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Research paper

Dynamic Service Adaptation Framework for Context Aware Mobile Cloud Learning Using Semantic-Based Approach

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Abstract

Current developments in IT involving mobile technology and cloud computing have also offered a modern way of teaching and learning. Effective learning methodologies that meet the learners' requirements as well as support learning resources (LR) with high flexibility, mobility and accessibility are currently the most key contribution of this technological advancement. Hence, Mobile Cloud Learning (MCL) has been introduced to boost the feature of m-learning that has already been on the market. MCL comprises of services that integrate with each other which are learning, assessment, feedback and analysis. These services need to be monitored, and continuous enhancement and evolvement are also required in the account of new learners' requirements for the upgrading of services or maintaining the Quality of Services (QoS). Service-oriented systems need to be enhanced through a dynamic adaptation process during runtime to sense and react to the learners' context or device's context known as context awareness to provide a better user experience. This is where ontologies and rule-based approaches are used for context representation, descriptions, and reasoning mechanisms to support the semantic discovery and matching of services. QoS consideration is essential to ensure the efficiency and correctness of the services offered during the adaptation process. Thus, this paper describes dynamic adaptation framework that leverages on a semantic-based approach for context-aware mobile cloud learning. This framework aims to support in-service adaptation by considering contextual information and QoS using ontologies and rule-based approaches.

Keywords: *Dynamic Service Adaptation; Context Aware; Mobile Cloud Learning; Semantic-Based Approach*

1. Introduction

Recently, complex and long-running systems have been developed in the context of mobile learning because these system systems need to remain flexible and evolvable. This will enable them to meet learners and teachers' requirements of learning environments and provide sufficient learning resources. There is a necessity to simplify the software solutions to accommodate the inconsistent demand for flexibility and increasing the systems' efficiency which in themselves are the dilemmas faced by developers. To overcome the problem, a dynamic adaptation of services in the context-aware system which is made up of a composition of services known as Service-Based Application (SBA) is offered.
Dynamic adaptation should be able to operate in a large-scale open environment and during runtime, where service may often show up and disappear at any time [1]. Dynamic adaptation of services operates during the system runtime. This process is important since the system will continue to operate without any human intervention and no interruption whenever new requirements or changes in the user's requirement a occur. The adaptation process should also consider functional and non-functional requirements as the main aspects of the services substitution or modification.
One of the reasons to support dynamic adaptation is the system is constantly aware of the changes in term of context [2]. Context is defined as any information that can be used to characterize the current situation of an entity. One of the promising ways to support dynamic adaption of services in the context-aware system is semantic-based approach [3]. Knowledge is represented using a well-defined meaning by using ontologies [4]. Ontology provides a formal representation and shared comprehension to a specific knowledge or domain of interest that helps to resolve semantic heterogeneity [5][4]. Ontology helps to provide three major advantages which are: (i) to achieve interoperability among SBAs, (ii) to facilitate communication between human beings, (iii) to improve quality and design of the SBAs [4].
There are some challenges faced by the current research where related works [6][7][8][9][10][11] found that a combination of adaptation approaches provides enriched information about the service and users' contexts in their adaptation processes. This is in comparison to an individual approach that provides weak support in terms of context representation. Besides, network availability, as well as the device's battery level, should be considered when serving LRs to the learners as they can get easily distracted if it takes a long time to load and display the learning content [12][13]. Thus, QoS should be considered in term of the response time and services availability. In addition to that, the correctness of the service adaptation should be in accordance with the context changes [14][1].
This paper comprises Section II that presents the background information about the dynamic adaptation process in context-aware mobile cloud learning. Related works on service adaptation framework discussed in Section III. Section IV presents a review

of the related works. Section V discusses the conceptual framework of dynamic adaptation in context-aware mobile cloud learning. Section VI comprises the study of the MCL system.

2. Background Study

2.1. Mobile Cloud Learning (MCL)

Mobile cloud learning is a combination of mobile learning and cloud computing which is the ability to use any mobile devices that connects to network access [12][13]. The main goal of MCL is to provide learners with personalized learning environment by considering their knowledge background, cognitive abilities, and their knowledge level. The key feature that has to be included in the MCL system is a dynamic organization of learning content, learning diagnosis and selection of learning strategies. According to Mobile Cloud Learning Recursive Model proposed by [15], MCL comprises of four recursive services which are learning, assessment, communication, and analysis as shown in Fig. 1. These services have a direct impact on student learning experience.

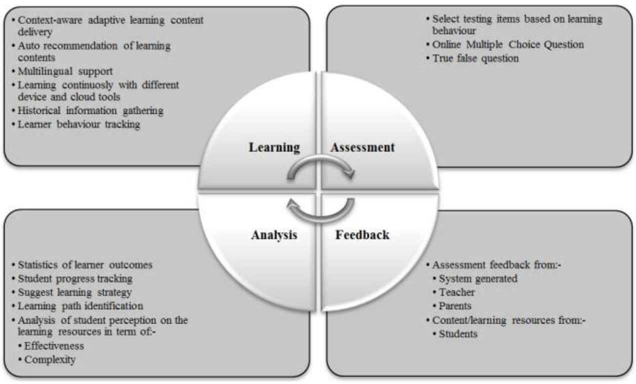

Fig 1: Mobile Cloud Learning Recursive Model [15]

The MCL recursive model provides advantages to learner context by capturing their learning activities for in-depth research and analysis. It also provides support for continuous learning, and the learning content is accessible for multi-platforms. There are different types of MCL equipped with e-learning technology depending on their perspectives.

