# PAPER An Interoperability Framework of Open Educational Resources and Massive Open Online Courses for Sustainable e-Learning Platform

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SUMMARY Massive Open Online Courses (MOOC) have been invented to support Virtual Learning Environment (VLE) for higher education. While numerous learning courses and contents were authored, most of the existing resources are now hard to reuse/redistribute among instructors due to the privacy of the contents. Therefore, Open Educational Resources (OER) and the Creative Commons license (CC) are interesting solutions available to alleviate such problems of MOOC. This research presents a new framework that effectively connects OER and MOOC for a life-long e-Learning platform for Thai people. We utilize the Fedora Commons repository for an OER back-end, and develop a new front-end to manage OER resources. In addition, we introduce a "FedX API" - including a packet encapsulation and a data transmission module - that organizes educational resources between both systems. We also proposed the CC declaring function to help participants on-the-fly declare their content license; therefore, any resources must be granted as an open licensing. Another important function is a Central Authorized System (CAS) which is applied to develop single signing-on to facilitate the OER-MOOC connection. Since the framework is designed to support the massive demand, the concurrent access capability is also evaluated to measure the performance of the proposed framework. The results show that the proposed framework can provide up to 750 concurrencies without any defects. The FedX API does not produce bottleneck trouble on the interoperability framework in any cases. In addition, resources can be exchanged among the third-party OER repositories by an OAI-PMH harvesting tool.

key words: Massive Open Online Courses, Open Educational Resources, FedX, e-Learning, sustainable sharing resources

# 1. Introduction

In the educational context, the learning environment has changed from traditional classroom-based to Internet-based learning. Distance education for Virtual Learning Environment (VLE) is increasingly requested to support this change. The knowledge society becomes a key approach to enlarge digital educational resources. This requires a new thinking about what constitutes effective and engaging education.

Manuscript revised March 30, 2016.

Manuscript publicized May 19, 2016.

<sup>†</sup>The authors are with National Electronics and Computer Technology Center (NECTEC), National Science and Technology Development Agency (NSTDA), Thailand. Therefore, the massive e-Learning system and life-long educational resources are issues that have been discussed for quite long time to encourage the VLE's activity [1]–[3]. In this paper, 'courses' and 'resources' are defined differently. Courses refer to educational programs for self-learning via the Internet instead of the traditional classroom such as lectures, training models, studios, or workshops. Resources, on the other hand, refer to any assets that are used in the education course such as images, videos, audios, and many more.

Massive Open Online Courses (MOOC) have had a major impact on higher education, where learners can learn at their own pace and remotely via the Internet [4]–[6]. One of the key successes of MOOC includes its ability to allow interactive learning using various current user-interaction technologies and social networking. The interactive learning as well as the capability to support massive accesses from a huge number of learners with connectivism is considered technically challenging [7]–[9]. Regarding the educational resources, such as learning objects, the demand to use such resources is continuously increasing. The Open Educational Resources (OER) provides a strategic opportunity to support the demand for knowledge sharing and capacity building. The OER movement is commonly defined in close connection with "openness" as it allows access to use and reuse educational resources [10], [11]. OER provides simple and free resources which support the development of a new education model. The instructor or teaching staff can reduce the cost of course development with the benefit of the OER rights. Recently, a topic of OER and MOOC contribution is a growing interest in creating the open education. There are many research studies which have been proposed and discussed in order to help instructors to construct learning materials and courses, and satisfy learners [12]-[15].

In developing countries such as Thailand, distance learning has been one important approach that allows learner to get access to ordinary courses. Distance Learning TV (DLTV) has been successfully implemented for a number of schools located in remote areas. The system provides course remotely from a central school in Bangkok via the satellite channel [16], [17]. In 2015, National Science and Technology Development Agency (NSTDA), Thailand, initiated a pilot project on Thailand MOOC [18]. The project is

Manuscript received September 28, 2015.

