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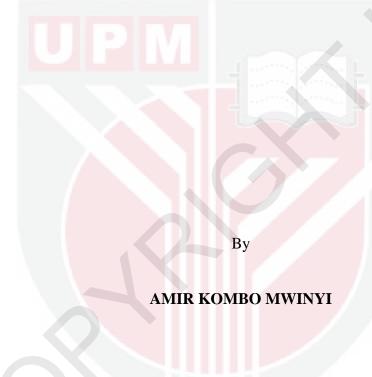

IMPROVED RSYNC ALGORITHM TO MINIMIZE COMMUNICATION COST USING MULTI-AGENT SYSTEMS FOR SYNCHRONIZATION IN MULTI-LEARNING MANAGEMENT SYSTEMS

AMIR KOMBO MWINYI

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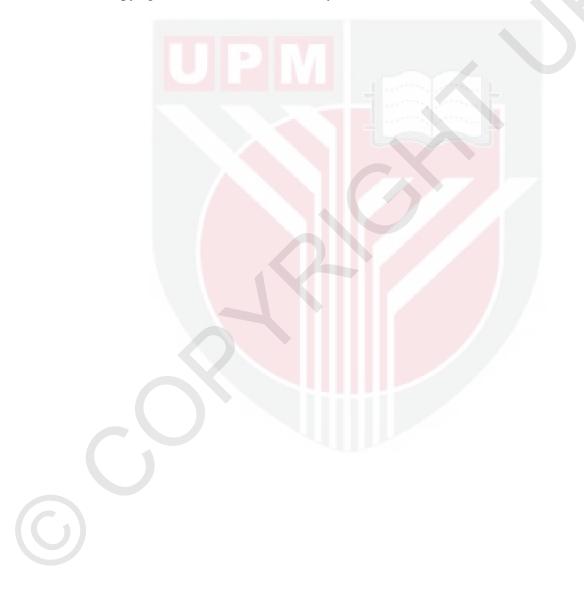
By

AMIR KOMBO MWINYI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Doctor of Philosophy
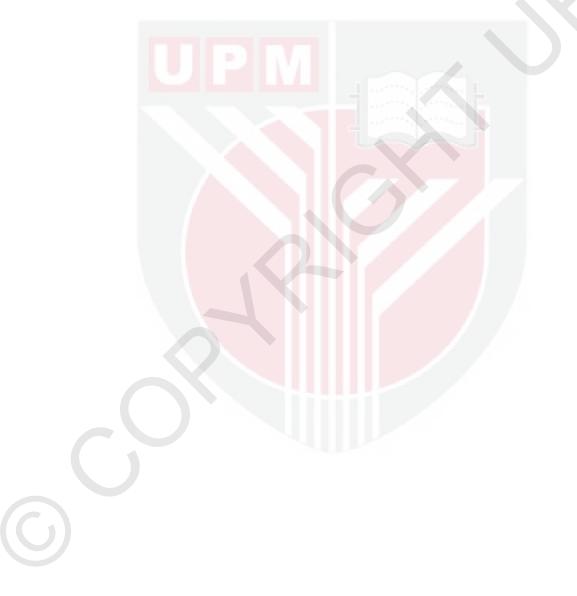
May 2017

DEDICATION

I dedicate this workd to my beloved mother, Fatma Salim Ahmed who devoted her valuable time to consistently pray and encouraging, as well as support and sacrifice, which will always be remembered but can never be repaid. To my people of my life, my wonderful wife, Nawal Seif Kassim, who has encouraged and supported me so much over the years, and to our lovely children, Asya Amir, and Akram Amir. To all family members for their support and unending encouragement in my entire endeavour.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the Degree of Doctor of Philosophy

IMPROVED RSYNC ALGORITHM TO MINIMIZE COMMUNICATION COST USING MULTI-AGENT SYSTEMS FOR SYNCHRONIZATION IN MULTI-LEARNING MANAGEMENT SYSTEMS

By

AMIR KOMBO MWINYI

May 2017

Chairman : Associate Professor Syed Abdul Rahman Al-Haddad, PhD
Faculty : Engineering

Remote file synchronization (RFS) is based on updating the outdated version of a file that resides on one machine to be similar to the new version of the updated file in another machine at a minimum computation time (cost). The problem of rsync algorithm synchronization process is that rsync tries to check folders and files one by one, which takes long time to synchronize them. Therefore, the aim of this study is to minimize the computation time during RFS by improving the standard rsync algorithm.

