Teamwork as a service: design of a cloud-based system for enhancing teamwork performance in mobile learning

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School of Information Systems and Technology

Teamwork as a Service: Design of a Cloud-Based System for Enhancing Teamwork Performance in Mobile Learning

Geng Sun

"This thesis is presented as part of the requirements for the award of the Degree of Master of Information Systems and Technology by Research of the University of Wollongong"

March 2013
DECLARATION

I, Geng Sun, declare that this thesis, submitted in fulfilment of the requirements of the award of Master of Information Systems and Technology by Research, in School of Information Systems and Technology, University of Wollongong, is wholly my own work unless otherwise referenced or acknowledged. The document has not been submitted for qualification at any other academic institution.

Geng Sun
28/03/2013
ABSTRACT

Since the technology of cloud computing has been widely adopted in many areas, it brings new ideas for promoting mobile learning. Practitioners and researchers are interested in drawing the aid of cloud computing to change the current hosting methods of learning management systems (LMSs) in order to provide more conveniences to education providers, better learning experiences to learners and lower costs to both of them. Hence, a new trend emerges, namely the mobile cloud-based learning.

Although cloud computing helps learners to access online learning contents through commonly used devices, it can be difficult to collaborate in mobile environment, for which there are comparatively less literature showing how to offer mechanisms to enhance teamwork performance. This thesis introduces a novel approach to fill those gaps in research.

Because applications over the cloud are service-oriented, they can interact flexibly and be easily composed to execute sequentially or in parallel to form a workflow. Based on this, we have identified a learning flow, a specification of workflow, embedding the Kolb team learning experience (KTLE). The learning flow is realized by the conjunction of the cloud-hosting LMSs and our newly designed service-oriented cloud-based system, Teamwork as a Service (TaaS). TaaS works as a third-party system to add teamwork-focused functions to current cloud-hosting LMSs, in which five web services are involved. In particular, the Survey Service aims to investigate and evaluate learners’ capabilities, especially in the aspects of Kolb’s learning style (KLS); the Jigsaw Service organizes a three-stage jigsaw classroom
over the cloud; the Bulletin Service offers a collaborative editing environment for learners to clarify their task schedules as well as evaluate the difficulties of published tasks in KLS and their preferences; the Inference Service conducts the teamwork-enhanced task allocation; the Monitor Service enables the mutual supervision during the in-progress team learning.

To coordinate most learners’ talents and give the more motivation, as the core of TaaS, the Inference Service groups learners into appropriate teams and allocates them to suitable tasks. Utilizing the KLS to refine learners’ capabilities, and combining their preferences and tasks’ difficulties, we formally describe this problem as a constraint optimization model. Two heuristic algorithms, namely genetic algorithm (GA) and simulated annealing (SA), are employed to tackle the teamwork-enhanced task allocation, and their performances are compared respectively. Having faster running speed, the SA is recommended to be adopted in the real implementation of TaaS.

We develop TaaS using PHP+Apache+Mysql, and introduce how to use it, by showing its typical user interfaces. To implement our designed learning flow, a well-known LMS, Moodle, is chosen to play as the role of cloud-hosting LMS. TaaS and Moodle are finally deployed over the Amazon Elastic Cloud Computing (EC2) infrastructure for working altogether to offer the integrated functions which not only facilitate the learning experience in mobile environment, but also enhance learners’ teamwork performance.
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PUBLICATIONS


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1 INTRODUCTION

1.1 Background

With the rapid growth of technology, the patterns of learning become diverse, which are no longer solely defined in the classroom and with paper-printed textbooks. In other words, the learning activities can take place in distance by multiple types of equipment. The distance learning is usually to expand its impact with the assistance of electronic means, simplifying the method of information delivery and deriving new fields of teaching approach. Many learning resources are released online, often in the digital form including text, image, audio, video, and so on. Therefore, learners can widely utilize the way of electronic learning (e-learning) to participate in learning activities and access learning content on schedule, where they are self-paced and able to make their own decisions to slow down or speed up their learning rate of progress as needed. Nevertheless, the utilization of e-learning is not to replace the traditional class-based learning but improve it by accommodating multiple learning styles using a variety of teaching methods and delivery mechanisms geared to different learners, so as to offer them the 24hour/7day learning experiences, eliminating the geographical barriers in some extent.

Many learning management systems (LMSs) have integrated those learning resources as well as useful functions together in order to provide ample learning experience in one-stop, which are mostly web-based. The utilization of LMSs is often associated with the delivery of online courses or augment of on-campus
courses, hosted by education providers (e.g. universities, colleges, secondary schools).

The learning opportunities are also able to be gained through the use of mobile devices especially when wireless network are well achievable, hence mobile learning (m-learning) becomes a novel trend of electronic learning (e-learning) from which learners are given more freedoms to do learning activities wherever they are and whenever they want. In those kinds of learning scenes, they are no longer required to sit in front of a computer or desktop, but can carry portable devices to facilitate learning in the mobile environment, no matter that they are at outdoor or on the trip. A phenomenon of m-learning is that the fragmentary pieces of time can be made good use.

M-learning is believed having the ability to enrich the learning profile and cover the gap among learner distributed in different countries. However, the specificities of mobile environment bring new challenges to the development and popularization of m-learning, in which the mobile devices’ limited storage and comparatively lower speed of processors are main issues restricting to enjoy learning experience as easy as through settled electronic devices. The applications running on mobile devices are not proven as reliable enough to handle the occurrence of expected errors.

On the other hand, the concept of cloud computing emerges to be highly recommended as the next generation for offering information composition and computing solution. It delivers services in a three-tier architecture, where consumers are allowed to customize software (e.g. applications and programs), platform (e.g.
middleware and operation systems) and infrastructure (e.g. severs, storages and network) by renting instead of purchasing licences of those, as well as provides its advantages in massive data handling, large storage and on-demand utilizing, holding all the computing process in large distributed systems containing millions of computers. For this reason, the local user terminal will be simplified as the device for input and output. The mobile devices are exactly competent to run the browser or client program to access computing capabilities and resources from the cloud, leading the integration of cloud computing into the mobile environment, from where the mobile cloud computing (MCC) comes as an extension of cloud computing.

Cloud computing changes the hosting methods of traditional system, certainly the LMSs are benefited to be deployed quickly and in large-scare, either by migrating current LMSs to cloud or directly developing them over cloud. Hosting LMSs over cloud, the duties of education providers are relieved by no more requirements for training technicians to take over the daily operation and accident recovery of LMSs, while the cloud service providers take full responsibilities to maintain those running in the normal conditions. The definition of m-learning has also been evolved by embracing it to MCC, where learners are free to use these cloud-hosting LMSs through mobile devices. This is a new learning style, namely mobile cloud-based learning (Rao 2010), which fosters learners to obtain the full advantages of cloud computing. In especial, it promotes the limitations in terms of high cost of devices and network, low network transmission rate and finite educational resources.
Literature shows that the communication quality has been enhanced by using mobile cloud-based learning. Numbers of online tools are mobile-accessible prepared in the cloud for accelerating interaction among persons. Furthermore, the cloud-hosting LMSs offer a vast of functions for building virtual environment for learning associated with others based on communication. Consequently, practitioners believe that mobile cloud-based learning benefits learners in many aspects of collaborative interactions, rather than just using their mobile devices only for input and output. The collaborative learning happens more and more frequently leveraged by the mobile cloud-based learning.

1.2 Statement of Research Objectives

Collaborative learning covers a range of approaches by which learners achieve academic purposes together. Compared with individual learning, collaborative learning has the benefits containing enhancing critical thinking in learners (Gokhale 1995), encouraging learners to take ownership of their own learning (Johnson and Johnson 1986) and retaining information longer (Totten, Sills et al. 1991).

In the mobile cloud-based environment, collaborative learning relies on that learners interact and cooperate via wireless network and over communication platforms, while the data storage and information sharing are totally taken care by the cloud. Learners are clustered due to different learning demands. Basically, there are two kinds of learner cohort in the mobile cloud-based collaborative learning, namely the virtual learning communities and the virtual teams.
The virtual learning communities are generally self-organized based on learners’ interests and similarities, with a comparatively inattentive personnel structure, where the join or quit of learners is free. Herein, the communication, especially effective discussion, is significant for learners to assimilate others’ idea in order to arrange their own learning schedules and consult related resources. Commonly, the virtual learning communities can be established according to the wide acceptance of any emergence of meaningful topic. In the mobile cloud environment, learners in one community may from different areas, even registering in different kinds of LMS.

To the contrary, the virtual teams are oriented to task-related outcomes, working altogether towards solving common problems with time constraints, often in the form of deadline. The formations of virtual teams are usually relevant to the syllabus of online courses, where their final outcomes should be assessed using criteria. Moreover, some companies are also interested in drawing the aid of mobile cloud-based learning to organize virtual teams for training employees, who are also assigned into collaborations towards work achievements, such as pair-programming in information system development, in the same way.

As the physical conditions are well-enabled for learners to enjoy collaborative learning, the learners still lack guidance to introduce them into effective direction of learning path, as well as the series of learning activity are not structured cohesively and coherently. The negative issues in traditional team learning are continuous to affect mobile cloud-based team learning. The literature shows that learners belonging to the same team often have differing learning styles and therefore require diverse
learning approaches. Each learner’s expectations and preferences also influence their motivation to work to the limit of their abilities. Current assessment criteria also lack mechanisms to track the entire learning experience, and are generally based on learners’ final outcomes. This means that problems can be hard to diagnose and solve in a timely manner, while the team learning is actually in progress. In addition, the context of mobile cloud-based learning is more specific than traditional learning, where once a teamwork assignment is given in a m-learning course, because of geographical separation and even time differences, learners are faced with many unpredictable difficulties for which they are not prepared and perhaps the biggest of these is insufficient communication.

How to build virtual teams and lead them succeed concern a lot of issues. In a study of problem-solving teams, social interaction is addressed as the key variable (Chatti 2011). In order for effective collaboration to occur, given that learners are strangers with little or no previous collaboration experience and with different cultures and personal experiences, it is essential to provide a shared social context for learners to socialize, learn, and construct knowledge (Gao, Baylor et al. 2005). To achieve coordinated collaboration, learners should be aware of three kinds of awareness: social awareness (who is around?), action awareness (what’s going on?), and activity awareness (how are things going?). A reference by Wang (2009) points out some activities is required when implementing applications to support mobile collaborative learning, which are grouping members, monitoring each member, displaying member status, synchronizing multiple discussion and discussion, and delivering messages.
Concluding those, promoting learning efficiency is gradually attached significance in the research of mobile collaborative learning. However, to our knowledge, there are still comparatively few studies dedicating to enhance teamwork performance in such novel environment, the mobile cloud-based learning, along with importing the huge power of cloud computing to maximise the value of m-learning. Hence, as the main objective of this thesis, we attempt to fill those gaps in current researches. Especially, we focus more on improving the work of virtual teams allocated to concentrated tasks in an online course. As a supplement, certainly, the task-related virtual teams in the work fields, such as teams of employees, can also borrow our research results to establish mobile training frameworks.

1.3 Contribution of the Thesis

The main outcome of the research is the design and implementation of a service-oriented system, Teamwork as a Service (TaaS), running over the cloud. The particular contributions are summarized as follows:

We have completed a comprehensive literature review by summarizing development tendencies and arguing current issues in e-learning and m-learning, especially for teamwork performance of those.

We have orchestrated a novel learning flow following the Kolb’s team learning experience (KTLE), in which the educational theories of jigsaw classroom method and Kolb’s learning styles are involved. The learning flow is recommended to be
executed in the cloud environment and accessed by mobile devices, by the associating work of web services.

To execute the novel learning flow, we have designed the framework of a service-oriented system which has five web services to work in conjunction with cloud-hosting LMSs by adding functions to them in order to enhance learners’ teamwork performance.

To realize the rational task allocation in the teamwork performance enhancement, the team learning scene has been abstracted into a math model, where the optimization purposes are defined in objective functions. Two heuristic algorithms, namely genetic algorithm (GA) and simulated annealing algorithm (SA) have been utilized to solve the problem, while their performance are also being evaluated to suggest which one is better to be adopted in the real system development.

The prototype of our designed system has been implemented by leveraging a well-known open-source LMS, Moodle, over a cloud computing infrastructure. It is proved to be able to work in the mobile cloud-based environment, and feasible to interact with cloud-hosting LMSs, typically Moodle in this thesis, through well-defined web service application programming interfaces (APIs).

1.4 Outline of the Thesis

The Chapter 2 reviews related literature to explore the benefit of embracing m-learning to MCC. Issues that negatively affect teamwork performance are concluded from two aspects, which are the similar as those in traditional learning and caused by
the specificities of the mobile environment, respectively. Some classic educational theories that will be utilized in our research are also introduced.

In Chapter 3, we compare some popular LMSs to list their functions for supporting collaborative learning, and analyses the requirement of how to strengthen them with the help of MCC. We design a service-oriented system to achieve that goal, wherein the functions five involved web services are separately introduced.

In Chapter 4, the work pattern of each service is introduced in detail. The universal modelling language (UML) is used to explain their operation processes and interaction rules. The principle of data calculating and recording is also presented.

The Chapter 5 discusses the problem of teamwork-enhanced task allocation, where the GA and SA are employed to realize the optimization. We state the math model, problem definition, and the particular computing step of those two algorithms. Results of evaluating their performances are shown subsequently.

The Chapter 6 describes the implementation of TaaS over the cloud, and proves its operation with cloud-hosting Moodle. Some typical screen shots of user interfaces (UIs) are demonstrated to show how to use this system in the view of teacher or learner.

The Chapter 7 concludes this thesis by discussing the advantages of our completed work, and recommends future work needed to extend this research.
2 LITERATURE REVIEW

2.1 Introduction

This chapter will discuss the issues of concern to the research topic. Section 2.2 presents the background of the mobile cloud computing, where three aspects, cloud computing, mobile computing and mobile cloud computing, are involved. Section 2.3 discusses the evolution from distance learning to mobile learning, which has the newest solution that draws the aid of mobile cloud computing to offer better learning experience and teaching approach. The mobile cloud-based learning benefits learners to access learning contents through lower-cost mobile devices, who are allowed to collaborate without the restriction of location and time. Although collaboration is much easier and more frequent supported by mobile cloud-based learning, the teamwork performance still suffers from many issues, carried on as those of traditional learning and caused by specificities of the mobile environment, which are stated in the section 2.4. The section 2.5 reviews educational theories that address the features and enhancement of teamwork, wherein the jigsaw classroom method, the Kolb’s team learning experience and the Kolb’s learning style are introduced to lay a foundation for our research.


2.2 Mobile Cloud computing

2.2.1 Cloud Computing

Cloud computing is the fusion of parallel computing, cluster computing, distributed computing, virtualization, etc. It becomes a new trend of the development of information technology nowadays. National Institute of Standards and Technology (NIST) currently describes cloud computing as “a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g. network, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction” (Mell and Grance 2009). The fundamental principle of cloud computing is that computing is arranged in large distributed systems instead of in local computers or remote servers. Benefitting from the continual improvement of process capabilities of the cloud, the burden of the user terminal is decreased. Ultimately, user terminal will be simplified as an input and output device which can access resources and computing capabilities from the cloud on demand (Vouk 2008).

Generally, cloud computing offers its functions in the shape of services, to the extent that a new viewpoint comes out, which is every IT resource and component can be considered as a service (XaaS). Typically, some researchers indicate that cloud computing has a three-tier up-down nature, differentiated by the types of provided services, wherein each tier is a kind of XaaS, namely Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS) (Rimal, Choi et al. 2009). The features of these can be argued as follows.
**Infrastructure as a Service (IaaS)**

IaaS is the most basic cloud service model that delivers the service of offering directly accessible computer infrastructure to consumers through the internet. The service providers have the duty to host and maintain the infrastructures, which are sometimes as physical, but more usually as virtual machines, or other resources, such as servers, storages, network capacities and load balancers. The consumers can access these services on demand from the resource pools deployed in the data centres, and control the real time operation of equipment, such as stopping running virtual machines or launching new remote servers, just by simple operation from web browsers or clients on their local computers. To utilize the infrastructure, consumers are commonly required to install the operation system images or applications over it.

Some examples of IaaS include Amazon Elastic Cloud Computing (EC2), Microsoft Azure, Eucalyptus, Google Compute Engine and HP cloud.

**Platform as a Service (PaaS)**

PaaS contributes a new model of delivering services which allows consumers to develop and run their applications without the complexity and cost of purchasing and managing the basic hardware and software. These services include not only the operation systems, web servers or databases, but also other services working as technical supporting, even the development and optimization of applications based on those platforms. An obvious evolution brought by PaaS is that many network resources expose web service application programming interfaces (APIs) to developers who consequently obtain programmable elements, including specific
business logics, to construct their characteristic applications. Furthermore, some advanced PaaS services offer visual tools so that consumers can develop and run their own highly scalable and robust web-based systems, such as Office Automation (OA), Consumer Relationship Management (CRM), Supply Chain Management (SCM), Enterprise Resource Planning (ERP), Human Resource Management (HRM), etc, without the ability of programming.