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DOI: 10.1587/transinf.2015EDP7382

collaborated by the Office of Basic Education Commission (OBEC) and governmental educational organizations. Thailand MOOC has an aim to set a new infrastructure for distance learning, providing more flexibility for teachers to arrange their courses suitable for their school schedule. Thailand MOOC is constructed from an open-source edX as it provides features generally used in various MOOC systems. On the other hand, the OER system is constructed based on an open-source Fedora Commons (http://www.fedoracommons.org/). It is aimed to gather media such as documents, images, video clips, etc useful for teachers to create online course resources or courseware.

Due to the importance of resource copyrights, free or open licensing is required to drive the OER production. However, an important requirement from our collaboration is to ensure the resource copyrights; therefore, the OER is needed to include a mechanism for submitting and reviewing resources. The Creative Commons (CC), http://creativecommons.org/, is then used for resource license declaration where every resource will be licensed by its own instructor based on the types of CC license provided. The edX Studio, a course creation tool under edX, has been modified to include an OER plug-in called FedX (Fedora Commons and edX), available for course creators to import media from the OER system. Moreover, users can access either the edX or the OER system using their unique login name, which is managed by a Central Authorized System (CAS). Courses and resources are collected and searchable in different aspects e.g. educational levels, fields, types of media, and authors. Instructors can export their contribution profile from the system for their references.

To achieve the massively accessible ability of MOOC, the Thailand MOOC system has been evaluated for its capacity to support huge numbers of user accesses. The accessibility in terms of task success against the number of concurrent users is measured at each system component. In this research, there are two main requirements which are 1) to provide sustainable resources for sharing in the educational section, and 2) to operate an e-Learning system to support a huge number of participants who can be a teacher, an instructor, a student, and others. Moreover, participants can apply sharing resources to create learning contents via any e-Learning system such as MOOC, LMS, VLE. The experiments of the research are evaluated as a case study in Thailand. The rest of this paper is organized as follows: Sect. 2 reviews related technologies. Section 3 describes the detail of the Thailand MOOC system, including policies, architecture, and functionality. Section 4 shows evaluation results and Sect. 5 concludes our observation.

# 2. Related Technologies

This section describes some important technologies used to construct the proposed system: Massive Open Online Courses (MOOC), Open Educational Resources (OER), and Central Authentication Service (CAS).

# 2.1 Massive Open Online Courses (MOOC)

MOOC, introduced in 2008, is a model for delivering learning contents to learners who want to take online courses. The aim of MOOC is to provide free to access, cutting-edge courses that could reduce the cost of university-level education and potentially enhance the learner opportunity for higher education. MOOC is designed to support a traditional study made available over the Internet with no limits on attendance, and no charge to a large number of people [4], [19]–[21]. There are two important key features of MOOC, namely,

- Open access: anyone can participate in an online course for free. Learners who have limited constraints for traditional learning due to time, location, and tuition fees can learn by themselves.
- Scalable content and system: courses are designed as global resources to support a massive number of participants. A large scale system is required to provide the large scale of courses, and also a reliable capability of connection.

MOOC has quickly gained popularity and expansion. It has shaped the openness of the higher education. The emergence of MOOC style innovations shows a convergence of interests in social, economic and technology developments in a global context. Open education has a lot of potentials, but there are still some challenges including how to change the characteristics of the higher educational environment. These changes are driven by factors such as globalization, worldwide growth, learning trends and behaviors, and educational characteristics [20], [22].

## 2.2 Open Educational Resources (OER)

In 2002 at a UNESCO conference, the concept of OER was proposed such that educational resources should be shared to public with an open license. Resources such as documents, textbooks, lecture notes, assignments, and more can be converted to OER [10], [11]. One of the challenges of OER is the sustainability of resource production aiming to hold resources for lifelong learning. Resources can be applied to share as a part of the global open content movement for teaching, learning and research. Resources are also available under legally recognized open licenses for people to reuse, revise, remix, and redistribute.