With modern technology, several researchers applied context-aware environment into MCL. Context-aware is one of the additional aspects of MCL that can help in the reasoning process to retrieve and provide added educational resources for learners [13]. Context-aware helps mobile cloud learning to be more flexible and allows for adjustments depending on learners' needs. The responses from learners using context-aware MCL are positive and encouraging because it shows better learning behaviors since they are a flexible, manageable, meets learners' needs and provides a 'fun' way of learning [16], [17]. Context aware system is described in the next section.

2.2. Context Aware System (CAS)

The context-aware system can be described as a software system that has the abilities to adapt their behaviours according to the perceived context or situation, without explicit user intervention. Several works have been conducted to formalize the meaning of context in the computing field, yet the standard definition has yet to be agreed upon. Brézillon et al. defined context as information that characterizes the interaction between application, humans, and environment [18]. While Schilit et al. defined context as identities of a nearby entity or people, location, objects and any changes of the objects [19]. The most common definition of context that has been used is defined by [20]. Context is formally defined as "any information to describe the entity's situation in which the entity can be a place, person or object between a user and application themselves." Context can be categorized into two dimensions, extrinsic and intrinsic [20]. Extrinsic or external dimensions refers to the context that can be measured by a sensor such as sound, touch, temperature, light, location and many others. Intrinsic or internal refers to internal context such as user's interaction, learner's goals, emotional state and task to complete.

The general concept of context awareness is the ability of an application to discover the contextual information such as the user's location, language, device's information or nearby devices. This concept was first introduced by [19] where they defined context awareness as the ability of an application to discover and react to the changes of user's context. Brown et al. defined that context awareness application can change its behavior depending on user's context [21]. In addition, [20] considers an application as context-aware if the application gives relevant information and services to users based on contextual information obtained from the users themselves.

In the context-aware system, the dynamic adaptation should be aware of changes in its context, adaptation policies and SLAs. The monitoring process is conducted in the running system, and dynamic adaptation is triggered if there is any violation of SLA arise, changes in user's context, system upgraded or system failure [22]. Thus, dynamic adaptation applied to the context-aware system by considering the contexts behaviour.

A number of context-aware systems have been developed and applied in many domains and discussed in [23] for instance, in e-health environment. Guermah et al. [24] in their context-aware system has adopted the Web Service Modeling Ontology (WSMO) in their E-health system where low-level context properties such as location, time and language are described in the system ontology. Based on these properties, dynamic adaptation triggered the system to find the nearest pharmacy whenever situation component called NearestPharmacy is active. Besides, Guermah et al. [25] who proposed the E-health system described their user's context by using Web Ontology Language (OWL). Dynamic adaptation is triggered if abnormal blood-sugar-level is detected and a warning alarm will be sent to the corresponding patient.

In an e-commerce system, Alferez et al. [2] in their research developed an online bookstore at Orange Country Bookstore (OCBS) that allows customers to search their desired book before proceeding to online payment. Dynamic adaptation of services is performed if there is any interruption during the payment. There are several contexts has been captured to perform the dynamic adaptation such as book info, credit card info, payment info, and user's info. OWL technology is used to represent these contexts semantically.

Likewise, in the smart environment technology, Hoftberger et al. [26] proposed a temporally predictable framework for service substitution embedded in a real-time system which is the Smart Car System. Dynamic adaptation process needs to be executed without shutting down the car system as it involves humans' life. Whereas, Han et al. [27] developed a smart building system which is called the Building Automation System (BAS). The system is also known as a heart of the building as it controls all the other components, devices, software, and hardware. This work mainly focuses on how to deal with different types of devices from different kinds of third parties and managing those devices. The dynamic adaptation of this system is triggered if there are any changes in context such as temperature or humidity.

In addition, Widad et al. [28] developed the Context-Aware Transactional Service (CATS) for room reservation system in a hotel. The system considers user's location, connectivity, and preferred language to help users to find an available room from nearby hotels. These contexts are semantically described in Environment Descriptor and Context Descriptor Meta model. Dynamic adaptation of services is triggered if there is any interruption during payment to find the available services provided by different providers. Several research had adopted this match and substitute method to replace failed or no longer available services [29].

Context-aware system is also being developed for the emergency response system. Ontology-Supported Case-Based Reasoning (OS-CBR) system introduced by Amailef et al. [30] supports the decision maker to give a prompt response to emergencies. OWL is used to represents the input of SMS text message from users during an emergency. Dynamic adaptation process will be triggered using predefined semantic knowledge in case the old solution conflicts with the new requirement. Users will be informed regarding the emergency, and the process continues to select new cases from the case repository.
All of the applications stated above are some of the context-aware systems which have been applied in various domains. The contributions provided by the context-aware systems can be in the form of contexts changes, dynamic adaptation process, and the technology used.