At present, the famous PaaS products include Google App Engine, Force.com, Orangescape and so on.

**Software as a Service (SaaS)**

Actually, the concept of SaaS comes earlier than cloud computing, evolving from the mainframe, the Client/Server (C/S) structure and the Browser/Server (B/S) structure. It is a software distribution model, in which the providers deliver the functions of applications and the associated data through the network, and consumer access those by thin clients or web browsers. Instead of purchasing licences and installing software, consumers usually rent the permissions of applications, by which they are billed depending on their real requirements and using conditions. Meanwhile, the providers take care of all the technical problems and managements, including security, availability, and performance. There are lots of SaaS products readily available for quick access, whether CRM, ERP, OA, SCM, HRM or some other function-specific applications can be accessed directly or by simple configuration.
The marketplace of SaaS is in intense competition, leaded by several IT giants, IBM, Microsoft, Oracle, Google and Apple, and also accelerating booms of several rising IT enterprises, such as Amazon and SalesForce.

2.2.2 Web Service and Service-oriented Architecture

A web service is a software module or application component that has the abilities of self-contained and self-describing, and is distributing over the internet and loosely coupled with each other. On the other hand, web service can be known as a technology that is persistently utilized and plays an important role since the concept of cloud computing has been presented, which concentrates on providing a set of standards to support application interaction and integration without the help of third-party hardware and software. The Simple Object Access Protocol (SOAP), Web Services Description Language (WSDL) and Universal Description Discovery and Integration (UDDI) are three main contributions of web service technology. SOAP describes how to encapsulate and transfer data using XML-based messages, by which the applications developed by different program language and running in different operation systems are able to communicate across firewalls. WSDL is an XML-based language that regularizes the mechanics of web services exposing their functions and specifies a contract that governs the interaction between requestor and provider parties. As a facility of registry, UDDI lists available web services in order to enable their publishing and discovery processes.

The growing of web service technology brings the research and applying of Service Oriented Architecture (SOA) into a new category of software engineering. Broadly,
SOA is a set of principles and methodologies of designing and developing software or applications in the form of interoperable web services. Following this approach, practitioners are encouraged to divide their designed systems into discrete functional components, namely web services, assembled by well-defined interfaces and protocols. The service consumer, the service provider and the service registry are pointed out as the three roles that work together to realize business purposes in a SOA environment, where each web service can be found dynamically, accessed programmatically and composited feasibly.

The research of SOA derives a lot of knowledge areas, such as web service modelling, web service communication protocols, web service relevance, web service composition, reusing of legacy system, business solution lifecycle and so on.

2.2.3 Mobile Computing

Mobile computing is a new technology that crosses multiple fields and rises popular in recent years, with the technology development of communication, network and mobile processors. Mobile computing becomes a new branch of distributed computing. It is the activity of using mobile devices’ computing abilities without pre-defined locations, towards publishing or subscribing information. Frequently-used mobile devices include portable computers, Personal Digital Assistant (PDAs), wearable computers, mobile phones and tablets, and the latter two devices are paid more attentions in recent years because they are commonly offered with touch screens. Accordingly, several mobile operation systems emerge to meet the
increasing requirements of running applications, for example, iOS, Android OS and Windows Mobile.

However, mobile computing is limited by the memory, battery power and processing speed of mobile devices, and that during the process of mobile computing, the conditions of network connection are usually diverse, possibly in high speed, low speed or disconnected. These may result in discontinuousness of the computing process, and security issues are also brought in because mobile devices are preferred targets of attack (Dagon, Martin et al. 2004). Some literature states that traditional mobile computing is inefficient and unreliable.

Mobile computing is closely related to the network connection, but benefitting by the widespread appearances of Wifi, 3G even 4G networks in our daily lives, the fast and stable network are not rare to assure the uploading and downloading of data. Hence, most researches aim to address the enhancements of performance and consumption of mobile computing, to which mobile cloud computing is proven to be a feasible solution.

2.2.4 Mobile Cloud Computing

Defined as an extension of cloud computing, mobile cloud computing (MCC) is the instance that uses the technology of that in mobile environments. Users are able to access resources and services, such as infrastructure, platform, software, over the internet through mobile devices.
MCC inherits the features of cloud computing (Rao 2010). Cloud is treated as a secure and dependable data storage centre, where millions of computers in cloud form a super-power server, providing the ability of massive data processing. The sharing, searching, management, mining and analysis of data can be executed systematically in the cloud. In addition, the scales of computer clusters in the cloud are changeful depending on different computing amounts, and they can work in parallel to achieve rapid response. The data backup mechanisms are mature in the cloud, similarly disaster recovery mechanisms are also ready to deal with the unexpected data loss.

As we mentioned before, applications, usually web services, in the cloud are loosely coupled, as a result of which the architecture of cloud-based system is scalable. In other words, this kind of system can be constructed by the functional collaboration of several applications, or be rebuilt by decoupling them and compositing with other applications. Using the technique of data migration, the problem of reusing legacy systems repetitively is figured out, along with the realization of quick deployment of popular systems.

A significant innovation of cloud computing is that it takes the granularities of services into consideration, distinguished by scale. It causes that various kinds of consumers who have separate requirements are totally satisfied after a one-time large-scale deployment of the same cloud-based system, without modifying and resetting the configuration exhaustively. Moreover, from the huge shared pool in the
cloud, consumers are free to acquire resources and customize services on demand, which reduces the quantity of waste.

MCC holds high Quality of Service (QoS). If there are vast increases of visits to the cloud at the same time, which may result in the congestion and disconnection of network, these kinds of conditions are in good charge of numbers of load balancers.

MCC also expands specific advantages due to its mobility. It dismisses the limitation of hardware for the reason of that the computing procedures are mainly running over the cloud as well as data storage rather than on mobile devices, so that mobile devices are deemed as user terminal equipment for inputting and outputting. The processor speed and memory space are no longer bottlenecks for complex operation.

Deeming mobile devices as sensors, applications or web services in the cloud have the abilities to learn the contexts of given environment situations. A typical outcome is the location-based service, which utilizes the geographic information, detected by embedded GPS of mobile devices, as the analysis data of cloud, and then pushes related references to consumers.

2.3 Mobile Cloud-based Learning

2.3.1 Distance Learning and Electronic Learning

Distance learning exists from ages ago. It enlarges the concept that learning activities have to be physically performed in a definitive place, often a classroom. Hence, in this distance learning, teachers and learners are separated by time and location, as well as learners and their classmates, or learners and their learning teams they
belonging to are distributed in distance. This type of education gives the teachers freedoms to arrange their schedule, and allows learners to work on their learning contents in their preferred time. In terms of these, more education opportunities are offered to learners who are unable to attend in traditional school due to disabilities or sickness (Woods, Maiden et al. 2011), who want to engage in advanced studies besides their full-time works, and who are willing to but far away from their ideal education institution, such as learners from developing countries.

A core component of the distance learning is the delivery of knowledge, which is usually by the aid of some additional methods. Also for covering the gap of distance, some tools and technologies are utilized to accelerate communication. For example, in earliest distance learning, teaching by correspondence through the post is commonly adopted.

Some open universities or open courses often employ the methods of television education or video conference in the twentieth century. Researchers determine this phenomenon as the rudiment of electronic learning (e-learning).

With the rapid development of Internet technologies, e-learning, which is the acquisition and use of knowledge distributed and facilitated primarily by electronic means (Wentling, Waight et al. 2000), is gradually playing an important role in pedagogy. Urdan and Weggen (2000) define e-learning in more detail as “the delivery of content via all electronic media, including the Internet, intranets, extranets, satellite broadcast, audio/video tape, interactive TV, and CDROM.”
Some meaningful comparisons of the features of e-learning are addressed in literature, shown as follows:

- Distance learning is supported by e-learning that teachers and learners are no longer required at the same location, while in-classroom learning experiences are also involved by taking electronic equipment as assistants.
- E-learning can be driven either by self-paced or instructor-led. Many education institutions have made learning resources available to learners, including lecture videotapes, lecture notes, lecture PowerPoint slides, reference books, etc. That is to say, learners can access those by themselves with their freedoms and preferences (Bates and Poole 2003). The beginning and ending of learning activities are in their own hands, and they decide which resources they should subscribe, what aspects they should emphasize and how long each learning stage should take. To the contrary, the roles of teachers also can be set in the e-learning, whose effects are making the guidance about related subjects, pointing out the right learning directions, sharing experiences and answering questions when learners are confused (OCED 2005).
- The activities on e-learning can be either synchronous or asynchronous. On one hand, two or more participants can exchange their ideas or information at the same period, typically supported by chat room, instant message software and video communication equipment. On the other hand, with the mature of the Web 2.0 technology, asynchronous learning activities, which use blogs, Wikis, discussion boards, etc., become frequent in recent years. So, participants are no
longer required to give their responses as soon as they have received information, without the dependency of other participants’ involvement at the same time.

There are many e-learning systems, sometimes also called learning management systems (LMSs), which are software applications for documentation, tracking, reporting, delivery and administration of education courses or training programs. Most LMSs that facilitate access to learning content and expand the usable range are Web-based. General learning contents of LMSs are in the forms of text, image, animation, streaming video and audio.

2.3.2 Mobile Learning

Mobile learning (m-learning) appears as a new trend of e-learning with the evolution of wireless technologies and widespread use of mobile devices (Sharple, Corlett et al. 2002).

The main difference between e-learning and m-learning is that the first takes place in front of a computer or in internet labs, while the second takes place at any location (Sharma and Kitchens 2004). For this reason, learners can utilize m-learning wherever they are and whenever they want. Learning activities happening on campus, at home or outside school facilities can be integrated into mobile education environment (Kim, Mims et al., 2006). In addition, a phenomenon of the use of m-learning is that the learners are using mobile devices and actually in movements while the teachers may use multiple kinds of equipment other than mobile devices and be located in unique places (Vanska 2004).
Koole, Mcquilkin et al. (2010) state that the m-learning promotes the utility of distance learning compared with which it has several additional features that should be considered when preparing how to deliver a quality education experience:

- Accessibility: it is primary for m-learning. The study environment is in movement and all study resources and learners are mobile. The learning activity cannot be broken off if the learning space-time is changed. Learners are not restricted by time and locations (Attewell 2005).

- Personalization: In the m-learning environment, the individual conditions of each learner are extraordinarily hybrid and complex, such as different bandwidths and network conditions at different times. Also, their mobile devices may have various screen sizes and type methods. Personalization is the characteristic that different individual learning needs and learning properties are adapted to different learners (Sharma and Kitchens 2004). It also should focus on delivering the appropriate contents to study in a particular way. Some researchers also address that the m-learning should be context-aware to adapt learners in different conditions (Economides 2008; Negella and Govindarajulu 2008; Zervas, Ardila et al. 2011).

- Convenience: Due to the limited memory and processing capabilities, learners generally use mobile devices to access m-learning resources via thin client or web browser; these portable devices should be realized to enable network connectivity, rapid setup and equipment reusing. The content readability, interface operability and learner satisfaction should be also taken into consideration (Georigiev, Georigiev et al. 2004).
Interactivity: There are three types of interactions in the m-learning: learner to learner, learner to teacher and learner to content (Koole, Mcquilkin et al. 2010). Each of these three interactions should be easily done, regardless the time and location.

Relatively, traditional m-learning more focuses on the content delivery, but lacks abilities to process assessment and feed back to LMSs. However, with the booming of technology, the context of m-learning evolves extremely to be more advanced than it in five years ago. Therein, obvious changes include the widespread use of intelligent equipment and the upgrade of infrastructures.

The intelligent equipment, typically the smart phone and tablet, improves the user experience of m-learning by offering the full-touch-screen and integrated computing capability. Due to their complete functions, they gradually replace the use of PDA, feature (non-smart) phone, portable media player and e-reader. To some extent, the limited screen and type method of traditional mobile device are promoted. Using these, learners gain more freedom to customize and download the learning materials based on individual mobile operation systems. Meanwhile, increasing applications and lightweight applications (apps) in the education area are available as well as the e-book can be read on a broad variety of mobile operation systems.

The problem caused by phone signals is somehow remitted relying on the support of 3G, GPRS and WIFI etc. Web contents of LMS system are available to be shown on screens of mobile devices, on which the online audio and video are also can be played smoothly. In addition, the communication approaches in the m-learning
environment become abundant with the support of upgraded infrastructure. Ting (2005) summarizes there are three types of communication approach in m-learning before 2006, which are voice communication (e.g. phone call), short text message and communication on internet (e.g. online chat and email), and the first two are served by communication-operation corporations (e.g. telephone companies) and charge by phone bills. Since 2006, more online tools and apps are invented for supporting instant communication. The voice communication and short text message are feasible to realize through the internet, additionally, the multimedia message is enabled to be transmitted among learner in this way. Thus the learners are billed by the usage of the network rather than the phone, even for free.

The development of m-learning is neither intended to replace traditional distance learning, nor about to restrain the course into pocket devices, but to enhance it with the value of wireless network, and augment the formal knowledge delivering (Ting 2005). Hence, it is believed that some new trends brought by m-learning will arrive in the near future, which can be concluded as:

- More mobile devices are brought into classrooms as the supplements of traditional learning resources. The formal learning is augmented by this means, according to which a scene of blended learning comes out (Vaughan 2010). For example, m-learning may be used to introduce some chapters of a course while the rest is conducted in real face-to-face education (Mellow 2005).

- More online courses are delivered through the LMSs, giving learners more choices to participate in on demand. They can use mobile devices to browser
learning resources, and accomplish, upload and check assignments, by one-stop service, which is more practical to arrange the education process.

- The e-book gradually replaces the traditional paper-printed textbook, the content of which is easy to update to avoid being outdated (Zawacki-Richter, Brown et al. 2009). Teachers and learners benefit from this convenience.

- More multimedia content is blended in teaching materials, which expresses knowledge in creative and vivid ways. The learning experience changes to non-baldness.

- Learning for multiple times and each time with small quantity becomes common. That is to say, learners are able to utilize more fragmentary pieces of time to learn, whether they are queuing up, on the way or at the time slot of other events.

- Combining social network with m-learning works to link learners, generate discussions and transmit information, in which the information push technology permits learners who are offline or in phone-signal-lacked areas never miss a message.

- Online collaborative learning rises popular which leads numbers of learners to join for working towards common goals.

- A great development that emerges in conjunction with m-learning is the cloud computing. We will discuss this new trend of m-learning in the next section.

2.3.3 Mobile Cloud-based Learning

We expound the disadvantages of traditional m-learning without cloud computing as the following two aspects:
For education providers, administrators and teachers, the deployment and management for LMSs supporting m-learning pose difficult problems to them. Because of a variety of user requirements, the m-learning system is obliged to set by user-defined, while how to choose and configure the extended components of LMSs is also not easy so that teachers and administrators have to get training otherwise they cannot adapt to the changeability of component configuration which is unique to each component.

On the other hand, the traditional LMS is defective in large-scale deployment. In research and utilization of m-learning, deployment from single site to provide overall services is generally centralized in the level of schools. But this traditional deployment cannot meet the requirement of granularities of several levels distinguished by scales. According to coarse-grained, equipment performance and security of m-learning would suffer from constraints and drawbacks root in providing services from region level or even country level. To the contrast, according to fine-grained, school, class and individual teacher require independent utility of m-learning by the aspect of personalization. Furthermore, quick deployment of the LMS is also a problem (Orr 2010). From beginning to normal operation, it takes a long time to complete network configuration, system software configuration and configuration for m-learning. Additionally, some of LMSs, for example, Moodle and Bodington, are open-source software that lack guide documentations and technical support. For this reason, once problem happens to the open-source m-learning system, general teachers and administrators have difficulty in solving the problem without aid from professional technicians. In the last, the cost is always the unavoidable issue caused by the charges of hardware, software, collocation, network renting and
electricity. Professional technicians are engaged in maintaining and for repairing m-learning system. The expenditure for them cannot be ignored. The repetition of m-learning deployment in each school is also a large waste of resources (Cobcroft, Tower et al. 2006).

For learners, although latest processors used in mobile devices are updated to high-speed, even their clock frequency can reach up to 2GHz, the power consumption is still failing the requirements of current m-learning. It can be oppugned about the process efficiency and reaction velocity when using mobile devices to run a complicated m-learning system. The highly centralized operation by mobile processors should also be supported by a high power of the battery, which is not fully settled in current products. The limited heat dissipation of mobile devices may also cause learners unsatisfied. Moreover, in the traditional mode of m-learning, the teachers arrange the learning content and design the learning process according to the syllabuses, whose knowledge hierarchies and the syllabuses are limited in depth and breadth to some extent. A result is how much the learners can gain is closely related to how much the teachers have imparted. Additionally, the formation of learner clusters is basically relevant to the education provider and teacher, who restrict the personnel structure of learners, the learning content, the strategy and path of learning in certain extents, causing the interaction and knowledge sharing are somewhat local and limited.

Nevertheless, all above issues are feasible to be solved along with a new trend, which is embracing mobile learning with MCC. Consequently, with the solutions that either
migrating current LMSs to cloud or directly developing them over the cloud, learners can learn through mobile devices (Sultan 2010). This is a novel way of m-learning, namely mobile cloud-based learning.