The efficient use of OER is an outcome of finding the best fit of resources that matches pedagogy in a particular setting. Each resource, like a unique puzzle piece, is created by different authors. Educators and learners must then identify an appropriate puzzle piece that could meaningfully fit a specific teaching and learning goal [23]–[25]. Another advantage of OER is to reduce the extra workload on the part of the instructor given the fact that there are resource constraints, and that the instructor commonly has a lot of

workload, which in turn leads to the problem of having limited time to search and acquire those resources [26].

Additionally, as an increasing number of people are making important decisions based on information found on the Internet, OER helps add increased pressure to ensure the high quality of learning resources, especially those freely distributed.

## 2.3 Central Authentication Service (CAS)

Web-based applications such as mailers, agendas, and others have largely spread over Information and communications technology (ICT). These applications often need authentication and security managements. To organize the authentication processes for saving administrative time and system resources, the concept of Single sign-on (SSO) is introduced by utilizing the central web access management service [27], [28].

CAS is an SSO protocol for the web that permits a user to enter one name and password in order to access independent multiple applications while providing their credentials only once. The CAS definition is close to OpenID Authentication which provides a method to identify user credentials for service providers on the Internet without storing user credentials at the service provider site for security reasons. CAS however differs from OpenID Authen in that it includes proxying features, flexibility, reliability, and its numerous client libraries [29], [30]. The CAS protocol involves three parties, namely,

- A web browser: It is an authentication interface for users. The web browser is used to perform HTTP redirections, an encryption engine using HTTPS, and stored cookies.
- A CAS client: It is the web application requesting authentication. It delivers resources only to clients previously authenticated by the CAS server.
- A CAS server: It is proposed to authenticate users, transmit, and certify the identities of authenticated users to CAS clients.

Lastly, CAS also involves a back-end service that does not have its HTTP interface but communicates through a web application with HTTPS instead.

#### 3. The Proposed System

The research contributions are described in this section by means of the ideological orientation covering an approached policy, a designed architecture, and the system procedure. Moreover, we discuss the implementation of the system with the emphasis on the inter-operability of educational resources. The discussion includes the system architecture, proposed functionalities, resources interoperability, open licensing declaration, and membership management. The details are explained in the following Sub-Sections.



**Fig.1** The overall ecosystem to support the approached policy for providing a sustainable e-Learning platform.



**Fig.2** The submission process of the proposed approach to archive a new resource to the repository for sustainable education contents.

## 3.1 Policy Issue for Education and the Nation

The goal of the proposed system is to invent a core ecosystem and an infrastructure for sharing resources among educational resources repositories and a large scale e-Learning system. A policy of the pilot project, Thailand MOOC, aims at the 'OPEN' concept for providing educational resources. Any resources in the shared archive must be declared as an open licensing by using the CC license as shown in Fig. 1. Resources can be applied, shared and reused in any education sections that will help enlarge the educational contents. Anyone, including participants from the local and third-party systems, can access and use resources in the open repository through the granted CC license, i.e. teachers can create their learning resources by using resources from the sharing repository with a legal right.

Given the proposed policy, a content submission process is defined. Figure 2 shows the process for registering resources to the repository. An open license declaration module is an important issue in the propose to protect and archive resources in the repository with right license declaration. An author, a teacher or an instructor who requires the storage of a new educational resource to the repository must declare CC license. After that, a granted reviewer will check the submitted resource, and make a decision to 'approve' or 'reject' it. The approved resource is then stored in the repository system. On the other hand, the rejected re-



Fig. 3 The system architecture of the interoperability approach.

source is returned to the owner for editing. The editor has a chance to re-submit the resource after editing.

# 3.2 System Design and Architecture

To achieve the goal and the policy of the proposed system, a concept of inter-changeable Application Programming Interface (API) between the OER repository and a MOOC system is originated. The proposed API is used to simply transfer data between two systems. Not only data transmission but also members verification is needed for keeping the 'ease of use' concept as a seamless system with a single signed-on operation. According to the requirements of the project, we decide to apply open source software to build the proposed system. There are two main parts, namely, Fedora Commons project utilized for the OER repository part [31], and Open edX used to provide the MOOC part [32]. Figure 3 shows the proposed design and architecture of the system.