2.3. Dynamic Service Adaptation

Adaptation can be defined as a process of modification, substitution or removal of the services in SBAs in order to satisfy new requirements, to fit with the new situation dictated by the environment, or violation of Service-Level Agreement (SLA). Adaptation process can be further classified into two different types which are static adaptation and dynamic adaptation. Static adaptation refers to the shutting down of the system and requires manual adaptation whereas, dynamic adaptation refers as an automation process of changing the behaviour of the system without stopping the system and no human intervention is involved [2].
Dynamic adaptation of the service is an execution process that dynamically changes the service composition by adding, removing or replacing the components. The dynamic adaptation process is important since the system will continuously operate without any human intervention and no interruption whenever new requirements or changes in the user's context emerge.
Over the past years, many researchers had come out with different approaches of service lifecycle for the development of SBAs, but most of them are lacking in the adaptation or evolution process [31]. An efficient mechanism and service lifecycle need to be used to adapt the services based on the situation and context where SBAs is mostly created in the context-aware system.
The life-cycle proposed by S-Cube network of excellence applies the service engineering concept with the aim of covering all the software engineering aspects including the requirements of gathering, analysis and identifying, constructing, deploying, evolving, quality assuring, maintaining and monitoring the services [32]. These phases are separated into two parts which are the evolution and adaptation parts. The evolution part covers the design iteration which leads to the redesign of the service application to adapt to the new requirements whereas; the adaptation is needed during runtime which is used when adaptation needs are addressed while the system is running.

2.4. Dynamic Service Adaptation in Context-Aware System Using Semantic-Based Approach

The leverage of Semantic-Based approach in dynamic service adaptation is mainly because they offered enough representation capabilities to develop a formal representation of the contextual model. This model can be reused, shared and extended for the need of specific domains but can also be combined with other sources of data. Schmidt in his research managed to satisfy all the demands in context modeling using a semantic-based approach such as incompleteness and ambiguity, level of formality, richness, and quality of information, partial validation and applicability to existing environments [33].
Semantic-based approaches for dynamic adaptation in the context-aware system have been acknowledged by researchers and developers to have five categories which are ontology-based solution, rule-based reasoning, middleware solution, code-level approached and message interception [34].
Ontology-based solution is an instrument for modeling contextual information, capturing knowledge and providing formal representation and high expressiveness for reasoning techniques. Rule-based solution consists of context-aware conditions and behaviours that are described in the form of if-then-else. Middleware solution allows low level details visible and transparent for the developer. The model-driven approach aims to transform from meta-models to executable code. Code-level approaches enrich the programming languages' syntax and logic for context execution. Message interception approach performs service adaptation by intercepting input or output messages and modifying them without affecting basic services' behavior and its functionalities yet, this approach still lacks reasoning strategies and context modeling.
Semantic-based approach defined by [3] represents knowledge using ontologies [4]. Ontologies have been used in the context-aware system because it provides reasoning for the context information and helps to promote knowledge sharing in dynamic and open systems. Ontologies provide a well-described semantic that helps in enhancing the efficiency of the reasoning process of context information as well as enables the service interoperability. Context can be modelled as ontology as it is one of the specific knowledge. The common web service ontology is the Web Ontology Language for Service (OWL-S), Web Service Modeling Ontology (WSMO) and Semantic Web Service Description Language (WSDL-S) [3] [4].

2.5. Modeling Mobile Learning Context Data Ontology

Mobile devices in education enable the learning process to be flexible as they take into account the mobile context such as temporal, physical and social context. This context information can be modelled as an ontology in the educational aspect to enhance the learning process. Thus, ontology can be used to classify the learning objectives, educational or curriculum contents with different level of granularity and mobile context data [35][36]. According to the learning context ontology in Fig. 2, a relationship between curriculum data, learning objectives and mobile context can be created. A mobile context represents the learning environment and condition; curriculum contents represent the subjects, topic, and subtopic while the learning objective represents the purpose of the learning.

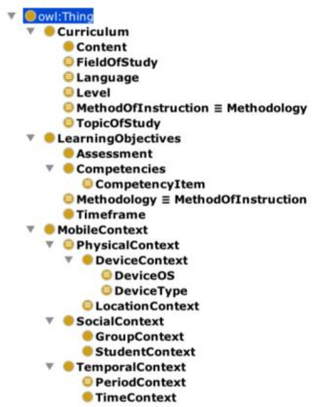

Fig 2: Mobile Learning Context Ontology (Protégé) [36]

3. Related Works

Several studies in the dynamic adaptation for context-aware systems using semantic-based approaches are reviewed. The learning environment should be interactive and fun. Since traditional learning activities only support static interaction, mobile learning comes into action and provides benefits in real time to facilitate students in their learning process and assessment.

Learning English is extremely popular among non-native English-speaking country and vocabulary is important in order to make others understand what we are trying to say. Thus, Chen and Li developed a personalized context-aware learning system (PCULS) for learning English vocabulary according to learners' location, time and vocabulary abilities [37]. These learners' context is essential in the reasoning process to provide suitable learning content to the specific learner. PCULS composed two sides which include the client's side and the server's side. Client-side aims to recommend new word to the learner that comprises of six intelligent agents and three databases, whereas the server's side is responsible for collecting English vocabulary from websites. It comprises two databases, one English course classification agent and one data management interface.

Learning with multimedia content is much efficient than a contextual content. With this in mind, Karadimce and Davcev developed a mobile application, Mobile Cloud Computing (MCC) that is aware of the network connection of the mobile user, measured by QoS [38]. This application is applied to middleware which is SOAP (the Simple Object Access Protocol) where the user can easily send their requests which will be processed within the mobile cloud learning environment. The dynamic adaptation of multimedia content faces issues with compatibility to different mobile devices.

Another research that supports mobile learning is Accessible and Personalized Mobile Learning System for (APMLS). This system is developed by Madani et al. [6] for learners with disabilities. The changing mobile context is taken into consideration the learning process such as location, time, physical environment and device status. The adaptation process of the system is divided into levels which are labelled as design-time level and run-time level. This system applied specifications generated by the IMS Global Learning Consortium which are IMS Accessibility Learner Information Package Specification (IMS ACCLIP), IMS AccessForAll Metadata Specifications (ACCMD) and IMS Learning Design (IMS LD) Level B to describe the primary resources and generate an adapted learning route according to the learner's disability type and mobile context information. Whereas XML file is used to describe the available alternatives equivalents resources.