Leveraging mobile cloud-based learning, the primary advantage which is seen obviously is the lower cost. The requirement of hardware and software is significantly reduced. In particular, since all of the data storage and processing are taking in the cloud side, the limited processor capacity and memory size of mobile devices are no longer bottlenecks for a pleasant m-learning experience, so as the learners can only use mobile devices, which only have to run a browser and connect to the wireless network, for input and output of data.

Similarly, administers and education providers need neither to own and set-up high-performance servers by themselves, nor to care about the background of LMSs running. The expenditure of purchasing and upgrading hardware is saved. Not only is the quick deployment of LMS well enabled by MCC, but also the cloud service providers have already hosted some popular LMSs, in large-scale and fine-grained. Therefore, the education providers in different levels and with different requirements are able to customize the whole or part of LMSs’ functions on demand, without exhaustively remaking and resetting. It is notable that the authorities to access the cloud-hosting LMSs are by renting charged by the usages, which are much cheaper than purchasing their licences. The reusing of legacy LMSs is feasible due to the applying of data migration technology, which avoids the waste of repetitive deployments for the same kind of LMS in different areas (Gao and Zhai 2010).
Teachers and administers need neither to be trained as technician to maintain the daily running of LMS, nor to keep abreast of the latest m-learning technologies. They can pay their full attentions on how to organize and deliver the teaching content to make learners being interested in and assimilating better (Rao 2010). This is because the professional teams from the cloud service provider take responsibility for all the technical problems.

Because the cloud is a huge pool of information, the learning resources throughout the world are integrated and shared to maximize the value of knowledge. Through easily querying, such as the key term searching, learners are able to discover and obtain the learning resources then freely choose which are needful to learn. Based on learners’ feedbacks and requirements, the update, modification and supplement of learning resources can be proceeded, so as the sole duty of the teachers and administers is to categorise and manage the learning resources and set corresponding access rules.

The mobile cloud-based learning catalyses the appearance of diversified virtual learning communities and virtual teams, which are dismissed the restraint of location, nation, culture background of learners and expanded the influence scopes (Liao and Wang 2011). Therein, learners are free to participate into those kinds of personnel structure of learner cohorts to exchange their ideas, discuss their viewpoints, share their experiences and learn from others’ strengths to find and improve their weaknesses, where more collaborative learning has a favourable environment to be happened among learners who have similar learning purposes. As a consequence,
teamwork is a more and more frequent learning activity and important learning approach in the mobile cloud-based learning (Chua and Tay 2012).

2.4 Issues of Teamwork Performance

Most of the virtual learning communities are self-organized, based on learners’ interests and similarities (Sobrero 2008). So the structure of them is inattentive, wherein no leaders exist to conduct the learning process or synthesize learners’ opinions. Learners are free to select and add the topics of common focuses of communities, decide how much quantity of learning should be taken, develop culture of their own and manage themselves to hold the community together, while they do not have to complete any outcomes to identify their learning achievements. Communities may amalgamate and grow, whose permanence depends on how long the learners stay interested in or their common focuses mainly reach rational answers.

The virtual team in the mobile cloud-based learning matches the features of the distributed team, whose members work towards a common target with time constrains such as deadline (Saunders and Ahuja 2006). To the contrast for the virtual learning community, the virtual team is allocated with specific work-related tasks and focuses on utilizing technology to prepare and output deliverables. The structure of the virtual team is cohesive that the task requirements and recognitions hold the teams together, which are not disbanded until the tasks are completed. After the collaboration, the outcome of a team should be assessed by criteria in order to judge how well the team members have worked together.
Above all, the virtual learning community is oriented to collaboration for gaining knowledge while the virtual team is oriented to teamwork for producing deliverable achievements. Particularly, in the mobile cloud-based learning, the task-related teamwork is mostly associated with the online courses, the pass or fail of which is generally expressed by marks or grades. So we can find that though familiar, the virtual learning community is still not the smallest unit for processing teamwork, yet which should be the virtual team.

The formation and operation of the virtual team are more serious and less random than those of the virtual learning community. However, its teamwork in the mobile cloud-based learning still lacks mechanisms to enhance its performance that make multi-person learning become more effective and efficient. The main issues come from two aspects.

2.4.1 Issues of Teamwork Performance in Traditional Learning

The issues of teamwork performance in traditional learning still exist in the mobile cloud-based learning (Schewabe, Goth et al. 2005; Feldmann 2006; Wu, Liu et al. 2010; Koh and Lim 2012):

- Learner types of members in one group are different. Each learner has dissimilar abilities to acquire new knowledge, and they may utilize diverse methods to learn optimally. For instance, some of them have exceptional skills of visual learning and some of them are good at manual work.
- Expectations of each learner in one team are different. For example, some of them want to promote their capabilities through exercises, while some of them
only want to get higher marks. Especially, the majority of the students want to get their marks as high as possible, but a few students are satisfied with a “pass” grade merely.

- The preferences of each learner may affect their final outcome, which means learners sometimes feel unmotivated while they are facing some bottlenecks in their loath tasks, or striving in their willingness. Learners who are keeners on their respective tasks are more likely to perform better.

- Current criteria used for assessing a student’s performance are based on final results of the whole group. It cannot mark each learner depending on their individual contributions. For example, if there is only one learner in a group caring about the assignment so as he does all the other group members’ work, this phenomenon is deemed as cheating. But in the mobile learning environment, teachers feel difficult to know the real completer of each task.

- The whole team’s achievement may be negatively affected by some under-performing learners. Specifically, in some kinds of collaboration, a learner’s task should take another learner’s work as the premise, while the delay of the latter one may cause the delay of the whole group. For example, if a learner who takes charge of collecting data has not finished his work, another learner with subsequent allocated task cannot start to analyse data, and the harmful delay may be in a chain reaction.

2.4.2 Issues Caused by Specificities of Mobile Cloud-based Learning

The specificities of the mobile environment may cause more issues that make teamwork even harder:
• Without the type of face-to-face communication, the communications in the mobile cloud-based learning are insufficient and not as convenient as that in traditional learning. Time zone diversity within a team is not rare (Pinola 2011). Therefore, the deep discussion is not easy to organize as well as the interaction may be not in time when confusion or misunderstanding happens (Cramton 2001).

• Due to team members’ diversity and asynchronism of online activities, the team leaders helpless in vision, strategy and direction are sometimes ineffective to run the daily process of the team. Whether a team’s task is likely to succeed or fail has premises how the nature of it is and how external factors are. However, the availability of reference and support, difficulty and feasibility of the team’s task lack evaluations in such context (Cramton 2001).

• It is not easy for team members to know about each other, which is usually through resumes and short dialogs, informally and unfocusedly. Team members may be unfamiliar with one another’s strengths and skills (Sharples, Arnedillo-Sanchez et al. 2009).

• It is difficult to decide how to have the right set of dedicated and competent team members, which is a large factor of making or breaking the good achievement of a team’s task. The team members are also uncertain about their common teamwork assignment, including what it is about, how it fits with their roles and expectations, and how it is connected to organizational goals (RW3 2010).

• The trust among team members varies due to several reasons, including lack of facial and body language cues to validate team members, participants’ fears of
isolation from each other, communicating changes in operating procedures, and a higher demand for individual accountability because of delays resulting from lack of preparedness (Ebrahim, Ahmed et al. 2009).

• Currently, for mobile cloud-based learning, there are neither mature methods to assure that the team members’ effort and knowledge are totally translated into performance, nor approaches to help learners maintain motivation and attention to their common task (Kukulska-Hulme, Sharples et al. 2013).

• There are also deficiencies in tracking the entire teamwork experience, where problems can be hard to diagnose and solved in a timely manner, while the team learning is actually in progress.

2.5 Related Educational Theories

In the educational area, there are vast of researches aim to address the features and enhancement of teamwork. Several of them related closely to our research are introduced as follows.

2.5.1 The Jigsaw Classroom Method

The Jigsaw method is one of the commonly used way to promote learners’ performance in collaborative learning with the main concept that “a better way to learn something is to teach it to someone other” (Aronson, Blaney et al. 1978). The basic premise of the jigsaw classroom is the team assignment is divided into sections in order to assign one section to each member in original teams. All original teams are oriented to the same team assignment, in which team members then work
individually on their allocated assignment sections. Two significant points of the jigsaw classroom method are the formation of “expert teams” and the regression to “original teams”. In detail, the learners (one from an original team) who take charge of the same assignment section join together to form an expert team, where learners exchanges ideas about their responsible section and master the concept. After they have developed a strategy, they back to their original teams to teach other team members what conclusion they have reached about their section, and also learn experiences summarized by other expert teams from their team members. Finishing these three stages, the original team is able to refine its understanding of the team assignment and revise its work so as to achieve a better performance. Millis and Cottell (1998) discuss an easier variation, named “within team jigsaw”, dividing the original team into pairs of learners, which replace the expert team. In each pair, the two learners work together and teach each other the knowledge needed to complete assignment as well as take mutual supervision for the progress of work. The jigsaw classroom method is also presented in different stage structure and different team sizes (Clarke 1994; Bratt 2008).

2.5.2 The Kolb’s Learning Style

Kolb points out that the types of behaviour in the team learning can be represented as concrete experience (feeling), reflective observation (watching), abstract conceptualization (thinking) and active experimentation (doing) (Kolb 1984; Kolb 1999; Kolb and Kolb 2005; Kolb and Kolb 2005). He also explains that an individual learner naturally prefers a certain learning style, combining each two of those four types of learning behaviour. Therefore, four learning styles are demonstrated, namely
accommodating, assimilating, converging and diverging. Briefly, the “accommodating” is learning from hands-on practice and intuition rather than logic analysis; the “assimilating” refers to discovering and understanding a wide range of information and then categorizing and conforming them into concise and logical forms; the “converging” is to solve problems into practical uses and find solution using learning experiences; and the “diverging” is more relevant to observation at concrete situations from many different viewpoints. Belbin (1993) and Loo (2004) mapped these four learning styles to four roles (accommodator, assimilator, converger, and diverger) which are equally important and generally existing in an experienced team (Belbin 1993; Loo 2004). The features of Kolb’s learning style (KLS) are shown as Figure 2.1.

Figure 2.1 The Kolb’s Learning Style (citing from Kolb’s work, 2005)
Some researchers have applied teaching approaches involving identifying learners’ KLS into real fields for improving education by recognizing the importance of consideration of individual student needs (Raschick, Maypole et al. 1998; Jones, Reichard et al. 2003, Thiele 2003). Some other authors also note that the concept of KLS can be also utilized to assist structuring virtual learning environment, adapting the design of course of online distance education to accommodate learners’ styles (Terrell and Dringus 2000; Richmond and Cummings 2005).

2.5.3 The Kolb Team Learning Experience

The Kolb team learning experience (KTLE) suggests a formal way to develop the teamwork in a sequential order, in which seven modules are involved. They are “introduction to teams”, “team purpose”, “team context”, “team membership”, “team roles”, “team process” and “team action”, respectively (Kolb, Kolb et al. 2004). For “introduction to teams”, team members should gain a greater appreciation for the strengths and weaknesses associated with the learning styles, preferences, and skills of them. For “team purpose”, the team discusses a clear and unanimous understanding of its purpose. For “team context”, the team defines the demands and obstacles that it may face, and action plan for accomplishing its goals. The “team roles” and “team membership” is therefore clarified clearly regarding learner’s strengths, weakness (both in KLS), and preferences, in order to navigate learners into the “team process” and “team action”, with different regions of the team learning and identified strategies. Some researches further introduce the well-defined structure of KTLE, and simulate its implementation in teams (Kayes, Kayes et al. 2005; Kayes, Kayes et al. 2005).
2.6 Summary

In this chapter, we have presented the background of our research through literature review. Cloud computing has the advantage that holds all the computing processes on the cloud side, wherein the quick and large-scale deployment of applications are well enabled. It offers new solutions to deliver computing power and storage scale, allowing consumers to rent rather than buy them, which are in the form of service. The coming of cloud computing reduces the requirement of consumers’ devices, which are consequently used for input and output of data. Accessing resources and services over the cloud through mobile devices is exactly feasible, leading an extension of cloud computing, namely MCC. On the other hand, m-learning becomes common with the rapid development of wireless communication technology and intelligent equipment, providing a novel experience for learning regardless the time and location. It is believed that MCC can facilitate m-learning in many ways, especially collaborative learning are more encouraged. However, collaborating in the mobile cloud-based learning, the teamwork performance suffers from many issues in traditional learning, which increase to a higher extent by the specificities of the mobile environment. Lastly, we have reviewed some widely used educational theories, which aim to address the problem of teamwork, to prepare a basis for our research.
3 METHODOLOGY AND DESIGN

3.1 Introduction

This chapter will describe the research method used for the design of the service-oriented system, Teamwork as a Service (TaaS). In Section 3.2, we compare the functions of some currently popular LMSs in order to achieve the objective of our research, which is to provide a novel approach to enhance teamwork performance by adding teamwork-focused functions as the supplement for current cloud-hosting LMSs. To execute those functions sequentially by TaaS, it is rational to orchestrate a teamwork-enhanced learning flow, which is introduced in Section 3.3. The newly designed learning flow follows the concept of Kolb’s team learning experience (KTLE). In addition, Section 3.4 outlines the details of the five web services involved in TaaS. Inspired from the literature review and combined with educational theories, we assign each web service to realize one or more modules of KTLE to organize a certain type of learning activity aiming to cover the gap for collaboration.

3.2 Motivation

As the preliminary work, we have compared some popular LMSs, listing their typical functions relevant to supporting collaborative learning in Table 3.1, which are Moodle, Blackboard, WebCT (now owned by Blackboard), Docebo and Rcampus.
Table 3.1 Function Comparisons of Popular LMSs

<table>
<thead>
<tr>
<th>Function</th>
<th>Moodle</th>
<th>Blackboard</th>
<th>WebCT</th>
<th>Docebo</th>
<th>Rcampus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal Webpage</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Group</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Group Webpage</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Wiki</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>One-to-one Chat thread (asynchronous)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>One-to-one instant message (synchronous)</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>3rd</td>
<td>No</td>
</tr>
<tr>
<td>Group Message (asynchronous)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Group Chat (synchronous)</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Audio Chat</td>
<td>3rd</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>3rd</td>
</tr>
<tr>
<td>Video Chat</td>
<td>3rd</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>3rd</td>
</tr>
<tr>
<td>Multi-person audio conference</td>
<td>3rd</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Multi-person video conference</td>
<td>3rd</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Email</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Forum</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Blog</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>MicroBlog</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Web Service API</td>
<td>Yes (PF)</td>
<td>Yes(PF)</td>
<td>No</td>
<td>Yes(PF)</td>
<td>No</td>
</tr>
<tr>
<td>Service-oriented system</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Mobile accessible</td>
<td>B / C</td>
<td>B / C</td>
<td>B</td>
<td>B / C</td>
<td>B / C (PF)</td>
</tr>
<tr>
<td>Currently being Cloud-hosting</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Open-source</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Free</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes(PF)</td>
<td>Yes(PF)</td>
</tr>
</tbody>
</table>

In Table 3.1, “Yes” means that LMS has already supported corresponding function, “No” means that function has not been developed yet, “3rd” means can be enabled by existing third-party solutions. “B” represents the “browser” and “C” represents the “client”, and “PF” denotes solely partial functions being supported.

From Table 3.1, we can find that common functions for supporting mobile team learning are gradually consummated in LMSs. Additionally, there is a trend that many LMSs are migrated to the cloud, and also several cloud-based e-learning
applications are available for learner to participate in online courses easily. Many current researches provide abundant overcomes to support personalized learning, such as context-aware adaptive m-learning tools (Negella and Govindarajulu 2008; Zervas, Ardila et al. 2011), learning resource recommendation (Soualah-Alila, Menders et al. 2012) and learning path optimization (Tam, Lam et al. 2012), being feasible to integrate in latest LMSs. So learners are able to obtain the majority of basic learning materials and technical supporting from cloud-hosting LMSs in order to complete their team assignments in the mobile environment. Nevertheless, as we discussed before, the organization of virtual team in traditional mobile cloud-based learning lacks mechanisms to control and normalize the whole process, as well as, teachers are guiding more macro-direction than particular instructions. Because that type of team learning is not well-structured, learners participate in teams optionally and process their assignments independently.

The context of mobile cloud-based learning is more specific than traditional learning, where learners are distributed in an immense geographical scope, even all nations around the world. Thus, once a teamwork assignment is released in a m-learning course, resulted by geographical dispersion and time-zone diversity, learners are facing many unpredictable difficulties on which they have not enough experiences, especially insufficient communications (Cramton 2001; Sharples 2009; Kukulska-Hulme 2013).

Though embracing mobile learning with cloud computing is a common solution benefiting learning experience in many aspects, as we discussed in Section 2.4, there
are still many existing issues that negatively affect the teamwork performance while the mobile cloud-based learning still lacks mechanisms to deal with those.