Fedora Commons is a robust, modular, open-source repository system for managing and disseminating digital contents. It is especially suited for digital libraries and archives, both for access and preservation purposes. It is also used to provide specialized access to very large and complex digital collections. Fedora Commons is developed as a web service using the Java language. It provides API called "*RESTful HTTP API*". With the API, we can manage resources via actions such as GET, POST, PUT and more in the HTTP web service protocol. Due to the lack of front-end interface and our required functions of Fedora Commons, we construct a new UX/UI front-end for operating OER resources including contents, members, roles, and the CC license.

On the other hand, Open edX system uses a different technology and development environment. Open edX is implemented in the Python language as web-based accessing by a large scale concurrent connection. It consists of two primary functions that are an e-Learning system (Open edX Learning Management System, LMS) for students and learners, and an authoring tool (Open edX Studio) for instructors and teachers to create learning courses. Both functions share learning resources via *XBlock* component [33]. XBlock is a component architecture that enables course authors to create independent course components. The course components can work effectively with other components in the construction and presentation of an online course. The merit of XBlock is that it is able to combine a variety of resources to create rich and engaging online courses. Open edX provides an XBlock Software Development Kit (SDK), which aims to enable the global software development community to participate by using the Open edX educational platform.

Moreover, third-party participants are also considered e.g. OER systems, e-Learning systems, LMSs, VLEs, etc. In the global usage, an OER repository can exchange resources among third-party OER repositories by harvesting tools based mostly on the Open Archives Initiative Protocol for Metadata Harvesting (OAI-PMH) standard.

# 3.3 Proposed Functionalities

## 3.3.1 Resources Interoperability

As explained in the Sect. 3.2, MOOC functions for a massive e-Learning system, while OER aims for shared resource archives. To integrate the OER with MOOC, we invent a new API called "*FedX API*", which stands for Fedora Commons plus Open edX, for exchanging resources among the two systems.

According to Fig. 3, the FedX API utilizes Fedora Commons's RESTful HTTP API and Open edX's XBlock SDK to create a common channel for exchanging learning resources. It is aimed as a data gateway for MOOC to access resources in the OER repository. We apply the fifteen



**Fig. 4** The packet encapsulation of the FedX API uses for tranmitting data between MOOC and OER systems.

Dublin Core (DC) elements to declare the metadata of each resource. Using the DC elements is beneficial for OAI-PMH based data harvesting across OER systems [34]. The FedX API structure is presented in Fig. 4. There are five sections in the packet structure as follows:

- REST CMD: it is used to define operation commands of RESTful HTTP API for taking actions in the Fedora Commons, i.g. GET, POST, PUT, etc.
- RDF Markup: it is a markup on content negotiation to deliver context-appropriate responses.
- Dublin Core Metadata: it is utilized for details of resources by adapting the fifteen of DC elements, i.e. title, description, date, right, etc.
- Data: it is an original content description and raw data, i.e. original file name, file size, etc.
- Checksum: it is a datum for detecting errors which may have been introduced during its transmission or storage.

Furthermore, the communicated transmission diagram is described in Fig. 5. The procedure begins with a sender sends a request command of RESTful HTTP API to a receiver. After receiving the command, a receiver responds by sending back an acknowledgement packet (ACK) to the sender. Then, the sender transmits all required data to the receiver including RDF Markup, resource metadata in term of DC elements, raw information data and body, and a confirmed checksum. The receiver subsequently returns ACK when finishing the resource transmission. Finally, the checksum datum is sent to the receiver to protect errors that may occur in transmission. After receiving all the pending data, a finished packet (FIN) from the receiver is responded to the sender and the connection is terminated.

Additionally, we apply sub-elements for extending extra information since the DC schema on the standard OAI-PMH harvester is limited at fifteen elements. It is not enough schema for transferring additional attributes needed.



**Fig.5** The transmission datagram of the FedX API between OER and MOOC systems.

For examples; 'dc.creator' can be extended for extra attributes to 'dc.creator.organization', 'dc.creator.contact', 'dc.creator.address', etc.