A context-aware adaptive and personalized system developed by Gomez et al. [7] is Units of Learning mobile Player (UoLmP). The semi-auto adaptation helps students to find available trainer according to the trainer's expertise and availability based on the input inserted by the students. Adaptivity and personalization in mobile learning are referred to as the process of fitting the system's functionalities; behavior, on the other hand, corresponds to the educational needs (goals), personal characteristics (learning styles) and particular circumstance (location and movement in the environment) [39].

Harchay et al. [8] developed a Service-based framework for student training assessment in a mobile environment known as the Mobile Semantic Web Assessment Personalization (MobiSWAP). The semantic-based approach has been used to perform the adaptation process. Context information is varied depending on the learner's need in a mobile assessment situation. Different learners have their own abilities, profiles, and needs.

Ubiquitous learning (u-learning) is a new learning paradigm that can be achieved not only through formal but also informal social learning modalities. It enables learners to identify and seize the learning opportunities to improve themselves. Karoudis and George formulated a framework for designing personalized learning path using selected pedagogical strategies [9]. The framework consists of the Presentation Layer, Adaptation layer and Personal Data Locker (PDL). The presentation layer is responsible for presenting the content of PDL in an understandable and meaningful way in order to support the reasoning process. Adaptation Layer encompasses rules for selecting both content and concept for the learning path. PDL layer is where the learners' profile, preferences, and knowledge are stored. Learning goal that is associated with the domain ontology can also be found in this layer for knowledge sharing purposes.

A Mobile Response System (MRS) system has been proposed by Fuad and Deb which facilitates in-class interactive problem solving using mobile devices [10]. To minimize the instructor's workload, this system uses cloud services in the infrastructure. Thus, it helps students to have transparent access and make the system extensible to any discipline. This system automatically prompts the students' devices to do exercises that are synchronized with the lecturer's material. Hence, the student will actively interact by providing feedback to the lecturer, ask questions or vote in the existing pool since MRS support for anonymous communication and MRS also includes analysis of students' performance.

Makwana et al. [11] presented a context-aware system which is a Web-Based Learning Platform (WLP) that adapts the learning contents according to the learner's parameter. This parameter is classified into two main categories which are context awareness and content adaptation (refer to Table 1). Context awareness considers three aspects: to be aware of the user's level of maturity, device configuration and cognitive load of the learner. While content adaptation can be categorized into network, device and resource adaptation. These three adaptations are based on the parameter passes linked to context awareness [11]. The description of mobile learning parameter discussed in Table 1.

Table 1: WLP Mobile Learning Parameter Description [11]

Context Awareness	
User Maturity	Learner's age is grouped into different categories, Junior (11-17 years old), Adult (18-45 years old) and Senior (46-65 years old). Each group consists of different contents.
Device Configuration	Responsive system design in considered since the system needs to adapt with changes in browser compatibility and screen resolution.
Cognitive Load	Cognitive load is important factor for user satisfaction. The higher the cognitive load, the lower user satisfaction in learning. In WLP, the short question or quizzes are provided depending on the learner's age group and the difficulty increase after each correct answer from learner.
Content Adaptation	
Resource Adaptation	CPU and RAM usages are checked by the application where these resources use their optimal level to reduce the loading time during the learning sessions.
Device Adaptation	Operation system such as Android and IOS platforms and browsers are considered since WLP contents can be presented in various screen resolutions and bowsers.
Network Adaptation	The displayed contents are based on the internet connectivity. If lower bandwidth, only basic images are displayed and if higher bandwidth, high definition images and videos are displayed.

4. Review of Related Works

Several types of research in the different domains have been selected and analyzed as these frameworks have adopted the dynamic adaptation of a context-aware system in SBAs. This is illustrated in Table 2. There are eight types of research; most of them combined several approaches to represent their contexts such as Ontology-Based solution, Rule-Based Reasoning and Model-Driven approach [6][7][8][9][10] and [11]. The individual approach helps to provide sufficient information about the services and context for dynamic adaptation process. Whereby, the combination of the approaches enriches the context representation of the services and contexts during the adaptation process. Thus, it helps the context reasoning process to find the equivalent services correctly and efficiently [8][7].

Table 2: Example of researches on dynamic adaptation in context-aware system using the semantic-based approach

M-learning System	Context Changes		Adaptation Approach	Technology Used	Automation
	Extrinsic	Intrinsic			
PCULS [37]	Learner's location	Time, and vocabulary abilities	Rule-Based	Fuzzy rules	Self-adaptation
MCC [38]	Network connection of mobile user	None	Middleware	Simple Object Access Protocol (SOAP)	Self-automation
APMLS [6]	location, physical environment and device status	Time	Model Driven & Rule-Based	IMS Global Learning Consortium, XML	Self-adaptation based on context changes
UoLmP [7]	Location and movement	Learning styles	Rule-Based, Model Driven & Code-Level	Context Aware Meta Model	Human-in-the-loop
MobiSWAP [8]	None	Learner's profile and age group	Ontology-Based & Rule-Based	REST, RDF, SPARQL	Self-adaptation based on context changes
ULF [9]	None	Learner's profile, time	Ontology-Based & Rule-Based	The Experience API (xAPI)	Self-adaptation
MRS [10]	battery level, internet connection,	Language, learner input, time,	Code-Level & Ontology-Based	Cloud IaaS and OWL	Self-adaptation based on context changes
WLP [11]	Device configuration	Learner's maturity and cognitive load	Ontology-Based & Rule-Based	OWL is used to describe user's context	Self-adaptation based on context changes