Previously, several algorithms and techniques have been proposed for partial file synchronization but many of them were based on controlling the block size, checksums, and delta compression of the matched blocks, to solve the searching problem of the rsync algorithm. This study proposed several techniques to improve rsync (irsync) algorithm in order to reduce computation time during RFS, by encompasses a Multi-Agent system (MAS) framework. This algorithm involves several agents, such as: initiator, sense_agent (SA), log_agent (LA), and search_agent (SeA). These types of agents have different capabilities, actions, and efficiency to the irsync algorithm in file synchronization.

The study proposed MAS framework in the Learning Management System (LMS) that involves the transfer of data from one machine to another. To meet this requirement, a new Multi LMS (MLMS) model using Sharable Content Object Reference Model (SCORM) specifications to share learning materials among different higher learning institutions (HLIs) has been presented. This model enhances the interoperability and collaboration of HLIs in terms of synchronization and sharing of learning contents. To evaluate the computation time of the new techniques, standard datasets, which include two versions of source codes emacs-19.28 with emacs-19.29, and gcc-4.8.1

with gcc-4.8.2, were used. The experimental results show that the improved rsync (irsync) algorithm yields a better performance against two previous algorithms, rsync algorithm and hierarchical folder synchronization algorithm (HFSA) in terms of reducing computation time and improve synchronization response time.

Therefore, the MAS framework was performed and the reduction of computation time was obtained by 19.86% compared to 42.25% of standard rsync. The results also indicated that reducing the searching time could enhance the irsync algorithm responsiveness time by 32.07% compared to 67.93% of the standard rsync. The integration of the proposed MLMS model with irsync algorithm was further tested through a prototype with MAS and show significant improvement over the cloud synchronization system which based on CDMI technology. These two systems were evaluated in terms of synchronization rate. The results revealed that the MLMS system with irsync (MAS) outperformed the cloud system.

Abstrak tesis dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Doktor Falsafah

PENAMBAHBAIKAN ALGORITHMA RSYNC UNTUK MEMINIMAKAN KOS KOMUNIKASI DENGAN MENGGUNAKAN SSTEM AGEN PELBAGAI BAGI PENYEGERAKAN DALAM SISTEM PENGURUSAN PEMBELAJARAN PELBAGAI

Oleh

AMIR KOMBO MWINYI

Mei 2017

Pengerusi : **Profesor Madya Syed Abdul Rahman Al-Haddad, PhD**
Fakulti : **Kejuruteraan**

Penyelarasan fail secara jauh (RFS) adalah berdasarkan kepada bagaimana untuk mengemas kini versi fail lama yang berada di dalam satu mesin untuk menjadi serupa dengan versi baru bagi fail yang dikemaskini dalam mesin lain pada kos masa yang minimum untuk pengiraan (kos). Masalah proses penyelarasan algoritma ialah rsync cuba untuk memeriksa folder dan fail secara individu, ini mengambil masa yang lama untuk diserak . Oleh itu, tujuan kajian ini adalah untuk mengurangkan kos masa pengiraan semasa RFS dengan menambah baik algorthma arsync piawaian

Sebelum ini, beberapa algoritma dan teknik telah dicadangkan untuk penyelarasan fail separa tetapi kebanyakan mereka adalah berdasarkan kepada mengawal saiz blok, semak jumlah, dan mampatan delta blok sepadan, untuk menyelesaikan masalah pencarian algoritma rsync. Kajian ini mencadangkan beberapa teknik untuk meningkatkan algoritma rsync (irsync) bagi mengurangkan kos masa pengiraan semasa RFS dengan merangkumi rangka kerja sistem multi-ejen (MAS). Algoritma ini melibatkan beberapa ejen, seperti: pemula, sense_agent (SA), log_agen (LA), dan search_agent (SEA). Jenis-jenis agen mempunyai keupayaan, tindakan dan keberkesanan algoritma irsync yang berbeza dalam penyerakan fail.