Figure 6 captures a user interface which utilizes the FedX API to the HTML editor, Tinymce Javascript platform in the Open edX Studio.

## 3.3.2 Open Licensing Declaration

In the design, the MOOC part is assigned for front-end of e-Learning functionality, and the OER part is served as the back-end system for administrating resources. Any participants can access learning courses and resources through the Open edX interface, i.e. students learn courses via edX LMS, or teachers create courses with the Open edX author-



Fig. 6 Using FedX API integrated with Tinymce Javascript HTML editor.



**Fig.7** The CC declaring function utilizes as real-time declaration to enable a CC license.

ing tool, and so on. The CC license declaration module is required in the framework due to the license policy mentioned earlier. As a result of this, resources used in creating courses can be declared via the OER license declaration module. Instructors, teachers, or authors who create a new content can choose the resources in the OER that can identify a license via the authoring tool.

According to Fig. 3, a CC integration module is implemented as part of the OER system. We use a CC Web Services interface that allows users to select CC types onthe-fly as shown in Fig. 7. There are six types of CC license: 1) BY CC (Attribution), 2) CC BY-SA (Attribution-ShareAlike), 3) CC BY-ND (Attribution-NoDerivs), 4) CC BY-NC (Attribution-NonCommercial), 5) CC BY-NC-SA (Attribution-NonCommercial-ShareAlike), and 6) CC BY-NC-ND (Attribution-NonCommercial-NoDerivs).

There are two ways for submitting a new resource to the OER repository. The first way is to submit a resource by an instructor via a Content Management System (CMS) in the Open edX through FedX interoperation, and another way is to submit at the OER front-end directly. Both ways manipulate the license with the CC Integration module in the OER section. This means that any archived resource – fed via Open edX or directly input to OER front-end – must be clearly identified to one of the six license types. Figure 8



**Fig.8** An user interface of the CC declaring function that on-the-fly enabled a type of CC license – in Thai language.



Fig. 9 The membership management diagram.

shows an example of the user interface of the CC integration function in the OER front-end.

## 3.3.3 Membership Management

In the designed architecture, membership management is another important function. Not only resources, but also the membership authentication information has to be shared among systems. An open authentication allows a web-site to either access or provide data to and from other websites securely. It is designed to be flexible and extensible, to allow any organizations to manage their members with resource access capability. This idea also benefits member management among our OER and MOOC systems.

Figure 9 shows the systematic diagram to manage membership in our proposed system. We use the CAS, which is a single sign-on protocol for the web, for the membership authentication and authorization. Its purpose is to permit a user to access multiple applications while providing their credentials. We prepare the CAS server for providing member authentication, and apply both MOOC and OER systems as CAS clients to validate the authenticity of members. Participants can access both systems in a single sign-on action. They can first login to any systems supported by CAS in order to validate the membership. After getting permission, they can access through to systems with the certified validation. In addition to all the functions described above, the career portfolio of the participants who are teachers and instructors can be reported by the system. An e-Portfolio module is used to represent the membership profile in terms of courses and resources contributions. This module summarizes the recorded information of the participants such as instructed resources, reviewing abilities, course administration, skills and interests, statistics of creators' resources accession, etc. An e-Portfolio data is automatically updated when changes are made to any contributions in courses and educational resources.

#### 4. Experimental Evaluation and Results

Based on the system design and framework, we need to evaluate its performance from the user point of view. Interesting measures include the performance of MOOC, the capability of the repository, the efficiency of resources interoperability, and the usability of the CC declaring function.

We prepared a research environment by using virtual machines, VMs, on the cloud hosting service and installed the contributed system onto those VMs to evaluate the system performance. We used two VMs to serve the proposed framework. The first VM installed the repository system, OER front-end, and a membership database with CAS. The other VM installed the Open edX MOOC platform. Each VM is driven by Linux operating system with Intel(R) Xeon(R) @2.65 GHz 4 cores and 4 GB of memory. Both VMs are located on the same network segment.