A character of m-learning is that its learning activities normally consist of two sections, online learning and offline learning (Trifonova and Ronchetti 2006). Mobile learners do not always keep online to access LMSs and attend tutorials, but they are free to download materials into their mobile devices for viewing offline and being introduced and guided into their practices (Attwell 2005). For mobile team learning, when some works need the equipment and materials other than mobile devices, even more procedures should be completed offline. Since online instructors usually do not engage with students in face-to-face interactions, they may be more concerned with the mechanics of course delivery than with the individual concerns of students. The online instructors (education providers, administers, teachers) are unable to reach every aspect of a matter, yet those things being unfocused at present are actually important to consider. A new concept, online to offline (O2O), would help to organize mobile cloud-based learning, in which the online instructors’ incompetence can be taken over by online systems (Wu, Hamdi et al. 2010; Wei, Wu et al. 2012). Therein, the process logic of mobile team learning should be defined distinctly by online systems, including the transaction details and deliverable resources. Thus, while learners are able to accomplish many of their teamwork tasks offline, for some necessary procedures, such as data entry and work submission, they should go back online to finish. Using online systems to command and restrain offline behaviours also helps to avoid confusion and misunderstanding, while offering more offline opportunities. Besides these, the needs for data and
computation during the team learning process can be taken charge of by the cloud, thus the complexity of the system will not be aggravated by the limitations of the mobile devices.

So the purpose of our research is not to engage in similar works repetitively, but to emphasize building a better context for team learning. When we attempt to utilize the O2O concept to enhance teamwork performance in the mobile cloud environment, we should consider several aspects to exploit the merits of online applications:

- These applications are better to be cloud-based in order to borrow cloud’s capability of computing and storage, so as to dismiss the limitation of mobile devices. Particularly, when too many learners are accessing the application at the same time, the load balancers provided by the cloud can permit the availability being not impacted by the suddenly increasing visit volumes.
- These applications should be service-oriented to support flexible interoperation, especially with current LMSs.
- The communication is even the most important factor in the collaborative learning, but the context of mobile environment cannot guarantee the communication is always in a well condition, even with the help of cloud computing, where the lack of signal or wireless network may result in negative effects. Our work is not to enhance the communication condition and keep it stable, but to make the finite communication more efficient and offer coping strategies to cover the gap due to insufficient communication.
• The interfaces of these applications should be user-friendly when accessing through mobile devices.

• The learners’ strengths and weakness should be identified, with regard to their learning styles, in order to allocate learners suitable tasks adapting their individual concerns (Simpson and Du 2004; Terrell and Dringus 2000; Thiele 2003; Richmond and Cummings 2005).

• The learning process should be concise and indispensable, and more importantly, be supporting rational grouping (Schawabe, Goth et al. 2005).

• The online applications should be able to track the entire learning process and have appropriate measures to let learners discover and solve problems in a timely manner.

3.3 Teamwork-enhanced Learning Flow in the Mobile Cloud Environment

Combining the architecture of the cloud environment, orchestrating a learning flow is a feasible way to facilitate teamwork. Learners can follow the execution of learning flow step by step and thereby refining their team learning activities.

Because the applications over the cloud are service-oriented and loosely coupled, and the application programming interfaces (APIs) of them correspond to a series of web service protocols, cloud-based applications are able to interact and interoperate. The service composition is an important method to integrate cloud-based applications or web services. Its effective goal is to orchestrate a workflow that arranges activities to
form a business process by automatically invoking web services in a logical sequence. Many approaches, such as WS-BPEL (Srivastava and Koehler, 2003) and OWL-S (Martin et al., 2003), are provided to execute the composition directly, quickly and smartly. Therefore, if we attempt to promote the mobile learning by the goodness of cloud computing, especially for enhancing teamwork performance, orchestrating a rational learning flow is necessary.

Learning flow, a specification of work flow, refers to the formal description of a set of rules and the process by how the learning activities happen and change (Cao et al., 2009). A completed learning flow includes time sequences, logical relationships, connected patterns and trigger conditions of various learning activities, blending them together as a reasonable formation of a process. Each learning activity, with the conditions of the beginning and the end, related resources and required supports, is one logical step of the whole learning flow.

We have illustrated some typical cloud-hosting learning management systems, all of which are mobile-accessible, forming as the Domain A. In the traditional way, the stages that the mobile learner uses applications in Domain A can be abstracted as the learning flow shown in Figure 3.1.
Kolb Team Learning Experience (KTLE) is a theory, with seven modules, for guiding how to form a team in a sequential order to improve team learning (Kayes et al., 2005). By following its guidance, we have identified a novel learning flow to enhance teamwork performance by automatically interoperating services and applications over cloud, in which the processing learning content activities are subdivided into the seven modules of KTLE, working in parallel with the activity of accessing learning resource.

Considering the granularities, we design five web services working in the Domain B to execute the teamwork-enhanced learning flow, by adding helpful activities into the whole learning process. They are the Survey Service, the Jigsaw Service, the Bulletin Service, the Inference Service, and the Monitor Service. Each of which takes one or more modules of the KTLE. Services from both Domain A and Domain B are working in conjunction to make the teamwork-enhanced learning flow come true.
As Shown in Figure 3.2, once learners have got their team assignments and accessed learning resource, the Survey Service is needful to support a platform for the “introduction to the teams”. According to Wheelan’s work of teamwork (2005), this is “forming stage”, in which team members try to know one another and construct sociable interpersonal relationships. Then they come into the “storming stage”, when they spend time on understanding the requirement of assignments and acquainting with the learning contents. Some approaches, such as brainstorming, are employed in their intense discussions. The Jigsaw Service and the Bulletin Service make this stage happening up to when the learners are gradually finding out their “team context” and “team purpose”. In the third, “norming stage”, learners should be clear about their “team membership” and “team roles”. So some web services work to define their responsibilities on which they should concentrate and have explicit cognitions.
After that, in the final “performing stage”, although team members work together
and actively attempt to collaborate in addition to finish their own tasks, manual
supervisions are encouraged to avoid conflicts and seek concords of their “team
process” and “team action”. The Monitor Service is for attaining this objective. A
new step in the learning flow can be triggered immediately when previous event
finishes or a message jumps in.

3.4 Service-oriented System Function Design

We briefly introduce these five services as follows, while the detailed work patterns
of each will be discussed in the next chapter.

3.4.1 The Survey Service

For “Introduction to Teams”, we design a Survey Service that offers interfaces to
learners for answering questions to investigate their capabilities. Considering the
limitation of screen sizes and typing method of the mobile devices, the survey is
single-choice based. The survey can be operated as self-assessment or peer-
assessment, which means the respondents of the surveys, can evaluate themselves or
the other group members working with them.

There are five sets of questions being pre-installed in the Survey Service, four of
which are for the four aspects (accommodating, assimilating, converging, and
diverging) of Kolb’s Learning Style (KLS) (Kolb 1984; Kolb and Kolb 2005), and
the last is for comprehensive teamwork skills. As shown in Table 3.2 and Table 3.3,
questionnaires for KLS come from Wheelan’ work (2005), and those for
comprehensive teamwork skills come from Lingard’s contribution (2009), respectively.

Table 3.2 Questionnaires for Assessing the Four Aspects of KLS Capabilities

<table>
<thead>
<tr>
<th>Accommodating</th>
<th>Assimilating</th>
<th>Converging</th>
<th>Diverging</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perceive concretely and process actively</td>
<td>Perceive abstractly</td>
<td>Like to seek results and applications.</td>
<td>Perceive information concretely</td>
</tr>
<tr>
<td>Learn by trial and error</td>
<td>Process reflectively</td>
<td>Perceive abstractly</td>
<td>Process reflectively</td>
</tr>
<tr>
<td>Are interested in self-discovery</td>
<td>Seek continuity</td>
<td>Process actively</td>
<td>Are imaginative</td>
</tr>
<tr>
<td>Are enthusiastic about new things</td>
<td>Need to know what experts think</td>
<td>Integrate theory and practice</td>
<td>Believe in own experience</td>
</tr>
<tr>
<td>Like change</td>
<td>Love ideas</td>
<td>Are pragmatic</td>
<td>Are insight thinker</td>
</tr>
<tr>
<td>Are risk taker</td>
<td>Are detail oriented</td>
<td>Dislike fuzzy ideas</td>
<td>Thrive on harmony and personal involvement</td>
</tr>
<tr>
<td>Are important related to people, and seek to influence</td>
<td>Exhibit intellectual competence in traditional classrooms.</td>
<td>Value strategic thinking</td>
<td>Seek commitment, meaning, and clarity</td>
</tr>
<tr>
<td>Are adaptable and flexible</td>
<td>Devise theories</td>
<td>Like to experiment</td>
<td>Have high interest in people and culture.</td>
</tr>
</tbody>
</table>

Table 3.3 Questionnaires for Assessing Comprehensive Teamwork Skills

<table>
<thead>
<tr>
<th>Comprehensive teamwork skills</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Attend online meetings and arrived promptly</td>
<td>Complete individual assignments on time</td>
</tr>
<tr>
<td>Introduce new ideas</td>
<td>Consider the suggestions of others</td>
</tr>
<tr>
<td>Accomplish a fair share of the work</td>
<td>Complete tasks with high quality</td>
</tr>
<tr>
<td>Provide help to others on the team</td>
<td>Share opinions and knowledge</td>
</tr>
<tr>
<td>Ask for help from others on the team</td>
<td>Listen to views and opinions of others</td>
</tr>
<tr>
<td>Adopt suggestions of others when appropriate</td>
<td>Seems committed to team goals</td>
</tr>
<tr>
<td>Communicate clearly with other team members</td>
<td>Show respect for other team members</td>
</tr>
<tr>
<td>Perform research and gathered information when necessary</td>
<td>Distinguish between the important and the trivial</td>
</tr>
</tbody>
</table>
3.4.2 The Jigsaw Service

Given “the team purpose” module in the KTLE is to help learners to deepen their understanding of the team assignment and broaden their knowledge to the related references, they are unnecessary to achieve the deliverables but have to make clear ideas about what they should perform in the next stage. Consequently, we use the jigsaw classroom method (Aronson, Blaney et al. 1978) to organize learners into efficient discussion, whose three stages can be imitated by the Jigsaw Service.

For “Initial discussion in original team”, the Jigsaw Service groups learners into four-person-sized original teams, keeping the total comprehensive teamwork skills of each team equal with others. Some changes are made to the traditional jigsaw method that, in each original team, a learner is assigned one of the four KLS roles rather than one section of a task, being different with each other (Belbin 1993).

For “Joining expert team to refine cognition”, it rebuilds four expert teams, within each of which learners who played the same roles in the original teams are involved.

For “Backing to original group to teach others what was gained in expert group”, it redirects learners into original teams from which they have come.
3.4.3 The Bulletin Service

After learners have discussed the team assignment topic in Jigsaw Classroom, they are encouraged to write down their ideas as solutions describing the detailed methods and procedures of solving imaginary tasks. The Bulletin Service provides a platform for learners to define the “Team Context”, over which they are able to publish schedules of imaginary tasks. As a requirement, a pre-planned task should meet the expectation that it is suitable for the workload of an imaginary team, which consists of several subtasks and detailed stages of them, whether offered by an original team in cloud jigsaw classroom or by an individual learner. Additionally, if a subtask is the premise for another subtask, the sequential relationship between them should be notified. According to Schwabe’s work (2005), the team size may also affect the quality of the whole team’s outcomes. Taking example by the real team learning
condition, we suppose the number of subtasks in a task is between 3 and 6, and learners are required to meet this task size while they are pre-planning (the relationship between the number of a task’s subtasks and the size of a team will be introduced in the next section).

Each imaginary task is alternative and potential to be adopted as a team’s assignment in the final task allocation. To specify its difficulty, the assignment publishers are asked to give every subtask expected-achievable values with regard to the four aspects of the KLS, in order to mark each of them to be better completed by a learner who has the appropriate capabilities.

Moreover, each learner is encouraged to give a preference grade to every published subtask when browsing the bulletin. As it is in WYSIWYG mode, publishing task schedule through the user interface is easy and feasible. In addition, subtasks’ difficulty and learners’ preference are also marked by single-choice.

3.4.4 The Inference Service

Pinola (2011) suggests that a solution to facilitate collaboration and reduce conflict is that leadership of mobile virtual teams can be shared. We borrow the idea and mend it by abolishing the concentrated leadership and dispersing the duty of it to the both sides of the O2O. Herein, the kind of duty that picks the suited learner to form a capable team and defines the clear-cut role for each team member is in charge of the Inference Service, which is the core of our solution as it attempts to solve the problem caused by the specialization of mobile cloud-based learning, using reasoning mechanisms.
Referring the capabilities and preferences of learners, and the expected-achievable values of subtasks, the operating principle of this service is to match each learner to the most appropriate subtask. On the other hand, in the inference process, learners who take subtasks belonging to the same task will be grouped into the same team, so that the attributes of whole strengths of a team are taken into consideration, accordingly, a successful team is probably not the set of the best learners.

We suppose two ways of forming a team, with different focuses. They are:

“Keeping the balance among each team”, which means the upcoming teams will have approximate comprehensive teamwork skills. In addition, the learners’ preferences and capability levels are diverse in confined shapes, meaning that if we regard each team as an independent unit, its integrated preferences and capability values are highly close to those of other units. Therefore, we can say that the inter-team competition among the upcoming teams starts from the same scratch line and is assured fair.

“Letting the learners show their capabilities mostly”, which means each of them is able to put their superiorities to use as much as possible, so that whether the team members are “good at” and “happy to” their upcoming subtasks will be the main indexes that direct the reasoning process of task allocation.

As each learner is allocated with an individual subtask, the time complexity of this problem refers to the factorial of the learner number. So the problem may have a very time consuming process to be solved by basic programming algorithms. Therefore, we take heuristic algorithm to seek the solution for the problem in an
acceptable scale of computing time, where two algorithms are chosen, namely genetic algorithm (GA) and simulated annealing algorithm (SA). These two algorithms aim to transfer the problem of task allocation from multi-objective optimization to single-objective optimization, taking the learners’ capabilities of KLS and comprehensive teamwork skills, the difficulties of subtasks and the learners’ preferences as the main indexes into consideration.

3.4.5 The Monitor Service

Grading by peer-assessment is an effective measure that is used for saving teachers’ time and improving learners’ understandings of course materials and cognitive skills (Sadler and Good 2006). Importing peer-assessment into the in-progress work is helpful especially in the mobile cloud-based learning, where the teacher and learners are apart in distance so that the teacher focuses more on evaluate learners’ final achievements rather than accompanies and supervises their entire team learning process. The Monitor Service aims to provide mutual supervision among learners, which replaces the rest duty of concentrated leadership, for “team process” and “team action”. Drawing idea of the “within team jigsaw” in a certain extent (Cottell 1998), in each team, each learner is assigned as the coordinator for another. The pair of completer/coordinator is linked by a file transmission channel, through which the completer sends his periodical outcome to the coordinator, who takes responsibilities to judge whether s/he has reached the rate of progress and are capable to continue or not, by grading him/her “satisfactory” or “unsatisfactory”. A penalty mechanism is embedded in this service. It automatically deducts the completer’s marks if he got any “unsatisfactory” grade in his in-progress work. Hence, it functions in requiring
learners to accomplish their work on time and in guaranteed quality not only at the end of the team learning but also for each stage. All lost marks will be accumulated and fed back to teachers at the end of team learning.

3.5 Summary

In this chapter, we have presented the methodology of our research and designed a service-oriented system, Teamwork as a Service (TaaS). The motivation of our research is to fill the gap that literature shows there are still insufficient mechanisms to enhance teamwork performance in the mobile cloud-based learning as well as most commonly used LMSs only provide basic collaborative learning environment but not organization of well-structured team learning activities. Therefore, we have orchestrated a teamwork-enhanced learning flow, executed by the conjunction of TaaS and cloud-hosting LMSs. Five web services, namely the Survey Service, the Jigsaw Service, the Bulletin Service, the Inference Service and the Monitor Service, concentrate on covering the gaps caused by the characteristics of mobile environments, making it easy to organize the necessary learner information gathering, efficient discussion, schedule planning, task allocation and mutual supervision. The detailed work patterns of these web services will be described in the next chapter, where the universal modelling language (UML) will be employed to explain the typical principle of system interaction.
4 SYSTEM FRAMEWORK

4.1 Introduction

In this chapter, we will introduce the detailed work patterns of TaaS, service by service, which works in conjunction with cloud-hosting LMSs to realize a teamwork-enhanced learning flow for mobile learners.

As shown in Figure 4.1, once the topics of team assignments are released, learners and teachers login the TaaS use their validated LMS accounts. The single-sign-on (SSO) technique is used to support the login process. The first information synchronization between TaaS and LMS is triggered, and both of them will share the same user information in the whole team learning process. For example, teacher ID, learner ID, course name and so on. The relationship of teachers and learners enrolled in the same course of Cloud-hosing LMSs will be fully migrated into TaaS. Accordingly, TaaS holds several independent learning cohorts, each of which is for one course. Users from different courses are isolated, and users who enrolled in multiple courses belong to several parallel cohorts in TaaS separately. Symbols on the connections will be introduced in the following sections. We suppose the learning scene that learners and teachers are being enrolled in one course as our introduction background, while those in multiple courses are easy to achieve the teamwork-enhanced learning flow in similar ways by adding activated learning cohorts to TaaS thereby enabling whom to utilize web services.
4.2 The Survey Service

Survey service offers interfaces to learners for answering questionnaires to investigate their capabilities. Considering the limitation of screen size and typing method of the mobile devices, the surveys are single-choice based. It can be operated as self-assessment or peer-assessment, which means the respondents of the surveys, can evaluate themselves or the other teammates working with them, by giving appropriate grades.