Most of the research considered extrinsic and intrinsic contexts to perform adaptation such as user's profile, user's location, preferred language, device information, user's interaction, goals or time. The technologies used are varied within the framework where most of them use OWL-S to represent their context. In terms of the automation of the adaptation process, most of them are self-adaptive frameworks [37][38][6][8][9][10][11] and only UoLmP by Gomes et al. [7] involved human-in-the-loop adaptation as it allowed user to choose their context if it cannot be detected automatically. In addition, functional requirements were taken into account while performing a dynamic adaptation of services, but most of the researches like [37][38] and [6] did not take NFRs into consideration such as effectiveness, availability, reliability, security, and correctness. All in all, context representation facilitates the service adaptation process to find semantically equivalent services, while the combination of adaptation approach enables the system to yield rich contexts representation and services representation and the quality attributes.

5. Conceptual Framework

A review of the dynamic adaptation of services in a context-aware system using semantic-based approaches has been presented. The adaptation approaches, the technology used, and contexts captured according to the respective domain have also been explained. Different domain requires different contexts that needed to be captured while at the same time considers different non-functional requirements. An interactive system such as learning system needs information from the user to improve their cognitive ability and satisfaction. Numerous research has focused on self-adaptation rather than human-in-the-loop adaptation as it enables the user to concentrate on the system without any interruption whenever a new request comes in. Thus, this section describes our framework for dynamic adaptation in mobile cloud learning application by considering two learner's context-dimensions which are extrinsic and intrinsic, and on the combined usage of semantic-based approaches such as ontology-based solution and rule-based reasoning.

The framework of Dynamic Adaptation of Context-aware Mobile Cloud Learning (DACAMoL) is presented in Fig. 3. This framework is designed based on the runtime environment to capture the learner's context and device's context from a mobile device application and to capture semantic reasoning to provide specific learning resources (LR) to the learners. As depicted in Fig. 3, the mobile device is used as a context sensing layer that continuously probes the user's profile and preference, user's input, device status and network connectivity status. The contexts are captured in numeric values, Boolean values, literals and time-stamped values. These contexts are then stored in their respective repository. Learner's input and learner's profile are stored in the Learner Repository while network status and device status are stored in the Device Repository. Whereas, the Content Repository stores any LRs that are retrieved from the server-side. These contexts are transformed using ontology representation which is then passed to the Dynamic Adaptation Management.

To address the research challenges of this paper, the framework combines an adaptation approach which is an ontology-based solution and rule-based reasoning that aims to support and enrich context representation. The DACAMoL framework also considers the status of the network, device's battery availability and correctness of the adaptation process for better learning experiences.

Dynamic Adaptation Management can be categorized into four main phases. Phase 1 is Context Acquisition; Phase 2 is Learner or Device Centric Adaptation, Phase 3 is Ontology Reasoning, and Phase 4 is Service Discovery that comprises Rule-Based Reasoning. Learning Ontology Management will be referred during Phase 3 before proceeding to Phase 4. List of LRs are discovered from the Service Discovery located in the server, based on perceived context, and they needed to be ranked to find the most equivalet services. These phases are discussed below.

5.1. Phase 1 (Context Acquisition)

Context acquisition is a process of acquiring the contextual information from context servers: In this framework, there are two ways to acquire context which are either sense or manually provided. Sense method is where the contextual data such as battery level and network status are sensed by the device. These contexts are then stored in the device's databases which are Learner Repository and Device Repository respectively. Whereas, manually provided is a method where learners are manually providing their contextual information via predefined settings such as their name, age, gender and preferred language. This method can be used to collect as many information according to the needs.