Additionally, we target the minimum number of concurrent accesses to 500 per service. We then test our systems with the number of concurrent accesses varied by 250, 500 and 750. There are two measurement factors - "Response time" and "Number of hits" - we are interested in for the evaluation. The response time is the amount of time a system or functional unit takes to react to a given request on the client side. The number of hits is an actual accession rate per second for a request, on the server side. Moreover, the system load is also used to monitor the load test functional behavior and measure performance. We used an Apache JMeter application, designed for the testing load of the functional behaviour and to measure performance [35], [36]. A JMeter is executed on a client located in a different network segment in order to mimic the actual usage. Two trial courses which were authored by collaborative organizations are used in the evaluation. The sizes of course resources vary with the learning resources including texts, images, documents, and videos. Its size starts from 100 KB until 50 MB. An error rate which is used here to refer to the request timeout is one of the measurement values we use to interpret the evaluation results.

The analytical results of the experiment are summarized in the next Sub-Sections.

# 4.1 Resources Repository Evaluation

Since the main advantage of the resources repository is to



Fig. 10 The average response time over server time and average number of server hits on the resources repository part.

 Table 1
 Resources information on the server part of the resources repository service.

250	500	750
230	300	730
0.0	0.0	0.6
≈30	≈40	≈55
≈15	≈30	≈50
	250 0.0 ≈30 ≈15	$\begin{array}{c cccc} 250 & 500 \\ \hline 0.0 & 0.0 \\ \approx 30 & \approx 40 \\ \approx 15 & \approx 30 \end{array}$

archive any educational resources and share them as a part of global open contents, the Fedora Commons is internally applied as a back-end collaborating with the OER front-end. General functions of the system are GET, POST and PUT operations. We assessed the performance according to the three sets of concurrency in two scenarios. The first scenario is downloading resources from the repository (GET operation), and the second is uploading resources to the repository (PUT and POST operations).

In the test, we evaluated only the OER system without collaborating with its other services. Figure 10 and Table 1 display the analytic results of the resources repository. The result shows that the response time over server time on high concurrent accesses is higher than that with less concurrent requests. Server workload also varied on a number of concurrent connections. Based on these results, the system can serve the connected concurrence up to 500 concurrences without error. Error rates will occur as a result of connection timeout when the number of concurrence close to 750 connections. As the results, we conclude that 750 concurrent accessions can be operated by the repository if a small amount of errors is permitted.

## 4.2 MOOC Performance Evaluation

MOOC system is the main system which connects participants in several roles. There are two main operations on the LMS for learners and the CMS studio for instructors. In the evaluation procedure, we design five testing scenarios including:

- Users register to LMS as learner and student roles,
- Users login to LMS as a student and take a course for learning,
- Users register to Studio as teacher, instructor and staff roles,



Fig. 11 The average response time over server time and average number of server hits on MOOC part.

 Table 2
 Resources information on the server part of the MOOC service.

Number of concurrence	250	500	750
Error rate (%)	0.0	0.0	1.1
Memory consumption (%)	≈45	≈55	≈70
Average load (%)	≈10	≈15	≈25

- Users login to Studio as the teacher and create a new course, and
- Instructor or teacher checks course activities.

The scenarios are simulated with an actual variety of participants – including students, learners, and teachers – who use the MOOC system. We used the statistics of the existing system usage from collaborators to determine the portion of evaluated scenarios. For each set of concurrent access numbers, we allocate 30%, 60%, 4%, 4% and 2% respectively for the five scenarios. We considered the response time on the client side and system efficiency on the server side. The results of the experiments are shown in Fig. 11 and Table 2.

The results suggest that the MOOC system can support a high number of concurrent requests, nearly 750 concurrences without any defects. This system can support more requests with a few of connection errors.

## 4.3 Resources Interoperability Evaluation

The FedX API is a key invention in our infrastructure for inter-changing resources between OER and MOOC. The efficiency of FedX is an important factor to express the overall performance of the approach. A bottleneck issue is inspected. An evaluation method focuses on the transmission efficiency of FedX API with the same scenarios as those used in evaluating the MOOC system. The result is expressed in Fig. 10 and Table 3.

