which has been used in determining conflicts in focus setting, initiative shifts in aggregation and revision phases during some collaborative sessions on problem solving. Constantino-Gonzalez and Suthers (2001) present