Given that there are five sets of questionnaires being set in the Survey Service, learners can choose one of the ten options to answer each question, which is an integer between 1 and 10, the higher the better.
Let the $L^k$ denotes the $k^{th}$ learner. In the Survey Service, $L^k$’s capability will be compiled from questionnaires, from both self-assessment and peer-assessment. The results of each question for evaluating $L^k$ will be recorded in a matrix, in which each column stands for a question while each row corresponds to a learner who gives the marks. So five matrixes are obtained, they are $\{AC^k\}$, $\{AS^k\}$, $\{C^k\}$, $\{D^k\}$ and $\{CT^k\}$.

For example, the capability of accommodating (AC) of $L^k$ can be stated as:

$$\{AC^k\} = \begin{pmatrix}
M^1_1 & M^2_1 & \ldots & M^n_1 \\
M^1_2 & M^2_2 & \ldots & M^n_2 \\
\vdots & \vdots & \ddots & \vdots \\
M^1_m & M^2_m & \ldots & M^n_m
\end{pmatrix} \quad (4.1)$$

where: $M^n_m$ means the mark for the $n^{th}$ question of the accommodating aspect, which is given in the $m^{th}$ assessment, and $M^n_m$ is an integer between 1 and 10. The $n$ depends on the question title’s order and the $m$ is in accordance with the sequence of questionnaire submission times.

In this matrix $\{AC^k\}$, means of each column describe strengths of different types of accommodating, and we use the next equation to calculate the value of accommodating capability of $L^k$:

$$AC^k = \frac{\sum_{j=1}^{m} \sum_{i=1}^{n} M^i_j}{nm} \quad (4.2)$$
In the same way, the Survey Service calculates the values for the other four matrixes. Hence, we got these values: \( AS^k \), \( C^k \), \( D^k \) and \( CT^k \). They represent the capability values of assimilating, converging, diverging and comprehensive teamwork skills, respectively. Therein, we let a 4-tuple \( KLS^k = \{AC^k, AS^k, C^k, D^k\} \) denote the KLS capability values of \( L^k \) according to that they are closely related.

For self-assessment in one course, which is usually required to be completed at first, learners are not allowed to do it for more than one time. In other words, during the period of one course, if a learner has already answered the questionnaires for evaluating himself/herself, the Survey Service will switch off the entry of self-assessment for him/her. The historical data of his/her survey results collected from other courses are continuing to use in this course. That is to say, if a learner is a new registered user of TaaS, the Survey Service will create five new capability matrixes for him/her to record survey results, and these matrixes will be wielded and updated along with his/her whole period of learning in different courses using TaaS. If a learner is not a newly registered user of TaaS, the Survey Service has recorded non-null capability values of him/her yet. The newly collected survey results will be added into his/her capability matrixes rather than replace the historical results in those.

For peer-assessment in one course, if certain learners used to be teammates once, no matter in any stage of Jigsaw Classroom or in the ultimate team working towards accomplishing assignment, they are able to evaluate each other for one time. After any change of team structure, the Survey Service releases the surveys to learners for
evaluating their teammates mutually within each previous team. In this way, a learner may evaluate another for more than one time during the process of a whole course, while the subsequent survey results will not cover those ones given at the first time, but add new rows to the bottom of whose capability matrixes.

The structure of surveys can be manually changed by teachers, by adding or reducing questions in surveys, causing that the number of columns in corresponding matrix changes. Similarly, sets of questionnaire for investigating new aspects other than these five can be added, as well as the five pre-set sets of questionnaire can be deleted if necessary. Accordingly, the types of matrix vary with the changing of survey structure.

The procedure of the self-assessment is shown as the UML active diagram Figure 4.2.
The procedure of peer assessment is shown as the UML active diagram, Figure 4.3
4.3 The Jigsaw Service

The Jigsaw Service aims to organize learners into discussion teams thereby deepening their understanding of the goals of their team assignment and define the expectation of the team purpose. As the Jigsaw Classroom has three stages, within which the personnel structure of the first one and the third one is the same. Two essential key points that we should consider is the formation of original teams and expert teams.
In our design, firstly, the Jigsaw Service extracts all learner information from the survey service and triggers a computing process about grouping learners into four-persons-sized original teams with nearly equal comprehensive teamwork skills \((CT)\) of each group.

Secondly, each learner in one original group is assigned one of the four roles of KLS. The method of role assigning is choosing the best player of each aspect, and if there is anyone leading two aspects in the team, choosing his/her best aspect. For example, in an original team, a learner A has the highest value of accommodating \((AC)\) of the team members, s/he is assigned as the “accommodator”; and another learner B leads converging \((C)\) and diverging \((D)\) in the team with the addition that s/he is better at converging, the jigsaw service assigns the “converger” role to him/her.

Thirdly, after the period of original team, the Jigsaw Service arranges learners who played as the same role in the original team to rejoin as an expert team. Consequently, there are four expert teams, respectively cluster of accommodators, assimilators, convergers and divergers.

Lastly, the Jigsaw Service redirects learners into the original teams from which they have come.

In the cloud jigsaw classroom, whenever during the original team learning period or during the expert team learning period, the Jigsaw Service provides a common interface for the whole team in which they can interact with each other, and shields the information of other groups. Each change of team structure in TaaS will be updated to Cloud-hosting LMSs. Therefore, learners are also organized into groups
in those systems as the same formations in TaaS. Given that most cloud-hosting LMSs provide the “Group” functions as well as abundant tools for supporting collaborative learning, learners are benefited to utilize such conveniences for assisting their discussions in the three stages of Jigsaw Classroom.

The work pattern of the Jigsaw Service is shown as the UML sequence diagram, Figure 4.4.

![UML Sequence Diagram](image)

Figure 4.4 UML Sequence Diagram for the Work Pattern of the Jigsaw Service
4.4 The Bulletin Service

The Bulletin Service borrows the idea from the famous Wiki system (Leuf and Cunningham 2001) to establish a collaborative editing environment for learners to plan the detailed task schedule of how to work out the team assignment. However, in the use of traditional Wiki systems, users are required to know some specific mark-up languages well in order to publish contents, even that some typical Wiki systems, such as the most famous one Wikipedia, have their particular editing language (Mader 2007). As being applied for text management, the Bulletin Service improves the inconvenience by offering the WYSIWYG mode. Hence, learners can type their text content directly to access and edit published task schedules through the UIs on mobile devices.

A published task schedule is prepared for the workload of an imaginary team, which consists of following parts: the task topic, the task introduction, several subtasks, stages of each subtask, detailed content and period of each stage, and sequential relationship between subtasks (if a subtask is the premise for another). The content is in text form and the period is counted by days.

How many task schedules can be published by one learner is not limited, while learners are encouraged to open their imaginations for supplying more ideas. The authority of accessing the Bulletin Service is differentiated into four levels, namely A, B, C and D. Take the example for a published task schedule, the level A is for the publisher, the level B is for the teammates of the publisher from the same original
team of the Jigsaw Classroom, the level C is for learners from other original teams, and the level D is for teachers, which are all shown as Table 4.1.

Table 4.1 Authority Setting for the Bulletin Service

<table>
<thead>
<tr>
<th></th>
<th>Upload task schedule</th>
<th>Modify task schedule</th>
<th>Accept modification from other learners</th>
<th>Reject modification from other learners</th>
<th>Check task schedule</th>
<th>Give expected-achievable values</th>
<th>Give preference grades</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>B</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>D</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Before inserting the content of a task, the learner can adjust its structure by adding/reducing the number of subtasks to not more than 6 and not less than 3 (recall Section 3.4.3), and adjust each involved subtask’s structure by adding/reducing the number of stages.

The subtask’s difficulty is marked by expected-achievable values, depending on the publisher and his/her teammates from the same original team of the Jigsaw Classroom. Let a published $S_{i,j}$ represents it is the $j^{th}$ subtask of the $i^{th}$ task. For $S_{i,j}$, the Bulletin Service allows authorised learners to type in a real number between 1 and 10 for each aspect of the KLS, in order to indicate that is to be better completed by a learner who has the approximate capabilities. The results are recorded in a matrix $\{ S_{i,j} \}$:
\[
\{ S^{i,j} \} = \begin{pmatrix}
V_1^1 & V_1^2 & V_1^3 & V_1^4 \\
V_2^1 & V_2^2 & \ldots & V_2^4 \\
\vdots & \vdots & \ddots & \vdots \\
V_m^1 & V_m^2 & V_m^3 & V_m^4
\end{pmatrix}
\]

where \( V \) is the value for one aspect of KLS given by one learner, the four columns denote the aspect of accommodating, assimilating, converging and diverging, sequentially, and each row represents the results given by one learner in accordance with time sequence. We use the next equation to calculate the final expected-achievable value, \( ST^{ij} \), of \( S^{i,j} \):

\[
ST^{ij} = \{ AC^{ij}, AS^{ij}, C^{ij}, D^{ij} \} = \left\{ \frac{\sum_{i=1}^{m} V_i^1}{m}, \frac{\sum_{i=1}^{m} V_i^2}{m}, \frac{\sum_{i=1}^{m} V_i^3}{m}, \frac{\sum_{i=1}^{m} V_i^4}{m} \right\}
\]

(4.4)

So we got a 4-tuple \( ST^{ij} = \{ AC^{ij}, AS^{ij}, C^{ij}, D^{ij} \} \), where each element is a real number between 1 and 10.

When browsing a task, learners are free to show their preferences to each subtask by choosing one of the five grades. The variable \( P_k^{ij} \) denotes the preference grade of the \( S^{i,j} \), given by the \( k^{th} \) learner. Note the \( P_k^{ij} \) is an integer between 1 and 5, the higher the grade is, the more preferred by the learner to do a subtask. Typically we can assume that there are five types of subtasks, which are in turn regarded as “very interesting”, “interesting”, “ordinary”, “uninteresting” and “very uninteresting” if they separately got the preference grades 5, 4, 3, 2, 1, by a specific learner.
The procedure of publishing a task is shown as the UML active diagram, Figure 4.5; the procedure of modifying a published task is shown as the UML active diagram, Figure 4.6; and the procedure of checking a published task by the learner is shown as the UML active diagram, Figure 4.7.

![Figure 4.5 UML Active Diagram for the Procedure of Publishing a Task](image-url)
Figure 4.6 UML Active Diagram for the Procedure of Modifying a Published Task

Figure 4.7 UML Active Diagram for the Procedure of Checking a Published Task
4.5 The Inference Service

As we attempt to define the “team roles” and “team membership” for the team learning at the same time, the Inference Service aims to group learners into their suitable teams. So the basic idea of our grouping mechanism is to allocate each learner to one subtask and assign the learners who take the subtasks belonging to the same task as a team. Consequently, learners are able to know who their teammates are and what they have to complete in the subsequent team learning processes. The main attributes we consider conducting the team formation are the capabilities of learners, the difficulty of subtasks and the preferences that learners versus subtasks, namely, in the form of our defined variables, $KLS$, $CT$, $ST$ and $P$. As discussed in Chapter 3, the Inference Service can group learners with the indexes of two scenarios, namely, “keeping balance among teams” and “letting learners show their capabilities mostly”, which should be chosen preliminarily by the teacher so as to trigger the inference process. The ultimately generated task allocation is several team/task pairs, within each of which several learner/subtask pairs are involved. The detailed mathematical approach for the teamwork-enhanced task allocation we will discuss in the next chapter, while the work pattern of the Inference Service is shown in the next UML sequence diagram, Figure 4.8.
Given that each learner is allocated with a subtask and grouped into a team by the use of the Inference Service, the Monitor Service invokes all the team information to coordinate learners into mutual supervisions when team learning is in progress.

The Monitor Service takes two preparations before learners start their work. Firstly, for each allocated subtask, it checks the period of each stage, and sets a time milestone at the break between two stages as the trigger of message notification. For example, if a subtask has three stages, the periods of each are 3 days, 5 days, and 5 days. Once the team learning starts, the Monitor Service sends a message at 3 days later to the subtask completer for noticing him/her the first stage is over, and then sends the second message at 5 days later and the third message after another five
days. Secondly, in each team, it appoints a leaner as the coordinator for each subtask, who is different from the subtask completer.

For each subtask, once the completer gets a message to notice that a stage is over, s/he is asked to submit his/her periodical outcome. A file transmission channel links the completer and the coordinator of each subtask, through which the periodical outcome uploaded by the completer is automatically sent to his/her coordinator. Downloading and reviewing the file, the coordinator takes responsibilities to judge whether his/her corresponding completer has reached the rate of progress and whether be capable to continue or not, by grading a “satisfactory” or “unsatisfactory”, respectively. In particular, if s/he grades an “unsatisfactory”, s/he is required to decide an “extra time” for his/her completer for work revision. A new message is sent to the completer when the “extra time” ends, who is noticed to resubmit his/her revised work. Then the coordinator judges it again.

If a completer has gotten the “unsatisfactory” for multiple times, the Monitor Service holds a vote in his/her team, therefore each team member except him/her receives his/her latest outcome and chooses one of the two options, “continue” or “warning”, after reviewing. All vote results are collected to reach a consensus, while the completer is allowed to start his/her work of next stage. Then the coordinator gives a mark to the completer for this stage. Note the mark is now in the form of number.

For each stage, suppose the largest times allowed for a completer to get “unsatisfactory” is $m$, and the actual time of a completer getting “unsatisfactory” is $n$, the procedure of mutual supervision is shown as Figure 4.9.
Figure 4.9 UML Sequence Diagram for the Procedure of Mutual Supervision for a Stage

The completer’s initial mark for a stage given by his/her coordinator may vary according to a penalty mechanism. Let the deduction weight for each “unsatisfactory” is $a$, and for each “warning” is $b$, where $a$ and $b$ are all real between 0 and 1. To calculate the completer’s ultimate mark for a stage and execute the penalty
mechanism, the Monitor Service automatically processes the completer’s times of repetition of “unsatisfactory”, $n$, with his/her initial mark. In particular, the completer’s ultimate mark for a stage may be in three conditions:

- If $n < m$, his/her ultimate mark equals to his/her initial mark multiplied by $a^n$. Specifically, if $n = 0$, the penalty mechanism does not affect his/her ultimate mark.
- If $n = m$, and s/he gets a “continuous”, his/her ultimate mark equals to his/her initial mark multiplied by $a^n$.
- If $n = m$, and s/he gets a “warning”, his/her ultimate mark equals to his/her initial mark multiplied by $a^n b$.

Note the $m$, $a$ and $b$ can be preset by the teacher.

After the completer submits the final outcome, the Monitor Service calculates the mean of his/her marks for all stages as his/her regular mark, and sums it with the final mark given by the teacher. Thus, the completer’s total mark for his/her team learning is obtained, which is outputted within a report to the teacher. Therein, the percentage of the final mark, $y$, in the total mark is authorized to be preset by the teacher.

For example, a completer obtains the marks, from his/her coordinator, for three stages of the subtask as 70, 75, 65, respectively, and the $n$ of each stage is 2, 0, and 3, respectively; and s/he gets a “warning” at the third stage. Let $a=0.8$, $b=0.7$, $m=3$, $y=60\%$, and the final mark given by the teacher is 63. So the total mark of the completer is $[(70*0.8^2+75+65*0.8^3*0.7)*(1-60\%))/3+63*60\%]=63.08$. 

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The procedure of processing a learner’s mark is shown as Figure 4.10.

![UML Sequence Diagram for the Procedure of Mark Processing](image)

Figure 4.10 UML Sequence Diagram for the Procedure of Mark Processing

### 4.7 Summary

It is notable that we took the example condition of all the learning activities being driven by the teacher. In other words, the teacher takes charge of deciding when to start each period of the team learning and structure learners to follow the learning flow. Actually, the run-up time for each learning activity, such as for the three stages
of jigsaw classroom and the formation of ultimate teams, can be pre-installed and TaaS therefore executes the learning flow automatically.

In this chapter we have introduced the rules for system interaction, along with definitions of some variables denoting the types of recorded data. Executing these web services sequentially, an entire teamwork-enhanced learning flow is realized that learners in virtual teams can participate in its involved activities through mobile devices, where their learning styles in KLS are identified by self-assessment and peer assessment, and a collaborative editing environment is provided for them to clarify task schedules along with evaluating difficulties and preferences. A cloud-based jigsaw classroom is also conducted for guiding them into efficient communication and learning from others. Moreover, while all ultimate teams are working on their allocated tasks, the Monitor Service allows them to take mutual supervisions in pairs, who are encouraged to finish their subtasks on time for each stage otherwise a penalty mechanism is appointed to deal with their unsatisfactory performance. Learners’ total marks for assessing their performance are also processed to be referred by the teacher. As the core of TaaS, the math model and computing procedure for task allocation in the Inference Service will be particularly discussed in the next chapter.
5 TEAMWORK-ENHANCED TASK ALLOCATION

5.1 Introduction

The core of TaaS is the Inference Service. It takes the data recorded in the Survey service and the Bulletin Service as raw information, and uses certain rules to make a unique rational decision what the “team membership” and “team roles” are. In the ultimate task allocation, each subtask is assigned to one learner, meanwhile learners who take subtasks belonged to the same task will be grouped into the same team.