The result shows that the proposed framework can reduce the response time factor in all concurrent cases while the number of hit of any cases is increased, compared with the individual MOOC evaluation. We then investigate and analyze the evaluated outcomes. We notice that a data communication within the MOOC system requires more system performance than an interoperability framework since a response action of the OER system is somewhat faster than the



**Fig. 12** The average response time over server time and average number of server hits on the overall with FedX interoperation.

 Table 3
 Resources information on the server part of the Overall service.

Number of concurrence	250	500	750
Error rate (%)	0.0	0.0	1.38
Memory consumption (%)	≈55	≈60	≈70
Average load (%)	≈15	≈25	≈30

MOOC system. As a result, the combination of MOOC and OER systems is not a burden cause affecting the efficiency of the proposed solution. The result confirms that the proposed framework can provide a high number of concurrent requests up to 750 concurrences with a bit of request timeout. The response time on the client side is acceptable for participants who interact with the system.

## 4.4 Analysis of Overall Functionalities

There are many functions developed to support the system functionality. System tuning is required to gain the best benchmark of operations. Several techniques are applied to complete the tuning requirements. Some details are described in the following.

Regarding the licensing integration process, we first used a web services interface of CC to enable on-the-fly license selection in online services. The function gave us the right operation. However, an execution time of the license selection depends on the Internet performance in that period. We solved the problem by using LicenseChooser.js which provides a lightweight method for integrating license selection into web applications.

Another crucial point is an overall reliability and scalability of the system. We need to tune several factors such as the performance networking (TCP & UDP), the web server optimization, and the operating system configuration. As for the network factor, the default setting of networking is generally prepared for basic usage. We modified the system to support high-bandwidth application, multiple users, and multiple connections. Regarding timeout, there are many timeout values of applications, e.g., timeout of the web server, timeout of the database, etc. We adjusted them to keep a stable connection to the client. Finally, an operating system optimization is also configured. Kernel parameters are involved for the running of CPU and memory with the best efficiency.

On further analyzing the evaluation results, a concurrent access action means one click of a client on the user point of view. However, a lot of actual transmissions are generated during the one-click process. We have monitored those transmissions and found that the average number of transmissions is approximately 200 responses per click. This means a huge transmission possible to attack the server performance while the number of concurrent accessions is increasing.

# 5. Conclusion

This research proposed an interoperability framework of OER and MOOC for life-long e-Learning platform with a case study in Thailand. There are two main requirements – providing sustainable resources for sharing educational resources, and operating the proposed framework to support a large number of participants. We discuss the implementation of the system with the emphasis on the inter-operability of educational resources. An approached policy, a designed architecture, and a system implementation to engage the research goal are explained in the paper. The system procedure by means of the ideological orientation is also described.

Regarding the design of the system architecture, the front-end UX/UI of OER is newly implemented to manage resources, and the Fedora Commons repository is applied to archive resources for OER back-end. An OER front-end combines an open licensing integrator to assist the participants in choosing a CC license type corresponding to the system policy. On the other hand, we deploy an Open edX platform for serving the MOOC section. A *"FedX API"* is introduced to make an interoperability system between MOOC and OER. A packet encapsulation and a data transmission diagram of FedX API have been extensively described. Additionally, a CAS technique is applied for unique login information. An e-Portfolio function is implemented to summarize and report the participants who contribute to the learning courses.

The framework is evaluated to support a massive demand. The concurrent usage is an important key to measure the performance of the proposed approach. The measurement reports confirm that the proposed framework can generally support up to 500 concurrent usages without any defects and up to 750 concurrent usages with a few errors by request timeout. The newly introduced FedX API does not produce a bottleneck trouble on the interoperability framework in any cases. Moreover, third-party OER systems are also considered to be interchangeable via any OAI-PMH harvesting tools. This means third-party learning systems can retrieve resources in the provided OER repository to help them build their contents as well.

There are some other important issues we plan to enhance the framework such as detecting plagiarism for contents and resources, declaring a learning course license, supporting existing SCORM standards, among other things.

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