Kajian ini mencadangkan rangka kerja MAS dalam Sistem Pengurusan Pembelajaran (LMS) yang melibatkan yang melibatkan pemindahan data daripada satu mesin ke mesin yang lain.Bagi memenuhi keperluan ini, satu model baru LMS pelbagai (MLMS) menggunakan spesifikasi Model Pengkongsian Kandungan Objek Rujukan (SCORM) untuk berkongsi bahan pembelajaran dalam kalangan institusi pengajian tinggi yang berbeza telah dikemukakan.Model ini akan meningkatkan daya salingkendali dan kerjasama institusi pengajian tinggi (HLI) dari segi penyelarasan

dan perkongsian kandungan pembelajaran.Untuk menilai keberkesanan teknik baru, dataset piawaian, termasuk dua versi kod sumber emacs-19.28 dengan emacs-19.29 , dan gcc-4.8.1 dengan gcc-4.8.2 telah digunakan.Keputusan eksperimen menunjukkan bahawa algoritma rsync (irsync) yang bertambah baik menghasilkan prestasi yang lebih baik berbanding dua algoritma sebelumnya, algoritma rsync dan algoritma folder hierarki penyelarasan (HFSA) dari segi mengurangkan kos masa pengiraan dan penjimatan masa tindak balas penyelarasan.

Oleh itu, rangka kerja MAS telah dijalankan dan pengurangan kos komunikasi tercapai pada 19.86% berbanding dengan 42.25% untuk rsyncpiawaian.Keputusan juga menunjukkan yang mengurangkan masa pencarian boleh menambah baik masa kegerakbalasan algoritma rsync sebanyak 32.0% berbanding dengan 67.93% untuk rsync piawaian. Integrasi model MLMS yang dicadangkan dengan algoritma irsync telah diuji melalui prototaip dengan MAS dan menunjukkan peningkatan yang ketaraberbanding dengan sistem penyelarasan cloud yang dikembangkan yang berdasarkan teknologi CDMI. Kedua-dua sistem-sistem ini telah dinilai dari segi kadar penyelarasan. Keputusan menunjukkan yang sistem MLMS dengan irsync (MAS) lebih baik daripada sistem cloud.

ACKNOWLEDGMENTS

I certify that a Thesis Examination Committee has met on 26 May 2017 to conduct the final examination of Amir Kombo Mwinyi on his thesis entitled "Improved Rsync Algorithm to Minimize Communication Cost Using Multi-Agent Systems for Synchronization in Multi-Learning Management Systems" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

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Declaration by Members of Supervisory Committee

This is to confirm that:
- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) were adhered to.

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LIST OF ABBREVIATIONS

ACL	Agent Communication Languages
AOM	Agent-Oriented Methodologies
AOP	Agent-Oriented Programming
CDMI	Cloud Data Management Interface
DAD	Detailed Agent Description
FIPA	Foundation for Intelligent Physical
GOD	Goal Overview Diagram
HFSA	Hierarchical Folder Synchronization Algorithm
MLMS	Multi Learning Management System
HPR	Human Practical Reasoning
KQML	Knowledge Query and Manipulation Language
LMS	Learning Management System
MAAD	Multi-Agent Architectural Description
MAS	Multi-Agent System
MRP	Multi-Round Protocol
PDT	Prometheus Design Tool
RFS	Remote File Synchronization
SCORM	Sharable Content Object Reference Model
SRP	Single Round Protocol
SSD	System Structural Description
SUZA	State University of Zanzibar

CHAPTER 1

INTRODUCTION

1.1   Background

Learning management system (LMS) also called Virtual Learning Environment (VLE) is a software application that is focused particularly on teaching and learning that provides course management, assessment, communication, collaboration, curriculum development, and task management automation (Chung, Pasquini, and Koh, 2013). Learners' can log on and work from anywhere around the world where Internet is available, at any time.

To realize the benefits of LMS, a growing number of institutions and business organization have embraced this concept of web based learning systems to fulfil their educational needs (Pavan, Santhi, and Jaisankar, 2012; Hejazinia and Razzazi, 2010; Xiang, 2008). Like other information technology innovation in recent years, the LMS is capable of adding a level of efficiency to institutions' or organizations' learning systems, with several number of benefits, such as: flexible learning times, distance education, manage, and delivering of digital learning contents to the students.