In this section we will discuss a constructive approach of task allocation in mobile cloud-based learning, using KLS to accurately allocate responsible tasks to each learner in order to enhance teamwork performance. We employ two heuristic algorithms, Genetic Algorithm (GA) and Simulated Annealing (SA), to facilitate the task allocation.

5.2 Learner and Task Modelling

Referring to Chapter 4, we let the \( L^k \) denotes the \( k^{th} \) learner. In the Survey Service, \( L^k \)'s capability will be compiled from the five sets of questionnaires, from both self-assessment and peer-assessment. Using equation 4.2, the values of each of the five matrixes recording the questionnaire results can be calculated. So we obtain five values, namely \( AC_k, AS_k, C_k, D_k \) and \( CT_k \), which represent the capability values of accommodating, assimilating, converging, diverging and comprehensive teamwork skills, respectively. Therein, we let a 4-tuple \( KLS_k = \{ AC_k, AS_k, C_k, D_k \} \) denote the
KLS capability values of $L^k$ according to that they are closely related. Note the $CT^k$ or each value of $KLS^k$ is a real number between 1 and 10.

In the Bulletin Service, a published $S^{ij}$ represents it is the $j^{th}$ subtask of the $i^{th}$ task. Its expected-achievable values are set in a 4-tuple $ST^{ij}$, where $ST^{ij} = \{AC^{ij}, AS^{ij}, C^{ij}, D^{ij}\}$, each value is a real between 1 and 10.

The variable $P^{ij}_k$ denotes the preference grade of the $S^{ij}$, given by the $k^{th}$ learner. Note the $P^{ij}_k$ is an integer between 1 and 5, the higher the grade is, the more preferred by the learner to do a subtask. Typically we can assume that there are five types of subtasks, which are in turn regarded as “very interesting”, “interesting”, “ordinary”, “uninteresting” and “very uninteresting” if they separately got the preference grade 5, 4, 3, 2, 1, by a specific learner.

### 5.3 Problem Definition

Suppose in a possible task allocation, the learner $L^k$ is allocated with the $S^{i,j}$, it is necessary to check whether they are roughly matching and on which level they suit to each other. We introduce two attributes to describe the deviation of that learner versus subtask. The first one is $DeP$, which stands for the preference gap between learner’s ideal and reality, where:

$$DeP^{ij}_k = 5 - P^{ij}_k \quad (5.1)$$
And the second one is $DeK$, which denotes the deviation of learner’s KLS capability values versus a subtask’s expected-achievable values, where:

$$DeK_{ij}^k = -\{\text{sign}[\sum (KLS^k - ST_{ij})]\} \cdot \left\| KLS^k - ST_{ij} \right\|$$  \hspace{1cm} (5.2)

Subject to:

$$KLS^k - ST_{ij} = \{AC^k - AC_{ij}, AS^k - AS_{ij}, C^k - C_{ij}, D^k - D_{ij}\}$$  \hspace{1cm} (5.3)

$$\left\| KLS^k - ST_{ij} \right\| = \sqrt{(AC^k - AC_{ij})^2 + (AS^k - AS_{ij})^2 + (C^k - C_{ij})^2 + (D^k - D_{ij})^2}$$  \hspace{1cm} (5.4)

Both of these deviations are the lower the better. An ideal $DeK_{ij}^k$ is below 0.

The basic idea of the task allocation is to assign learners with their appropriate subtasks. However, it may result in a situation where the chosen subtasks cannot compose into full tasks. For example, there are two tasks, each consists of three subtasks, but the Inference Service allocates two subtasks of each to four best-suited learners. In this situation, teams cannot be formed. Moreover, in team learning, it cannot start with the condition of learners having got their individual subtasks beforehand, as they still need to be grouped into teams. To enhance teamwork performance, we need to consider the whole strength of a team when grouping them. Furthermore, if suitable, it is possible that two or more teams are assigned the same task as their assignments. To avoid misunderstanding, we use a variable $x$ to mark a team tag. Sums of $DeP$, $DeK$ and $CT$ in a potential team $x$ can be stated as:
\[ x \text{DeP}^i = \sum x \text{DeP}^{ij}_k \]  
(5.5)

\[ x \text{DeK}^i = \sum x \text{DeK}^{ij}_k \]  
(5.6)

\[ x \text{CT} = \sum x \text{CT}^k \]  
(5.7)

\(N^i\) denotes the number of subtasks in the \(task^i\), which is an integer between 3 and 6 (recall Section 3.4.3).

We will separately discuss features of two scenarios of forming a team.

“Keeping the balance among each team”

It means that if we regard each upcoming team as an independent unit, its integrated comprehensive teamwork skills, preferences, and capability values are highly close to those of other units. Therefore, we can deem that the inter-team competitions between the upcoming teams start from the same scratch line and are supposedly fair.

Briefly, each upcoming team should have the nearly equal \(xCT\), followed by the respectively proximate \(xDeP^i\) and \(xDeK^i\).

“Letting the learners show their capabilities mostly”

It means each of them is able to take advantage of their superiorities as much as possible, so that whether the team members are “good at” and “happy to do” their upcoming subtasks will be the main indexes that supervise the reasoning processing of task allocation.
That is to say, each upcoming team’s $\Delta DeP^i$ and $\Delta DeK^i$ should be minimized. Under this premise, the $\Delta CT$ level between teams is better to be kept in balance as possible.

As the Inference Service is part of the TaaS working for assisting real mobile-based cloud learning, several situations should be considered realistically. The ultimate purpose of each learner who participates in the cloud-based course is to get a final grade for their team assignment, in order to pass the subject. So in the task allocation, no learners should be left out, though they might have unsatisfactory capabilities or unexpected performance. On the other hand, overflowing subtasks, which results in the unshaped team, is not allowed or encouraged. An integrated task should be allocated to a team rather than just part of its subtasks being allocated to several learners.

5.4 Algorithms

5.4.1 Related Works

The scale of solution spaces of the teamwork-enhanced task allocation is $k!$, where $k$ is the number of learners. We have tried seeking the solution for task allocation using basic programming algorithms, the mixed integer programming (MIP). However, it takes hours to run the computing process, while with the increasing of $k$, the running time becomes even longer to an unacceptable scale. Hence, we attempt to use heuristic algorithms to tackle the problem out.

The problem of task allocation is concerned in many research areas, and currently their purposes are reached in lots of literature, in which the heuristic algorithms are
widely utilized, especially when the problem models are large and complex. The heuristic is a technique designed for solving a problem more quickly when classic methods are too slow, or for finding an approximate solution when classic methods fail to find any exact solution. This is achieved by trading optimality, completeness, accuracy, or precision for speed. For example, Vidyarthi, Tripathi et al. (2003) present a study of two task allocation models in distributed computing system based on genetic algorithm (GA), and then these models are upgraded in their further work (Vidyarthi, Tripathi et al. 2009), GA is also utilized for dynamically mapping tasks to processors in a heterogeneous distributed system (Page, Keane et al. 2010); in globally distributed software projects, individual tasks can be allocated to resources across locations using GA (Fernandez and Basavaraju 2012); the task allocation problem in multiple robot systems is inspected by Khuntia, Choudhury et al. (2012), in which each robot is assigned to one single tasks by GA or simulated annealing (SA), and SA is proven producing better solutions than GA; SA also has ability to allocate task with the purpose of maximizing reliability of distributed systems (Attiya and Hamam 2006).

However, there are comparatively less researches investigating the task allocation problem in the educational area, wherein the heuristic algorithms are even adopted rarely. In the next section, we describe the details of using genetic algorithm (GA) and simulated annealing (SA) to solve the problem of teamwork-enhanced task allocation. To simulate the real scene of mobile cloud-based learning, which is large-scale and distributed, we suppose the number of learners and tasks/subtasks are big enough.
5.4.2 Genetic Algorithm Method

GA is an optimal self-adaptive heuristic algorithm, which simulates the natural biological selection and genetic evolution mechanism. The basic idea of GA is inspired by evolution process in the natural world, to optimize candidate solutions towards better ones (Holland 1992; Andrew, Thomas et al. 2010). Traditionally, candidate solutions start randomly and change in generations, by selection, crossover and mutation. Every generation is evaluated by a fitness function and the new generation is then used in the next iteration of the algorithm. Once a satisfactory of fitness level has been reached, the iterations terminate and the algorithm outputs the final generation as the optimal solution.

To start the GA operation, arrays of $k$ learner/subtask pairs are randomly generated, where $k$ is the number of learners. In each array, the integrities of tasks should be checked. If any overflowing subtask exists, that array will not be adopted as the initial solution. Taking these initial solutions as individuals (chromosomes), we need to encode them into populations (genomes) for creating the first generation. Let the population size is $2k$, an example of genome encoding is shown as the Figure 5.1.
A fitness function transfers the task allocation from multi-objective optimization to single-objective optimization. For the first scenario mentioned in Section III, to make the proximate \( \Delta CT \), \( \Delta DeP \) and \( \Delta DeK \) between teams, total teams’ variances of these parameters should be respectively minimized. However, for each attribute, several solutions may have different means but with the similar variances. A special situation is that the original difference of potential teams is little. To avoid the evaluation blindly terminates in a partial balance, we take minimizing the means of the \( DeP \) and
the DeK of all teams into consideration. So we use the next equation as the fitness function:

$$R_m = \alpha \sqrt{\frac{1}{n} \sum_{i=1}^{n} \left( \frac{\bar{x}_i^{CT} - \bar{x}_i^{CT}}{N_i^{CT}} \right)^2} + \beta \sqrt{\frac{1}{n} \sum_{i=1}^{n} \left( \frac{\bar{x}_i^{DeP} - \bar{x}_i^{DeP}}{N_i^{DeP}} \right)^2}
+ \gamma \sqrt{\frac{1}{n} \sum_{i=1}^{n} \left( \frac{\bar{x}_i^{DeK} - \bar{x}_i^{DeK}}{N_i^{DeK}} \right)^2} + \epsilon \bar{x}_i^{DeP} + \eta \bar{x}_i^{DeK}
$$

(5.8)

For the second scenario, in a candidate solution, minimizing the total DeP and DeK is more important than minimizing the variance of CT. so we take the next fitness function:

$$R_m = \alpha \sqrt{\frac{1}{n} \sum_{i=1}^{n} \left( \frac{\bar{x}_i^{CT} - \bar{x}_i^{CT}}{N_i^{CT}} \right)^2} + \sum_{i=1}^{n} \left( \beta \bar{x}_i^{DeP} + \gamma \bar{x}_i^{DeK} \right)
$$

(5.9)

where each Greek letter in (5.8) and (5.9) represents the weight for that attribute.

The aim of selection operator is to remove the poor solution with higher fitness. Then the selected individuals evolve to the next generation through the effect of crossover operator and mutation operation. In this paper, we choose “top percent selection” as the selection operator, “uniform mutation” as the mutation operator. Specifically, the “partially matched crossover operator” is able to deal with the appearance of the unfeasible solution that, after crossover, in a genome, a learner is repetitively assigned while another learner is leaved out. The example process of partially marched crossover and uniform mutation are shown in Figure 5.2 and Figure 5.3, respectively.
Figure 5.2 An Example of Partially Marched Crossover
The pseudo code of GA is shown below:

---

**Input:** $KLS^k, CT^k, ST_{ij}^k, P_{ij}, N_i$

**Output:** $Team^i/Task^j$ pairs (sets of $L^k/S^j$ pairs)

---

**begin:** Calculate $DeP, DeK, CT$.

- Randomly generate arrays of $k L^k/S^j$ pairs
- Check the task integrity in each array, give up unmatched ones.
- Take the matched individuals as the initial population. Make the population size as $2k$.

**for each** individual $\in$ population **do**

- Evaluate the fitness of each individual using $R_m$.

**end for**

**while** iteration times $< \max$ iteration time **do**

---

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Select the individuals with lower fitness.
Use crossover operator to produce offspring.
Operate offspring through mutation operator.
Evaluate the fitness of new individuals using $R_m$.
Take the lower-fitness individuals to replace the old ones.

end while

Output the task allocation.

End

5.4.3 Simulated Annealing Method

SA is a generic heuristic algorithm for locating a good approximation to the global optimization problem in a large scale. It borrows the idea from annealing in metallurgy, a technique involving heating and controlled cooling of a material to increase the size of its crystals and reduce their defects (Kirkpatrick, Gelatt et al. 1983).

The initialization of SA is similar to that of GA. The initial solution set is formed by numbers of randomly generated candidate solutions, each of which is an array of $k$ learner/subtask pairs. Certainly, the integrities of tasks should also be checked. Let the initial set include $2k$ matched candidate solutions.

The operation of SA includes two loops, namely the inner loop and the outer loop. In the inner loop, an objective function is defined as same as the fitness function $R_m$ in GA, (5.8) for the first scenario and (5.9) for second scenario, respectively. The target of objective function is using $R_m$ to evaluate each solution in order to obtain the
calculation result, namely energy \((E)\), which is also called fitness in GA. In a
candidate solution, 2 learner/subtask pairs are randomly selected, and their positions
of learners are swapped, in order to generate a new solution. The energy of current
solution \((E_{\text{current}})\) and new solution \((E_{\text{new}})\) should be evaluated by \(R_m\). Then we take
the Metropolis Criterion as reference for accepting new solution. The acceptance
probability \((AP)\) can be stated as:

\[
AP = \begin{cases} 
1, & E_{\text{new}} < E_{\text{current}} \\
\exp\left(\frac{E_{\text{new}} - E_{\text{current}}}{t_{\text{current}}}\right), & E_{\text{new}} > E_{\text{current}} 
\end{cases}
\]  

(5.10)

where \(t_{\text{current}}\) is the value of current temperature parameter. The inner loop terminates
at the condition of that the energies of the optimal solution in 5 continuous new
solution sets \((E_{\text{optimal}})\) vary in a very narrow range. To mark the range clearly, we let
the variance of these 5 continuous energies less than 0.001.

In the outer loop, the initial temperature \((t_0)\) should be high enough to allow
acceptance of any energy moving. We set \(t_0 = 100\). A cooling strategy is used to
update the previous temperature parameter \(t\) by multiplying a cooling schedule
incremental multiplier \(\lambda\), so:

\[
t_{i+1} = \lambda \cdot t_i
\]

(5.11)

where \(0 \leq \lambda \leq 1\). If the temperature decreases too fast, the algorithm may be trapped
in local minimum (Granville, Krivanek et al. 1994). Hence, we claim a useful value
0.95 as the \(\lambda\) in this paper.
There are two alternative termination conditions of the outer loop. Firstly, the parameter $t$ meets the lowest temperature ($t_{\text{stop}}$), which is $10^{-7}$ in this paper. Secondly, the optimal solutions searched by SA do not change obviously for continuous times, which means, as we set, the variance of 5 continuous energies is less than 0.001. The final solution is outputted once any of these two conditions is met.

The pseudo code of SA is shown below:

---

The pseudo code of SA

**Input:** $KLS^k, CT^k, ST^{ij}, P^i_k, N^i$

**Output:** Team$^i$/Task$^i$ pairs (sets of $L^i/S^j$ pairs)

**begin:** Calculate $DeP, DeK, CT$.

Randomly generate arrays of $k L^i/S^j$ pairs

Check the task integrity in each array, give up unmatched ones.

Take the matched solutions as the initial solution sets. Make the set size as $2k$.

$t = t_0$

**while** current temperature $t >$ lowest temperature $t_{\text{stop}}$ **do** // outer loop

**for each** solution $\in$ solution set **do** // inner loop

evaluate the energy of current solution ($E_{\text{current}}$) using $R_m$

choose two learner/subtask pairs

swap the position of learners to produce new solution

evaluate the energy of new solution ($E_{\text{new}}$) using $R_m$

accept new solution based on acceptance probability $AP$
---

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select the optimal solution in the solution set  
evaluate its energy ($E_{\text{optimal}}$)  

    if variance of 5 continuous $E_{\text{optimal}} < 0.001$
        break  // terminate inner loop
    end if

end for

select the optimal solution in the solution set  
evaluate its energy ($E_{\text{optimal}}$)  

    if variance of 5 continuous $E_{\text{optimal}} < 0.001$
        break  // terminate outer loop
    end if

$t = \lambda t$  // cooling

end while

Output the task allocation.

End

5.5 Experiment Results for Algorithm Evaluation

In this section, we present the experiment results of teamwork-enhanced task allocation by GA and SA, and compare their performances. Both the algorithms are implemented in Matlab, running on a laptop with 2.40 GHz Intel Core i5 CPU and 4GB memory.