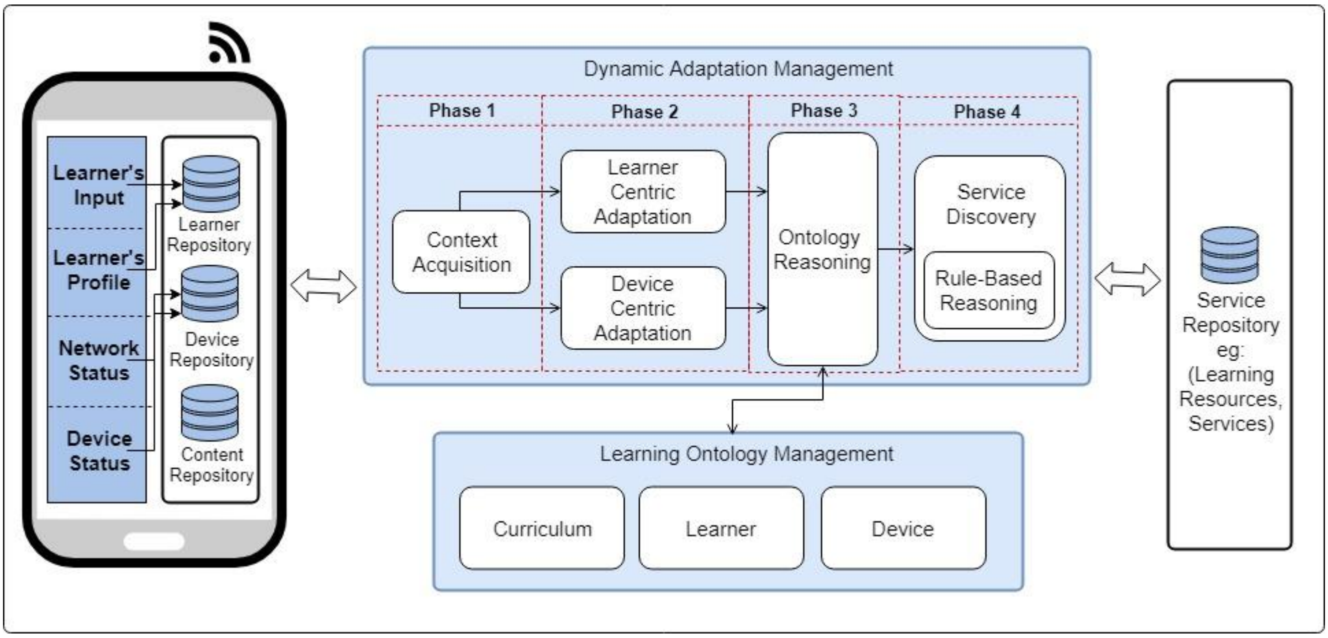

Fig 3: Dynamic Adaptation of Context-Aware Mobile Cloud Learning (DACAMoL) Framework

5.2. Phase 2 (Learner Centric Adaptation and Device Centric Adaptation)

Learner-Centric Adaptation and Device Centric Adaptation are two components in Phase 2 that are responsible for aligning the adaptation process according to their contextual acquisition. Learner profile and learner input from Phase 1 are pushed to learner-centric adaptation component, whereas network status and device status are pushed to device-centric adaptation component. The best mobile cloud learning application is the application that can provide learning resources based on the learners' background knowledge, their preferences, goals as well as the learner's device status. Thus, the contextual information correlates with the adaptation process that will be performed.

5.3. Phase 3 (Ontology Reasoning)

The context is defined in OWL-S during Phase 1 which it will be used in Phase 3. This will allow the reasoning process to correspond to the subject domain. To allow the reasoning process, the context is mapped on the ontology that resides in the Learning Ontology Management. The ontology described in the learner and device specifications is according to the British educational ontology amendment [36]

5.4. Phase 4 (Service Discovery and Rule-Based Reasoning)

The mapping result from Phase 3 will be used in Service Discovery component to search any available and equivalent LRs from the Service Repository. The discovery process browses through available LRs from the repositories according to the context representation, functional requirements, and QoS. The discovery process uses a rule-based approach to find available LRs from the repository. After the pull, all available and equivalent contents from the repository based on the rule-based approach that consists of if-then-else rules are used to rank the LRs. This process aimed to construct a suitable LRs to meet the learners' needs based on their contextual parameters. If the searching results consisted of more than one LRs, the best LR is ranked based on the QoS level. If no LRs are available, the LR should appear unavailable in the mobile learning application before a new LR is constituted.

6. The Case Study

In this section, we present an exemplary educational scenario that aims to describe how a learner's contextual information can be used for adapting the learning flow in Context-aware Mobile Cloud Learning (CAMCL). The aim is to provide a better learning experience and learning resources. To be specific, we have adopted a learning scenario used for primary students in Malay subject related to a "Let's learn the Malay language" task. A typical scenario would be of 8 years old students, using their Android phone to connect to CAMCL. The students interact with CAMCL interface where they specify the activity that they want to learn. CAMCL follows the mobile cloud learning recursive model [12][15] which provides four main services which are learning service, assessment service, feedback service and analysis service.
A use case diagram that describes the functional requirements in CAMCL is presented – refer to Fig. 4. Two main users are involved in this application which is the learner and event API. In the beginning, the learners on their own provide contextual information to the system such as their name and ages on an individual basis, while the device information such as the battery status and network status is automatically sent to the event API. Based on these learners' contextual information and device's contextual information, the learning activities flow, and learning resources affected by the environment and services adaptively deliver the contextual information.
Then, the learner is presented with a set of adapted activities and materials that he/she needs to complete and deliver. The learner may browse the available activities such as "Learn Alphabet" or "Learn Syllable". Each of these activities comprises learning levels such as Level 1, Level 2 and Level 3. To achieve a higher level in each learning module, they need to complete the lower level before proceeding to the higher level. By completing these two learning modules, learners can proceed to answer the online Multiple-Choice Questions (MCQ). This assessment module consists of 3 levels, and the learner needs to get a high score to proceed to a higher level.
The learner's input or score is considered as learner contextual information which may result in the complexity of learning resources. Let us assume that the battery level of the device is 70 percent connected to telco service. Learners may stick to the same level whenever they get a poor score. Besides, learners are able to

give feedback related to the learning resources as well as the assessment module. Event API analyzed the learner's performance and learner's input before suggesting a suitable learning strategy for learners. Event API is alerted about each learners' context and the device's context in order to reconfigure a suitable learning resource for a specific learner.