There are a number of software utilities such as Microsoft's AciveSync, Puma Technologies' IntellSync, GoodSync, Dropbox, SmartSync, and rsync that allows synchronization between desktop computers, mobile devices, or web accessible tousers' accounts (Shaoyan, 2009; Agarwal, 2002; Hansen, 2010; Drago, 2012; Gonçalves, 2014; and Kijewski-Correa, 2012). In this scenario, files or records can be updated by several different parties, and size of the file and time stamps can be used to determine which version on which device is the most recent. Synchronization can be used for remote backup of data sets that may have only changed slightly between backups (Tridgell, 2000). In this case, the overhead of keeping the old version at the server is usually unreasonable. File synchronization has also been considered for efficient HTTP transfer between clients and a server (Tridgell, 2000). The advantage is that the server does not have to keeptrack of the old versions held by the clients, and does not need to fetch such versions from disk upon a request.

The RFS is a data transfer method where the sender does not have knowledge about the files held by the receiver in the communication system. Consider the following scenario, Sender S has a copy of file (*string*) f_{new} and Receiver R has an old copy of file f_{old}, the challenge is to design an algorithm that is capable of enables Receiver R to have a copy of file f_{new} while minimizing the communication cost between the two sides. In this case, Sender S will only sends parts of the file that do not match the Receiver R, and hence minimize the communication cost of sending the whole file to the receiver which in turn increase performance of the communication system, particularly in a slow communication link.

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Because of the distributed nature of the source code and mirroring of web pages in several servers, synchronization must concurrently consider the communication cost and time taken to transfer changes over the network to achieve high performance. These changes in most cases are updates where an old version of the file is already presented at the source side (Tridgell, 2000). One issue of the file synchronization is the development of effective algorithm that is capable of reducing communication cost in order to reduce computation time. The main advantage of rsync algorithm (Tridgell and MacKerras, 1996) is the ability of utilizing the existing file (at the target device) and updating it remotely without having prior information of the relative states of the files at the other end of the link. The main idea of rsync is to transfer only changes that are not the same between old file and new file held in different computers. This means that instead of sending the compressed (*diff*) file from source to target like other methods of transferring file, such as remote copy (*rcp*) command and file transfer protocol (*ftp*), rsync compares two files remotely by using two types of signatures (weak and strong) from the sender (source) to the receiver (target). The algorithm then sends only those parts of the file that are not matched the receiver file. The difficult part of RFS algorithm is that the sender does not have a copy of the files that held by the receiver. Rsync tool is a famous open source utility used by UNIX distributions that uses rsync algorithm to sync files and folders from one location to another.

This study focuses on the file synchronization and implementation of new techniques for rsync optimization. The second part of this thesis based on designing of interoperability model of multi learning management system (MLMS). This model is then used in the implementation of MLMS prototype that takes advantage of the improved rsync algorithm developed in this research project. This study also investigates the usability of improved rsync algorithm in the collaboration of multiple learning management system (LMS), so that to minimize the overall data transfer time.

1.1.1 Issues in new Synchronization Algorithm

The system design requirements for improving rsync algorithm and the new interoperability multi learning management system using agents is divided into functional and non-functional requirements. The functional requirements specify what this new interoperability learning system should do, while the non-functional requirements specify how this collaborative system should behave. In this new system the following functionalities have been identified:

a) **Searching**: The agents should be able to search a similar file at the receiver device and should provide a high speed searching process. This can be achieved by collaboration of more than one agent and the awareness of the current situation of the environment.

b) **Autonomy**: This property means that agents can work independently and make their own decisions. When consider a system consisting of more than one agent, then the autonomous characteristic of the agent required that the system should be decentralised. Therefore, the responsibility of controlling the agent' action should performed by the agents themselves.

c) **Adaptiveness:** Agents must be able to continuously adapt to their dynamic environment in order to provide up-to-date learning contents, and determine what to do next to maintain it. This is important, because many scenarios are characterised by dynamism and inherent uncertainty. Consequently, agents will have limited knowledge of the prevalent conditions before deployment. Adaptive agents are capable of continuously adjusting a MLMS model of their environment to best reflect the information that has been gathered so far, and are able to predict and evaluate the outcomes of future decisions.

d) **Performance**: An improved rsync algorithm should ideally be able to give guarantees on the searching speed and interoperability collaboration provided by the MAS. Whereas potential empirical results might be sufficient reason to adopt an algorithm in learning web domains with synchronization capability, and other applications that needs to send only portion of the file instead of transferring the whole file.