Firstly, we determine that these two algorithms make the task allocation feasible. The data of learner and task information with all attributes are randomly simulated by Matlab, obeying normal distribution. For the function $R_m$, we set the weights, in the
first scenario, $\alpha=0.5, \beta=0.15, \gamma=0.25, \varepsilon=0.05$, $\eta=0.05$, and, in the second scenario, $\alpha=0.2, \beta=0.4, \eta=0.4$. For GA, we set the crossover probability is 0.9, meanwhile the mutation probability is 0.2. For both GA and SA, the number of learners ($k$) and subtasks are separately chosen as 100 and 200.

Having met the terminal condition, the algorithms output solutions, including 100 learner/subtask pairs, for allocating learners to their most appropriate subtasks. Both the algorithms can give the results as we predicted. For example, the output of GA is shown in Figure 5.4 and Figure 5.5, and of SA is shown in Figure 5.6 and Figure 5.7.

In the first scenario, we can find that learners are divided into 20 teams by GA or 23 teams by SA, and the values of total $CT$, $DeP$ and $DeK$ of each team are separately balanced on nearly the same levels. That is to say, the three attributes between teams are all in close proximities, which mean that the teams have almost equal capabilities and preferences to achieve goals of their responsible tasks. And in the second scenario, as the solution would group learners into 22 teams by GA or 25 teams by SA, the $DeK$ attributes of each team are below 0, so that each team is competent to their allocated tasks. The $DeP$ level of each team is less than 3. Due to the team size is 3 to 6 persons, the result means the allocated tasks are enjoying high preferences as being deemed better than “interesting”.

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Secondly, we compare the performances of GA and SA. We dismiss the restraint of max iteration times for both of them, and let them run in the conditions of 50, 100 and 150 learners. The convergences are satisfactory. The results of algorithm running are shown as the Figure 5.8-5.13. Both algorithms converge after 200 iterations, and GA gives the ultimate results with lower $R_m$ value than SA. In the first scenario, the
diversities between the $R_{m}$ values outputted by them are quite gradually expanding with the increase of learner numbers, while that kind of diversities do not alter obviously when the number of learners reach a certain amount in the second scenario. So we find that the GA has better, but not distinct, efficiency for the teamwork-enhanced task allocation.

Figure 5.8 Comparison of the performances of GA and SA for the 1st scenario (50 learners)

Figure 5.9 Comparison of the performances of GA and SA for the 1st scenario (100 learners)
Figure 5.10 Comparison of the performances of GA and SA for the 1st scenario (150 learners)

Figure 5.11 Comparison of the performances of GA and SA for the 2nd scenario (50 learners)

Figure 5.12 Comparison of the performances of GA and SA for the 2nd scenario (100 learners)

Figure 5.13 Comparison of the performances of GA and SA for the 2nd scenario (150 learners)
As shown in Table 5.1, the running time of GA and SA increase in linearity, according to the number of learners. However, SA is absolutely faster than GA. In addition, the running time of GA does not vary very much due to the change of crossover probability and mutation probability.

Table 5.1 Running Time of SA and GA

<table>
<thead>
<tr>
<th>Number of Learners</th>
<th>Running Time (in seconds)</th>
<th>SA</th>
<th>GA</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>6s</td>
<td>77s</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>13s</td>
<td>161s</td>
<td></td>
</tr>
<tr>
<td>150</td>
<td>19s</td>
<td>242s</td>
<td></td>
</tr>
</tbody>
</table>

Above all, although SA yields a little poorer solutions than GA, it is still recommended to be adopted in the Inference Service of TaaS, because it responses in a shorter time.

5.6 Summary

In this Chapter, we have introduced the core of TaaS, the task allocation, which is designed for avoiding the confusion and the misunderstanding in the teamwork process, and letting the learners give full play to their talents. We have described a model of this problem, combining learners’ capabilities and preferences, and tasks’ difficulties. Two heuristic algorithms, GA and SA are used to solve the problem. Their algorithm details are given in Section 5.4. Experiments prove that both algorithms are feasible to complete the teamwork-enhanced task allocation, yielding the results satisfying our design purpose. We also have compared the performances of both algorithms, in Section 5.5. Due to SA’s faster running speed, we suggest that it is better to be adopted in the real implementation of TaaS.
6 SYSTEM IMPLEMENTATION

6.1 Introduction

According to the teamwork-enhanced learning flow identified in Chapter 3, the system work patterns described in Chapter 4 and task allocation algorithms introduced in Chapter 5, in this chapter we will discuss the implementation of TaaS over cloud, associating with the migration of Moodle to the Amazon Elastic Cloud Computing (EC2) infrastructure. Section 6.2 briefly introduces the well-known open-source LMS, Moodle, and its available web service APIs for extending its functions from invoking external web services. Section 6.3 illustrates the implementation details of TaaS, where some screen shots of user interfaces (UIs) are given to demonstrate the normal functions of TaaS, and a UML class diagram is used to list all the web methods supporting system work. Section 6.4 presents how to deploy TaaS and Moodle in the standardization of Amazon EC2.

6.2 Introduction for Moodle

Moodle is the abbreviation for the “modular object-oriented dynamic learning environment”, which is an open source e-learning system created by Australian teacher Martin Dougiamas based on constructivism (Moodle 2013). Profiting from its advantages, such as free, cross-platform and combination of advanced educational themes, Moodle is widely used as a capable learning management system not only in education, but also in development, training and business activities. A prominent
feature of Moodle is that it allows dynamic modular design, which means it can be taken apart as modules and then be rebuilt together on users’ demand. Users feel free to add and delete learning content to Moodle during the learning process. Developers can modify the common functions of Moodle by altering the relative modules. To add specific functionalities, they can extend the construction of Moodle by adding modules and creating plug-ins. Technicians can deploy Moodle at any platform supporting PHP, typically in the environment PHP+Mysql+Apache. The core modules of Moodle are system management module, course management module and learner module. The system management module is mainly used by system administers to maintain the normal operation. The course management module provides easy use to teachers for organizing learning resources and publishing guidance to learners. Learners participate in the learning process through the learner module to accomplish the assignment arranged by teachers, read online materials and record their results. Moodle also offers discussion forum, chat room, online calendar, etc., as assistance for daily learning (Dougiamas and Taylor 2003).

At present, Moodle is mobile-accessible by calling on from either the browser or the client (Moodle 2012). The practitioner and researcher in educational area suggest that migrating Moodle to the cloud is a modern idea to benefit m-learning by many conveniences, which is proven as a feasible project in many cases (Fleming 2011; Moodle 2012; McNaught 2011). Hence, we choose the Moodle as our experimental platform to work as the role of cloud-hosting LMS in our designed learning flow. For the composition of learning flow, the interaction and interoperation between each two services are highly relied on the well-defined portals in web service
standardization. Thanks to the release of the latest version of Moodle, many web service application programming interfaces (APIs) are provided. Those APIs expose some functions of Moodle in the form of web service, so that those functions are accessible through other web services or applications using one or a number of protocols, as well as the Moodle can be added functions from external web services through those well-defined portals. At present, the protocols of REST, SOAP and XML-RPC are enabled in the web service API of Moodle (Moodle 2012). From the web service roadmap of Moodle, we select its APIs needful for allowing it to interact with TaaS for compositing the teamwork-enhanced learning flow, which are listed in the Table 6.1 (Moodle 2013).
### Table 6.1 Needful Web Service APIs of Moodle (Citing from Moodle.org)

<table>
<thead>
<tr>
<th>Area</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>core_user</td>
<td>core_user_get_users_by_id()</td>
<td>Get users by id</td>
</tr>
<tr>
<td>core_user</td>
<td>core_user_get_course_user_profiles()</td>
<td>Get course user profiles by id</td>
</tr>
<tr>
<td>core_user</td>
<td>core_user_get_users_by_field()</td>
<td>Retrieve users information for a specified unique field (e.g., cohort, grouping or a group)</td>
</tr>
<tr>
<td>core_course</td>
<td>core_course_get_contents()</td>
<td>Get course content (including user data, such as learners’ grades)</td>
</tr>
<tr>
<td>core_course</td>
<td>core_course_update_courses()</td>
<td>Update courses (including user data)</td>
</tr>
<tr>
<td>core_cohort</td>
<td>core_cohort_get_cohorts()</td>
<td>Get cohorts</td>
</tr>
<tr>
<td>core_cohort</td>
<td>core_cohort_get_cohort_members()</td>
<td>Get cohort members</td>
</tr>
<tr>
<td>core_group</td>
<td>core_group_get_groupings()</td>
<td>Get groupings</td>
</tr>
<tr>
<td>core_group</td>
<td>core_group_get_course_groupings()</td>
<td>Get all groupings in specified course</td>
</tr>
<tr>
<td>core_group</td>
<td>core_group_assign_groupings()</td>
<td>Assign groups from groupings</td>
</tr>
<tr>
<td>core_group</td>
<td>core_group_unassign_groupings()</td>
<td>Unassign groups from groupings</td>
</tr>
<tr>
<td>core_group</td>
<td>core_group_create_groups()</td>
<td>Create new groups</td>
</tr>
<tr>
<td>core_group</td>
<td>core_group_get_course_groups()</td>
<td>Return all groups in specified course</td>
</tr>
<tr>
<td>core_group</td>
<td>core_group_delete_groups()</td>
<td>Delete all specified groups</td>
</tr>
<tr>
<td>core_group</td>
<td>core_group_add_group_members()</td>
<td>Add group members</td>
</tr>
<tr>
<td>core_group</td>
<td>core_group_delete_group_members()</td>
<td>Delete group members</td>
</tr>
</tbody>
</table>

In Table 6.1, the differences of cohort, grouping and group should be explained. In the definition from Moodle, the “cohort” refers to numbers of learners in an organization, with a larger scale than “grouping” in which several “groups” may be involved. Typically we can take the example that the all learners enrolled in one school form a “cohort”, wherein the learners who choose the same course belong to
the same “grouping”, in which they may be divided into several “groups” to process their team learning due to education demands. Actually, the meaning of “group” is as same as the “team” always mentioned in this thesis.

6.3 Implementation of TaaS

We choose the PHP as the development language of TaaS. Besides the five web services, we have prepared a User Management module to handle the daily management of user and control accounts, where the single-sign-on (SSO) technology is embedded to allow the users (teachers and learners) to log in TaaS easily if and only if s/he has a valid Moodle account.

There are several ways to realize SSO, such as cookies-based, agent-based, broker-based and token-based. The appearance of a recent technique named SAML extremely simplifies the SSO (Hebig, Meinel et al. 2009), especially in web service and cloud environment. SAML is the short for security assertion markup language, which is a new XML-based protocol approved by OASIS and implemented by open-source organization openSAML (Cantor, Kemp et al. 2005). If there is a communication about login between two systems, SAML can transmit the identity information and the request message in the form of XML schema and SAML protocol. So no matter on what environment these two systems operate, if both of them support SAML, the login request can be approved. SAML can transmit based on SOAP or some other protocols.
There are three roles in SAML federation environment. The first one is the identity provider (IdP) that plays as the asserting party providing the request including the identity information. In this paper, the IdP is Moodle. The second one is the service provider (SP) which uses identity information to make the decision about allowing or rejecting the request. In this paper, the SP is TaaS. The third one is the user, which is the learner or the teacher in this thesis.

Moodle provides a plug-in to deal with the SAML authentication. So we just need to install and activate it, and configure Moodle as the IdP and TaaS as the SP in it. The procedure of SSO is shown as Figure 6.1.
Figure 6.1 The Procedure of Using SAML to Realize SSO Between TaaS and Moodle

On the other hand, in the mobile cloud-based learning, there are still a lot of learners using non-Moodle LMSs to conduct learning activities. We also consider the situation that TaaS can be utilized exclusively without the cloud-hosting LMSs, for
business companies to train employees towards collaborative work in the form of task-related virtual teams. So TaaS also holds a completed registration mechanism within its User Management module, by which users (teachers and learners) can create their new accounts for logging in to obtain the service from TaaS.

We create a new database of TaaS to store newly generated teamwork-related data during the execution of learning flow, such as learners’ KLS capabilities (\(KLS\)), preferences \((P)\), etc, as well as the basic learning information, such as learner name, course name, etc. If the user logs in by SSO using Moodle accounts, his basic learning information is invoked from Moodle through its web service APIs, primarily from the areas of core_user and core_course. In addition, the new database exposes a web service API for remotely invoking from LMSs other than Moodle.

Next, we will demonstrate the working condition of the system of TaaS, bringing in some specific screenshots of UIs to explain in visual form. The screenshots are caught when we are accessing EC2-hosting TaaS through a Samsung Android Tablet, while the deployment on Amazon Cloud will be discussed in the next section.

The first step of using TaaS is login:

- If the user (teacher or learner) logs in by SSO using valid Moodle account, TaaS invoke the user’s basic information about all his/her involved cohorts (schools) and groupings (courses) from Moodle through its APIs in the areas of core_cohort and core_group. If s/he belongs to multiple groupings (courses), TaaS shows a dialog box with options to let him/her choose a unique course (grouping) for accessing services of TaaS at this time.
If the user logs in using account directly registered on TaaS, the teacher user can create new cohorts for schools and groupings for specified courses, or choose existing cohorts s/he belonging to and one of involved groupings for login at this time. Accordingly, the learner user has to choose to log in the existing cohorts and one of the existing groupings at this time.

After the login is successful, the main page of the teacher user is shown as Figure 6.2.

![Figure 6.2 The Main Page of the Teacher User](image)

The teacher user can click buttons to launch several events.

- The “Import course learner” is used to invoke the information about all learners of this course from the web service APIs of Moodle (if the teacher is non-Moodle user and does not log in by SSO, this button is no effect).
• The “Modify structure of survey” button is used to enter into the page for changing the structure of surveys, where the teacher user can add/delete questionnaires in any questionnaire set, add/delete the questionnaire sets, or change the content of any questionnaire (Recall Section 4.2).

• The “Check learner information” is used to enter the page for showing all learners’ user names, clicking each of which the main page of whom is shown.

• The “Check team formation” is used to check the formation of teams whatever are the original teams or the expert teams of the jigsaw classroom, or the ultimate teams after task allocation (recall Section 4.4).

• The “Check published tasks” is used to check all the tasks with their containing subtasks published in the Bulletin Service.

• The “Check submitted tasks” button is used to open the page for showing the completed tasks submitted by the ultimate teams, where the teacher can download the files and give each of them a final mark by filling a number in a textbox. Once the teacher fills in the final mark for a learner, the Monitor Service processes the learner’s total mark according to the penalty mechanism (recall Section 4.6). If the learner is a Moodle user, his total mark is synchronized to Moodle through invoking its core_course_update_course API.

• The “Set automatic operation” button is used to open the page where the teacher can set the automatic run-up time for starting the three stages of jigsaw classroom respectively and triggering the Inference Service for computing task allocation.
- The “Check learners’ total marks” button is used to open the page for showing all learners’ total marks after processing by the Monitor Service.

- The teacher can manually trigger the three stages of jigsaw classroom, by choosing one of the three options in the dropdown list, where the options “Form original teams”, “Form expert teams” and “Reform original teams”. If the teacher and his/her responsible learners are Moodle users meanwhile, the newly generated team information is automatically synchronized to Moodle through its APIs in the area of core_group. (It should be a dropdown list if showing on a computer or laptop, but the appearance is a little different showing on a touch-screen tablet, where three options will popup if touching the textbox-like window.)

- The teacher can choose one of the two options on demand from the dropdown list (idem) next to the text “Organize ultimate teams and allocate subtasks” to trigger the work of the Inference Service, whether grouping teams in the first scenario or the second scenario, using simulated annealing algorithm (recall Chapter 5). If the teacher and his/her responsible learners are all Moodle users, the newly generated team information is automatically synchronized to Moodle through its APIs in the area of core_group.

- The teacher can pre-set the deduction weights for the learner’s each “unsatisfactory” outcome \( a \) and each “warning” \( b \), the max times allowed for getting “unsatisfactory” \( m \), and the percentage of the final mark given by teacher \( y \) in the total mark, by filling the textboxes respectively and clicking “OK” buttons for confirming (recall Section 4.6).
An example UI of checking team formation is shown as Figure 6.3 and Figure 6.4, where the former shows example information of expert teams in jigsaw classroom and the latter shows example information of ultimate teams grouped by the Inference Service. The data about learner and tasks are randomly generated.

Figure 6.3 Example UI of Checking Team Formation (Expert teams in Jigsaw Classroom)
Figure 6.4 Example UI of Checking Team Formation (Ultimate Teams Grouped by the Inference Service)

The main page of the learner user is shown as Figure 6.5.
Learners’ capabilities in five areas are summarized in a bar chart and can be checked by their teammates. His/her team information and task information are shown on the bottom of the main page.