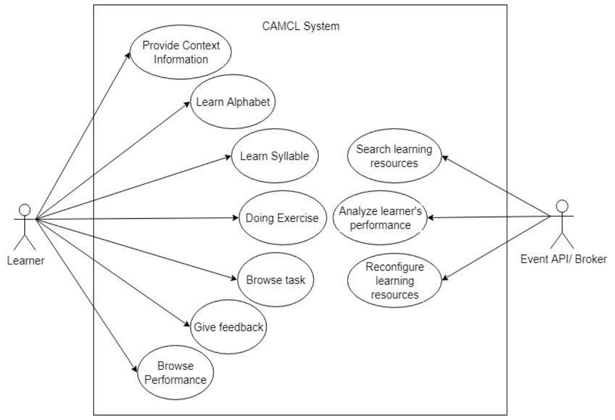

Fig 4: Use case diagram for CAMCL

Based on the use case scenario, the process is described using CAMCL framework below:-

6.1. Phase 1 (Context Acquisition)

Learner contexts and device contexts are captured accordingly (refer to Table 3). A string of data instances such as age and language are categorized under the learner's profile context element and stored in the learner's repository. Another learner context such as the learner's scores is captured in an integer format and the learner's feedbacks in a string format. These learner inputs are stored in the learner's respective repository.

The device context which comprises the network status and device status is captured and stored in the device repository. Network status identifies whether the device is connected to the internet or otherwise. A device status considers the device's battery level which would be from a low-level context to a high-level context. The low-level context captures the information about the battery's level in an integer format which is from 0 to 100 percent. These low-level contexts are then converted to high-level contexts using identified rules (refer to Table 4).

Table 3: The required contextual information

Context Element	Data Instance	Data Storage
Learner profile	String: {age}	Learner repository
Learner Input	Integer: (0<= Mark <=100) String: {learner feedback}	Learner repository
Network Status	String: {connected, not connected}	Device repository
Device Status	Low level context to high level context (Battery level) String: {low, medium, high, full, charging}	Device Repository

Based on Table 3, low-level contexts are converted to the high-level context using the identified rules. The battery level is considered as Low if the range is 0 to 24 percent. The battery is *Medium* if the battery level from 25 to 49 percent, whereas *High* battery level is from 50 to 74 percent and *Full* battery level is from 75 to 100 percent. The device is in *Charging* state whenever the device is plugged in.

Table 4: Low level context to high level context

<table>
<tr><th>Low Level Context Battery Level (%)</th><th>Rules</th><th>High Level Context</th></tr>
<tr><td>0-24</td><td>int level =
batteryStatus.getIntExtra(BatteryManager.EXTRA_LEVEL, -1);
if (0<level<24){
batteryLevel = low}</td><td>low</td></tr>
<tr><td>25-49</td><td>int level =
batteryStatus.getIntExtra(BatteryManager.EXTRA_LEVEL, -1);
if (25<level<49){
batteryLevel = low}</td><td>medium</td></tr>
<tr><td>50-74</td><td>int level =
batteryStatus.getIntExtra(BatteryManager.EXTRA_LEVEL, -1);
if (50<level<74){
batteryLevel = low}</td><td>high</td></tr>
<tr><td>75-100</td><td>int level =
batteryStatus.getIntExtra(BatteryManager.EXTRA_LEVEL, -1);
if (75<level<100){
batteryLevel = low}</td><td>full</td></tr>
<tr><td>0-100</td><td>int status =
batteryStatus.getIntExtra(BatteryManager.EXTRA_STATUS, -1);
boolean isCharging = status ==
BatteryManager.BATTERY_STATUS_CHARGING
|| status ==
BatteryManager.BATTERY_STATUS_FULL;
if (status = true){
batteryLevel = charging}</td><td>charging</td></tr>
</table>

6.2. Phase 2 (Learner Centric Adaptation and Device Centric Adaptation)

Contextual information is extracted from the given scenario where the adaptation process will be based on context changes caused by the learner and device. The learner contextual extraction for learner-centric adaptation is depicted in the Context Changes column on Table 5. The age of the learner is eight years old. During the start-up of the application, the learning resources are set to Level 1 as it is specifically created for the eight-year-old learner. Level 1 is considered the easiest learning resources compared to Level 2 and Level 3. Thus, if the eight years old learner can score between 40 to 59 percent during his/her first assessment, he/she may answer a more difficult question during the second assessment.

Since device contexts are also extracted, device centric adaptation is considered. Based on the scenario, the device is connected to the internet, and the battery level is 70%. Hence, the LRs display high-resolution images as stated in Table 5.

Table 5: Adaptation process based on context changes

Adaptation Type	Context Changes	Adaptation Process
Learner Centric Adaptation	Age = 8	Learning Resources: { **Level 1** (Age = 8); Level 2 (Age = 9); Level 3 (Age = 10)}
	Mark = 0 to 100 (%) Poor (0-39) Average (40-59) Good (60-79) Excellent (80-100)	Assessment question: { Level 1 (Easy); Level 2 (Medium); Level 3 (Hard)}
	Feedback	Suggest suitable learning strategy
Device Centric Adaptation	Network status = Connected	Learning Resources: { LRs with high resolution image (**ifConnected**); LRs with low resolution image

		(ifNotConnected)}
	Battery Level = (70%: High)	Learning Resources: { LRs with high resolution image (**High**, Full, Charging); LRs with low resolution image (Low, Medium)}

6.3. Phase 3 (Ontology Reasoning)

The contextual data are mapped into ontology in the form of hierarchy concept and relationship among the subject domain. There are three main subjects; curriculum, device context, and learner context. Each activity that uses the case study is extracted and mapped onto the ontology respectively- refer to Fig. 5.