1.1.2 Multi-Agent Systems (MAS)

Basically, MAS contains multiagents to achieve certain goals or responsibilities (De Oliveira *et al*., 2006). In addition, MAS as proposed in various applications is a promising technology paradigm that comprises attractive characteristics like autonomous, intelligent and proactive which can be applied in software engineering and other disciplines for developing various systems of different complexity or applications (Zambonelli *et al*., 2003; Gunasekera et al., 2013). In order to show the importance of MAS, Talib *et al*. (2012) presented the security issue in cloud computing by incorporating MAS for securing Cloud Data. They introduced a new security access control formula called Formula-Based Cloud Data Access Control. MAS's architecture that was presented consisted of two types of agents: Cloud Service Provider Agent which could provide access to the cloud resources and Cloud Data Confidentiality Agent which was responsible for formulating new access control for Cloud Data Storage.

Furthermore, Ogunnusi and Razak (2013) have introduced a fault-tolerant distribution security protocol for distributed mobile agents which are part of MAS entities to reduce the network intrusion attacks. They utilized wireless local area network (WLAN) environment to detect the intrusive packets in the domain. This new distribution protocol for attack detection has included various agents: Mobile agent, agent server and backup agent server. All these agents are working collaboratively with other components like, certification authority, security domain, messaging system, execution platform and keystore in order to ensure security of collaborating mobile agents from any possible attacks while migrating to the execution platform.

For MAS to work efficiently in any platform there must be a communication and sharing of knowledge to accomplish their goals and tasks. When the agents collaborate and share knowledge, they do so within a group of agents with different capabilities to solve a set of problems. Nor et al. (2009) mentioned three types of knowledge: Organizational knowledge, managerial knowledge and technical knowledge that can

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be incorporated into the groups in the society or community to share information. MAS have been shown to contain different agents with different capabilities to achieve flexibility and enhance the interaction of system. For the purpose of this study, MAS can be used to facilitate the searching process in the file synchronization in order to reduce the communication overhead.

MAS can offer various means of collaboration (Wooldridge and Jennings, 1995), among different types of agents in the system. Agents are capable of collaborating with other agents not only for exchanging data, but also for helping one another to perform certain tasks. This can be seen also from the model developed by Perez and Uresti (2014), where a number of agents are working together to predict the opponent next move. The model has been illustrated by an experiment with the RoboCup 2D Soccer Simulator. In this study, the agents used had to collaboratively make decisions based on the course availability in the multiple LMS system. In addition, for knowledge sharing and interaction, MAS has to work together to find solutions or solve social or business problems, as individual agents have incomplete capabilities to solve complex problems (Sajja, 2008). Therefore, there is a need for MAS to work together and to share information that maximum performance of the system can be attained.

Boulaalam et al. (2013) have conducted a research that involves mobile agents to accelerate the new product development process. In their study that based on Auto ID, they have incorporated mobile multi-agent system technologies, to improve the innovation process in the enterprise. In their proposed architecture of intelligent product, innovation can be improved by introducing the new product generation by utilizing MAS before the end of the ex-product version.

1.1.3   Multi Learning Management System (MLMS)

Currently, there are a number of LMSs which categorized as open source and proprietary supported LMSs. Many of the large vendors, including Blackboard, Desire2Learn, and eCollege fall into the proprietary supported software systems category. As a result, they have a technical development team and an experienced support services staff prepared to help their users on implementation, troubleshooting, and use their products. All of these companies are continuously updating their products and partnering with other companies as new tools become available. When integration is required with other software systems that is beyond the particular technical team expertise, these vendors have a dedicated professional services groups available to address their specific concerns.

Recently, efforts have been made to design online systems that provide online courses, which encompass multiple e-learning systems. But more sophisticated system which has the ability to dynamically adapt the LMS and to present instructional learning materials according to the learner's needs is needed to support shareable and collaborative learning environments (Lee and Chong, 2003). According to Lee and

Chong (2003), a first priority should be given to an intermediary system that the main goal is to integrate distributed LMSs to facilitate information sharing and collaborative learning environment between the shared parts.

To show the importance of integrating more than one LMS, Lee and Chong proposed a model which taking advantage of middleware framework, that enable the development of instructional materials that can be able to utilize the distributed *heterogeneous learning sources*. The middleware system that developed by Lee and Chong (2003) was capable of providing sharing and redistribution of learning objects, and carry out collective learning across virtual learning community called Community-Based Learning (CoBL). In this framework, Lee and Chong have used MAS to manage the learners in the community and utilize of shared data model for integrating multi community. Figure 1.1 illustrates the educational middleware which is applied in CoBL.