The learner can click the “Participate in survey” button to use the Survey Service, where s/he is asked to choose whether for self-assessment or peer-assessment before beginning to answer the five sets of questionnaire. An example UI of answering questionnaires is shown as Figure 6.6.
S/he can click “Publish task plan” button or “Check alternative tasks” to use the Bulletin Service, entering new pages to fill the related contents in textboxes. An example UI of publishing task plan is shown as Figure 6.7. The structure of tasks is scalable, by clicking the corresponding buttons for adding/reducing subtasks and adding/reducing the stages of subtasks. Based on his/her authority for a task, s/he also can set its subtasks’ difficulties in KLS when publishing and preferences when checking, which are shown in Figure 6.8 and Figure 6.9, respectively (recall Section 4.4 and Table 4.1).
Figure 6.7 Example UI of Publishing Tasks in the Bulletin Service

Figure 6.8 Example UI of Marking Subtasks’ Difficulties
S/he can click the “Submit periodical outcomes” button to obtain an upload link for submitting periodical outcomes, which are transferred directly to his/her coordinator. Given a learner is also the coordinator for one of his/her teammates, s/he can click the “Coordinate teammate’s work” button to deal with this job. The example UI for process mutual supervision is shown as Figure 6.10.
If a vote is held inside a team because a team member’s in-progress work is always unsatisfactory, the other team members can click the “Vote” button on their own main pages to express their decision, by choosing “warning” or “continue” in the subsequent pages (recall Section 4.6).

The status of the message box changes when any new announcement arrives or any new activity happens, which notice what should be done in the next steps of team learning activity. Some typical messages are shown in the Figure 6.11.
Figure 6.11 Example UI of Message Box

The UML class diagram of the whole system of TaaS is shown as Figure 6.12, where each abbreviation can be referred to Chapter 4 and Chapter 5. Each web method can be invoked by Moodle, other cloud-hosting LMSs or other web services through SOAP messages based on analysing the WSDL of its corresponding web service of TaaS.
6.4 Amazon Cloud

The Amazon company provides numbers of products, all in the series of Amazon Web Service (AWS), to help developers and practitioners to establish their
computing solutions over cloud, which are usually constructed in the conjunction of several kinds of AWS. Currently, Amazon offers a free usage tier for one-year trial of several kinds of AWS in finite usage. Because the purpose our system implementation is to test and prove that TaaS can work in the cloud environment and flexibly interact with cloud-hosting Moodle, we are benefited to choose products in the free usage tiers of AWS to establish the cloud environment for our system implementation, where the Elastic Cloud Computing (EC2), the Simple Storage Service (S3) and the Elastic Block Store (EBS) are mainly concerned.

The EC2 is a typical kind of IaaS that gives opportunities for hosting systems in the remote environment and with easy steps of deployment to achieve the resizable compute capacity of Amazon Cloud. The consumer needs to launch an instance, which is one or a cluster of computers, to run as a virtual server for the system s/he wishes to host. The instance we launched is a micro Windows instance, with 613MB memory and 64-bit platform, running in the region of “Virginia, US east”.

The EBS provides persistent block-level storage volumes for EC2. In our implementation, the EBS is used to store the Amazon Machine Image (AMI), which is a special type of pre-configured operation system and virtual application software which is used to create a virtual machine within the EC2. There are numbers of ready-made AMIs are available in the Amazon marketplace, we choose one “Ubuntu” images to run on the instance we have launched.
The next step is to set the security group of our launched instance, in which we open the portal 22 for secure shell (SSH), 80 for HTTP, 8080 for HTTPS and 3306 for Mysql. Then we bind an elastic IP with the instance.

The AWS adopts the SSH to permit the secure data communication, which is, however, not built on the Windows, the operation system on our local computer. So we need to draw the aid of SSH tools. Following the guidance of Amazon documentations, we use the PuTTYGen (Amazon 2013) to generate a key pair, and then use it as the unique identity to connect to the running instance through the Windows client of SSH, PuTTY (Amazon 2013).

Once the connection succeeds, we obtain a command window, where we can use the Linux-like command to operate the running instance. In our chosen “Ubuntu” AMI, the installers of PHP, Mysql and Apache have been already packaged. So we just need to install them sequentially in the Ubuntu operation system as the server environment. Next, we upload the packages of Moodle and TaaS to store in the S3 and install the two systems. Several relevant configurations are made up, including activating a load balancer. Hence, the Moodle and TaaS are hosted over the cloud as Domain A and Domain B, respectively (recall Chapter 3).

To enable the interaction and interoperation between Moodle and TaaS, another preparation is that we should log in the cloud-hosting Moodle as the administer to enable the “web service” and “mobile web service” functions in the “setting” tab of its system module, along with opening the protocol of SOAP for public use. So all the web service APIs of our cloud-hosting Moodle are exposed over the cloud, which
means the functions and resources from Domain A are able to be accessed through well-defined portals by TaaS or any other cloud-based applications using standard-matched SOAP messages.

Having done all above steps, the deployments of TaaS and Moodle are finished. Typing in the elastic IP in the browser, both these cloud-hosing systems are able to be accessed at present.

### 6.5 Summary

In this chapter, we have introduced the implementation of TaaS. To achieve the teamwork-enhanced learning flow, the LMS we choose is a well-known open-source one, Moodle, which has several web service APIs allowing its functions being invoked from external applications. The SSO between Moodle and TaaS is realized in the User Management module of TaaS, to provide an easy login for the Moodle user, which also holds its own registration mechanism. Several typical UIs are shown to identify how to utilize TaaS to gain the functions for promoting team learning, from the view of teacher user and learner user. The procedure of deploying both Moodle and TaaS over the Amazon EC2 infrastructure in conjunction with two kinds of AWS (S3 and EBS) is described in Section 6.4.
7 CONCLUSION AND RECOMMENDATION

7.1 Summary

The theme throughout this thesis is how to enhance teamwork performance in the mobile cloud-based learning. To expand the layout of our research, several topics of problems are concerned which need to be addressed separately.

Firstly, we conduct a literature review to find the relationship among “mobile cloud computing”, “mobile learning” and “teamwork performance”. In the Chapter 2, we discussed the features of cloud computing and e-learning, which are two novel concepts coming from the progress of information technology. The cloud computing evolves the current approaches of system development and deployment, and the e-learning gives more opportunities to deliver the education service. With the widespread use of wireless communication technology, both cloud computing and e-learning have their extensions to deal with the specificity of the mobile area, namely mobile cloud computing and m-learning. It is believed that embracing m-learning to mobile cloud computing benefits both the education provider and learner by bringing in substantial advantages, leading the collaborative learning becomes more and more convenient and common. The personnel structure organized to process collaborative learning in mobile cloud-based learning is mainly in two types. Therein, comparing to the virtual learning community, the virtual team is more oriented to task-related outcomes, requiring serious formation and operation. However, literature shows that the team performance of virtual team needs to be brought into forefront because it is
still affected by adverse issues, which are carried on as those of traditional team
learning or caused by the specificities of mobile environment. In that chapter, the
educational theories and related works are also introduced to lay a foundation for our
research.

Based on the issues concluded in the Chapter 2, the Chapter 3 focuses on how to
offer a new approach to promote the collaborative learning facilitated by the mobile
cloud. We compare several mainstream learning management systems to list their
functions supporting collaborative learning in order to gain the purpose of our
research, which is to orchestrate a novel learning flow containing certain types of
learning activities, following the concept of the KTLE. The learning flow should be
realized in conjunction of the Cloud-hosting LMSs and several newly designed web
services, the latter of which are therefore not to repeat the existing functions of LMSs
but to emphasize the enhancement of teamwork combining the special conditions of
mobile environment. The research methods are also introduced in this Chapter. Each
of the five novel web services, namely the Survey Service, the Jigsaw Service, the
Bulletin Service, the Inference Service and the Monitor Service, performs its own
superiorities, according to one or more modules of the KTLE. The integration of
them is a service-oriented system, Teamwork as a Service, which delivers functions
in the form of service which allows users to easily obtain one-stop learning
experience through mobile devices to engage in the procedure of KTLE in order to
enhance teamwork performance.
The Chapter 4 expands the introductions given in Chapter 3, presenting more details of the work patterns of those web services. To make the involved mechanisms clearer to understand, the UML diagrams are employed to explain the rules of service interaction. The effect of each web service is to organize a certain type of learning activity, in which the concerned learners are responsible to publish and evaluate several tasks/subtasks. Subsequently, several kinds of data are generated to denote the attributes of them and their relevance. We also declare the structure of data storing and the calculating method that refines those data into concise variables. The penalty mechanism, which encourages learners to accomplish their allocated subtasks in specific time and satisfactory quality for any stage, is realized in the Monitor Service, which also automatically accumulates the deductions to output a total mark for each learner.

The Chapter 5 introduces two heuristic algorithms to find the optimal solutions for the task allocation. The problem is defined in a math model and the optimization purposes are described by objective functions. The computing procedures of the both algorithms are discussed in detail, particularly about how to generate and accept new solutions thereby replacing previous solutions with poorer fitness.

The Chapter 6 illustrates the working conditions of TaaS. We choose Moodle to work with TaaS altogether for executing the teamwork-enhanced learning flow over the cloud, where the two domains of systems exchange data through well-defined web service APIs. Some typical UIs are shown to determine how to input data to TaaS as well as in what shapes the outputted results are shown on the screen.
7.2 Discussion

For learners, mobile learning is definitely a novel and helpful way to obtain knowledge, which gives them more convenience to learn at anywhere and utilize fragmentary pieces of time. Gaining wide acceptance, it is believed that deploying LMSs over the cloud brings in many advantages to promote m-learning, so that TaaS is somehow naturally should be cloud-based to store data and hold the computing process outside of the mobile devices. Though learners may not care about or truly understand what conditions of background the systems and applications supporting m-learning run on, they have actually benefited from the ability of the cloud computing. The most obvious advantage brought by the cloud is that the requirement of their mobile devices is dismissed.

Why we decide to design TaaS as service-oriented and cloud-based rather than in other types is partially due to the above reasons, but not limited to these. In addition, for practitioners and education providers, with the concept of XaaS that every application over the cloud delivers its functions in the form of service, using cloud computing actually economizes their budget and simplifies their work, by which they need not to spend time and financial resources on choosing and owning servers. If they adopt TaaS to enhance learners’ teamwork performance in the mobile cloud-based learning, the repetitively deployment of TaaS can be replaced by renting the service from the provider (i.e. those who are us in this thesis) hosting the TaaS by one-time large-scale deployment. Therein, they do not need to train technicians or teachers do not need to get familiar with the technical details of daily operation of applications. Moreover, as we design TaaS to be linked to work with various cloud-
hosting LMSs operated by different education providers, the consumer volumes of TaaS would be the sum of those of all linking LMSs. The suddenly increasing visitor volumes may cause the running of normal server breakdown, but the cloud is more robust. It is because there are numbers of load balancers being provided in the cloud, which dedicate to permit the availability of system hosted over it. Likewise, the unexpected data loss is no longer an issue that puzzles the operation of TaaS, which can be protected by the well-enabled disaster recovery mechanisms provided by the cloud.

The main advantages of the cloud computing are not only the capabilities of huge storage and massive data handling, but more important in bringing a reached agreement that applications have scalable structure. On-demand service is a prominent feature of cloud computing. Thanks to web services in the cloud environment being loosely coupled, the architecture of service-oriented systems is flexible. TaaS is therefore customizable depending on the teaching plan in mobile cloud-based learning, which means parts of these five web services can be de-coupled or re-coupled to work individually to meet special requirements. For example, when quick learner information gathering is the sole preparation step embedded in the course, we only need to manipulate the Survey Service to support the online survey and result collection. Similarly, if we plan to extend TaaS’s structure, we are not faced on a huge complexity but can enjoy its scalability so as to flexibly add web service to it or to composite it with another XaaS products.

In any case, the use of the integrated system is recommended for enhancing teamwork performance. In many cases in the mobile environment, learners’ behavior
and mental abilities vary greatly, while teamwork is more related to human-to-human interaction rather than human-to-machine interaction. Even though collaborative learning tools are not rare in the current Internet environment and the use of social networking is improving the convenience of digital communication, the learning activities of virtual teams are still difficult to maintain, because of such problems as incompatibilities between different learners’ abilities and learning styles. Thus, it is useful for an online system to contribute to the guidance and regulation of what learners do offline, so as to maintain progress towards their common goals. Additionally, as TaaS exposes standardized service-oriented APIs that allow dynamic integration over the web, they can be easily invoked by external services and are seamless to work in conjunction with LMSs for building a function-complete virtual learning environment.

TaaS has the ability to solve problems which could undermine the work of the whole team. The main enhancements of teamwork performance brought by TaaS are the following:

- The mature KTLE theory helps learners to structure the essential competencies necessary for team learning in a succinct way, which can be executed smoothly using mobile devices.

- Learning styles are identified by means of KLS, in order to explore learners’ strengths. It aims to improve efficiency by ensuring that the completer is the ‘expert’ in the subtask s/he is entrusted with. For example, a learner who is better at active experimentation and concrete experience is appropriate to be allocated a subtask of “accommodating”, whereas a subtask of “assimilating”
suits a learner who has stronger skills of abstract conceptualization and reflective observation.

- Knowing one another is very useful to help teammates prepare for their following work. However, in the mobile learning environment, learners find it difficult to introduce themselves due to their limited interactions. TaaS does not focus on describing learners’ social features, hobbies or resumes, but rather gathering necessary data about learners’ individual capabilities. It directly introduces learners by a visual tool, bar chart, thereby establishing a culture of trust within the team.

- The cloud-based jigsaw classroom gives learners opportunities to discuss and understand the different dimensions of team purpose, with the principle that “a better way to learn something is to teach it to someone else”. Similarly, they are encouraged to assimilate others’ viewpoints.

- Learners participate in real practices to explore the nature of team context, and critically demonstrate how to solve problems. Learners plan for themselves based on their actual situations and skills. Thus, their tasks are achievable.

- Though challenging, it is essential for team members to pre-plan a way to achieve their target successfully. Detailed task schedules are necessary to avoid confusion and the waste of resources. They also have opportunities to edit the content of published task collaboratively, by which the ideas from multi-learner are synthesized, reducing the one-sidedness of tasks published by unique learner.
• Learners who see their work as habits rather than choices are more likely to perform better, and have more motivation when faced with difficulties. So we take their preferences into consideration in TaaS.

• We formalize the problem of team grouping into a mathematical task allocation, using SA to achieve the multi-objective optimization that lets learners exploit their talents fully and complement each other’s talents. The arbitrariness of team formation is minimized, and some negative interpersonal factors in traditional team learning are avoided.

• Creatively importing peer-assessment in the process of team learning means that mutual supervision is now available so that learners can keep pace with each other. It promotes positive competition within the team, and decreases the chance that the whole team’s outcome be delayed because of a few under-performing members. To some extent, TaaS is also able to detect and prevent a student from claiming another’s work as their own, or to arouse learners to accomplish their allocated subtasks step by step rather than to put off doing their work until the last minute before deadline.

7.3 Future Work

Because this thesis introduces the work for a Master degree research project with a duration one and a half years, time is neither adequate for considering the specificities of the mobile environment overall, nor for implementing and testing the full functions of TaaS. There are still issues remaining to be addressed in the future work.
We will offer a client program of TaaS based on the Android mobile operation system, which would be helpful to provide easier use than accessing through the browser.

The data used in illustrating the performance of both GA and SA are randomly generated. We may collect them from the real learning scene that utilizes TaaS to demonstrate the feasibility of the teamwork-enhanced task allocation. Multiple case studies will be also brought in to analyse to what extent TaaS can facilitate learners in mobile cloud-based learning.

The approach to gathering learners’ capability values in \textit{KLS} and \textit{CT} may be not only limited in the self-assessment and peer-assessment, which are comparatively a little subjective. These capabilities can also be summarized from learners’ behaviours of how they always learn in the mobile context, how they use cloud-hosting LMSs and how they perform in previous team learning. We may establish a mechanism to collect their historical data that describe those behaviours, and use the approach of data-mining to extract the meaningful ones. A rule of mapping those data to our defined five capabilities values (four in the 4-tuple \textit{KLS}, and the other is \textit{CT}) will also be studied so that no matter how the original data come from, the math model of task allocation still makes sense and the algorithms we created are still able to find the optimal solution to adapt each learner to their suitable individual assignment in the team learning.

The uncertainty of the mobile environment would be taken into consideration. The mobile learning context may be situation-dependent or location-dependent,
impacting the condition of team learning as well. Using the mobile device as a sensor, the data denoting the constantly changing location and external situation can be caught. In this case, the purpose for organizing virtual teams is different. We may need to establish a new model to abstract more kinds of learners’ attributes while the algorithms should also be altered accordingly to discover a way to infer an optimal solution considering more indexes.

This thesis pays more attention on enhancing the virtual teams’ teamwork performance, targeting on the issues existing in mobile cloud-based learning concluded from literature review. Nevertheless, in the same learning environment, the virtual community is identically a significant type of learner cohort. Given that learners participating in the virtual community are not required to accomplish deliverables as well as they are not evaluated based on their final outcomes, they obtain more freedom than learning in virtual teams and are unnecessary to follow our designed teamwork-enhanced learning flow all along. Considering those differences, how to facilitate their learning is related on recommending learners into their suitable communities. We will attempt to use some clustering algorithms to realize the organization of personnel structure of the virtual community, based on learners’ similarity, interest or some other attributes. And some rules are also need to be defined to permit the harmony of community. Findings of the new research is recommended to be implemented in web services in order to be integrated into TaaS to extend its functions, so that the novel TaaS would be able to deal with all types of collaborative learning and enhance learners’ performance in the mobile cloud-based learning.
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