Figure 1.1 : Interacting middleware in CoBL (Lee and Chong, 2003)

The CoBL framework makes use of three advanced technologies (i.e. agent-based communication, component-oriented development, and shared data model). The agent paradigm is employed in the system architecture in order to support communication. The component-oriented development technology allows the design of learning support systems that are context-independent. Shared data model was used to integrating heterogeneous communities, MLMS in our case.

A framework which plays very important part of the community learning (CoBL) was developed using component-oriented. The framework maintains all activities needed for CoBL, also general patterns of the CoBL, which describes state, behaviour, and constraints of learning contents. The CoBL framework manages learner profiles and

pedagogical patterns by using rules and constraints in order to determine which learning pattern is best for particular learning conditions (Lee and Chong, 2003). As part of its functionalities, the CoBL framework is required to work with different learners and heterogeneous learning materials in a diverse learning environment. The CoBL framework was built on small components that can be to communicate and collaborate using well-defined interfaces.

Figure 1.2 : Space component (Lee and Chong, 2003)

The fundamental functionality of the CoBL framework is divided into four different types of components: first is space components, second is active components (using agents to support communications among LMSs), third is resource components (including knowledge bases, and databases), and fourth is dynamic components (i.e. runtime environments). Each component plays a very vital role in supporting the framework. Space components include their own active components, resource components and dynamic components (Figure 1.2). In addition, the resource components keep student (learner) knowledge and lesson. Moreover, the active components (agents) have very important features that giving them the capabilities like communication, autonomous, and proactive which enable them to work in the dynamic environment (Dynamic component). These features facilitate the decisions making that are necessary to create dynamic views. The combination of those four components form improved, adaptive and collaborative LMSs (Lee and Chong, 2003).

1.2   Problem Statement

The main concept of file synchronization is to minimize the amount of data transmitted from the constrained devices. The concept of file synchronization is very simple and easy to understand. File synchronization operates in the situation where two devices held similar files in which it checks the differences between two devices in order to avoid unnecessary transfer of data that already resides in both devices. Therefore, synchronization normally updates both data files by transferring only changes that unmatched during the synchronization process.

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There are various algorithms that have been developed to solve synchronization problem, where synchronization of two devices occurs remotely in which both devices do not held the old versions of the data sources. This challenge comes when there are two versions of files in two computers, one is updated and other is outdated. The question is how can we update the outdated version in a minimum computation time in terms of reducing transfer computation time? This will be achieved by reducing RFS computation time during file transfer and file searching process (Ghobadi et al., 2011; Qian et al., 2013; Yang et al., 2014; Sala et al., 2016). According to Ghobadi et al., rsync tried to check folders and files one by one during file synchronization which takes high amount of time to update old files or folders at receiver sides.

Currently, there are many algorithms and tools to solve synchronization problem between different devices. Some of them transfer the entire file if a change has occurred from the updated version, example ActiveSync, and HotSync (Chang, 2009, Schoeny et al., 2014). But if the synchronization involves transfer of huge amount of data between two devices, the transfer of entire file is not sufficient (Ghobadi et al., 2011; Bitouze and Dolecek, 2013; Schoeny et al., 2014; Yang et al., 2014; Sala et al., 2016).

The main gap in the above and other previous literatures in the RFS is that, there is a lack of using multi-agent approach to reduce the computation time in file synchronization. The MAS have shown optimum performance in various applications (Maalal and Addo, 2012; Wang and Botea, 2008; Frankovič and Oravec, 2005; Jansen and Pooch, 2004; Pierre, Hoang, and Pelletier, 2003). Also MAS has been used in conjuction with MD5 to improve file synchronization across different machines in the system called multisync (Niazi et al., 2005). Niazi et al., (2005) they presented an application (Multisync) that utilized mobile agents in a multi-agent system for synchronizing user files seamlessly without user intervention. Another studies that involved MAS and shown good performance in file synchronization were conducted by Manzoor and Ijaz, (2008); Kim et al., (2013); and Kotulski (2015). Again, MAS based system has been used to reduce communication effort between the neighbor subsystems using event-based synchronization (Demir and Lunze, 2012).

This study also focuses on designing an interoperability MLMS model that utilizes an improved rsync algorithm that developed in this study in order to solve the interoperability issue (Leal, and Queiros, 2011) in distributed learning systems. Martínez and Navarra (2007) defined interoperability as "the ability of different computer systems, applications or services to communicate, share and exchange data, information and knowledge in a precise, effective and consistent way". The improved rsync has been used in interoperability MLMS model to support the synchronization among MLMS so that students can be able to receive updated file automatically from any LMS. The significance of interoperability and collaboration of educational systems is very critical in today learning process (Leal and Queirós, 2011). According to Leal and Queros (2011), currently there is a difficulty to reuse courses in learning institutions with LMS from different vendors; this is a suitable example of the problem found in the majority of the LMSs. Universities in HLIs particularly in Malaysia each

university use its own LMS where by no collaboration and sharing of courses with other LMS in other universities are offered (Embi, Hamat, Sulaiman, 2011).

As another objective of this study, the applicability of this model has been tested in the prototype that developed in this study which utilized this proposed interoperability MLMS model. This prototype has been tested and evaluated by comparing it with cloud synchronization system that developed by Yang et al., (2014).

1.3 Research Objectives

The main objective of this research project is to design and implement the new algorithm which will reduce file computation time of searching outdated files during remote file synchronization to enhance rsync algorithm.

Specific objectives of this research were:

i. To design MAS framework with irsync algorithm for reducing the computation time (cost) of the rsync algorithm. The reduction of computation time in irsync is based on the capability of agents to detect changes and transferred only modified (changed) in the file.
ii. To create interoperability MLMS model that utilizes the irsync algorithm to facilitate learning contents synchronization and collaboration in the MLMS. The potential techniques (irsync and MAS) of the interoperability MLMS model compared with the rsync in terms of response time.
iii. To develop and evaluate MLMS prototype that took advantage of the interoperability MLMS model to synchronize learning contents in different courses in MLMS. The prototype has been tested and compared with CDMI in terms of synchronization rate.

1.4 Research Scope

Synchronization and learning management systems are very gigantic research areas, covering computer communication, data compression, data similarity, resource utilization, e-learning, knowledge management, database management, and information sharing. In this study, the main focal point was RFS where the receiver has no prior knowledge of the information stored in the sender, and the development of interoperability model of multiple LMSs that enables the sharing of learning contents (courses). Therefore, network protocols, concurrent synchronization, and other LMS functionalities are not covered in this research. In order to measure the performance of the new algorithm, remote synchronization computation time, communication time caused by agents, and MAS responsiveness in RFS were considered. In terms of interoperability model of MLMS, prototype was developed and compared with the Cloud storage synchronization. The computation time of the irsync and interoperability of the model were quantified. The comparison of these two systems (with and without agents) was evaluated.

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To measure the performance of irsync algorithm, a simulation is done using two versions of standard data sources stored in two computers. The performance of irsyc was measured based on the computation time, response time (responsiveness), and communication time by comparing it with standard rsync algorithm and HFSA algorithm. It is also considered that all necessary information for sharing data are ready to be used in all MLMS. Therefore, for the interoperability MLMS model, the objective is to develop a model that integrates multiple LMSs to improve learning process.

In the interoperability MLMS model, the main e-learning standard compliance with combination of MAS with Sharable Content Object Reference Model (SCORM) which facilitates the sharing of learning contents among MLMS.

1.5   Thesis Organization

This thesis presents the rsync algorithm improvement, modeling and development performance evaluation of collaboration MLMS. The remainder of this thesis is organized as follows:

In Chapter 2, the study discusses previous related works. A number of previous techniques are reviewed thoroughly. Based on this review, different techniques used in file synchronization and rsync in particular are reviewed in order to analyze the state of the art. In this chapter, key methods has been identified and adopted with some modification in this research.

Chapter 3, this chapter covers the methodology used in this research. A new algorithm that encompasses intelligent agents to improve rsync algorithm is proposed. In addition, this chapter also presents a generic model for the problem of interoperability in MLMS. Furthermore, system requirements specifications and the basic behaviors of each agent are theoretically described.

Chapter 4 presents the results and discussions of the improved algorithm and collaboration MLMS prototype. In this chapter, performance of the improved rsync algorithm was discussed and compared against standard rsync. Also the empirical analyses of the prototype evaluations were presented.

Finally, Chapter 5 concludes and describes the research directions for future work to extend the agents applicability in the LMS environment. In this chapter, the contributions of this study were also outlined.

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