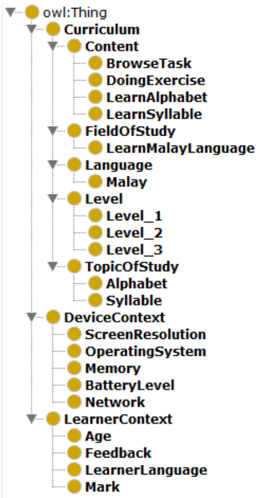

Fig 5: Ontology for the study (Protégé)

Listing 1 shows a concrete example of the study that describes Learner-context and Device-context using OWLS. The listing shows the learner's context such as age, preferred language, and their feedback. While the device's context describes the screen resolution, battery level, memory space, operating system and network connection.

```
<?xml version="1.0"?>
<rdf:RDF>
    <context name="Learner">
        <owl:DatatypeProperty rdf:ID="Learner">
            <contextparameter rdfs:domain rdf:resource="#Learner_Age"/>
            8</contextparameter>
        </owl:DatatypeProperty>
        <owl:ObjecttypeProperty rdf:ID="Learner">
            <contextparameter rdfs:domain rdf:resource="#Learner_Language"/>
            malay</contextparameter>
            <contextparameter rdfs:domain rdf:resource="#Learner_Feedback"/>
            Good Content</contextparameter>
            <contextparameter rdfs:domain rdf:resource="#Learner_Mark"/>
            89</contextparameter>
        </owl:ObjecttypeProperty>
        <owl:DatatypeProperty rdf:ID="Availability">
            <contextparameter rdfs:domain rdf:resource="#QoS_Constraints"/>
            99%</contextparameter>
        </owl:DatatypeProperty>
    </context>
  <context name="Device">
      <owl:DatatypeProperty rdf:ID="Device">
          <contextSubCategory name="ScreenResolution">
              <contextparameter rdfs:domain rdf:resource="#width" type="static"/>
              208</contextparameter>
              <contextparameter rdfs:domain rdf:resource="#height" type="static"/>
              320</contextparameter>
          </contextSubCategory>
          <contextSubCategory name="Battery">
              <contextparameter rdfs:domain rdf:resource="#TotalBatteryLevel" type="static"/>
              100</contextparameter>
              <contextparameter rdfs:domain rdf:resource="#BatteryLevel" type="dynamic"/>
              70</contextparameter>
          </contextSubCategory>
          <contextSubCategory name="Memory">
              <contextparameter rdfs:domain rdf:resource="#TotalMemory" type="static"/>
              2</contextparameter>
              <contextparameter rdfs:domain rdf:resource="#AvailableMemory" type="dynamic"/>
              1.3</contextparameter>
          </contextSubCategory>
      </owl:DatatypeProperty>
      <owl:ObjecttypeProperty rdf:ID="Device">
          <contextparameter rdfs:domain rdf:resource="#OperatingSystem" type="static"/>
          Android</contextparameter>
          <contextparameter rdfs:domain rdf:resource="#Network" type="dynamic"/>
          connected</contextparameter>
      </owl:ObjecttypeProperty>
      <owl:DatatypeProperty rdf:ID="Availability">
          <contextparameter rdfs:domain rdf:resource="#QoS_Constraints"/>
          99%</contextparameter>
      </owl:DatatypeProperty>
  </context>
</rdf:RDF>
```

Listing 1: Context representation using OWLS – Learner and Device Context

Despite representing the learner's context and device's context using OWLS, the services offered by the system are described as well. There are several types of services which are included in this system which are learning the alphabet service, learning the syllable service, exercise service, feedback service and learner's performance service. Learner alphabet service is described below: -

```
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#">
    <owl:Ontology rdf:about="">
        <owl:versionInfo></owl:versionInfo>
        <rdfs:comment></rdfs:comment>
        <owl:imports rdf:resource="http://www.w3.org/2002/07/owl"/>
    </owl:Ontology>
<!--  Created: Thu Apr 19 14:13:17 2018  -->
    <owl:Class rdf:ID="alphabet"></owl:Class>
        <owl:DatatypeProperty rdf:ID="level1">
        <rdfs:domain rdf:resource="#Alphabet"/>
        <rdfs:range rdf:resource="#Level1List"/>
    </owl:DatatypeProperty>
        <owl:DatatypeProperty rdf:ID="level2">
            <rdfs:domain rdf:resource="#Alphabet"/>
            <rdfs:range rdf:resource="#Level2List"/>
    </owl:DatatypeProperty>
    </owl:DatatypeProperty>
        <owl:DatatypeProperty rdf:ID="level3">
            <rdfs:domain rdf:resource="#Alphabet"/>
            <rdfs:range rdf:resource="#Level3List"/>
    </owl:DatatypeProperty>
</rdf:RDF>
```

Listing 2: Learn alphabet service represented using OWLS

Based on Listing 2, the service is described accordingly, and this service will be used if there are any reasoning processes that are labelled as service in Phase 4.

6.4. Phase 4 (Service Discovery and Rule-Based Reasoning)

The most popular semantic rule used to find equivalent services and rank the service is Event-Condition-Action (ECA) with typical form *IF-THEN-(ELSE)* or WHEN (event) WITH (condition) THEN (action). Fig. 6 shows the adapted functional model of the CAMCL that comprises of activities that will be performed sequentially through the defined rules; Rule 1, Rule 2 and Rule 3. Basically Rule 1 will be triggered if there are changes in the learner's context or device context. Hence, if there is a need in adaptation, this rule is used to find any available service. Rule 2 is used to select and lock the best service among the discovered services. Once the best service is selected, these services need to be adapted to the current system using Rule 3.

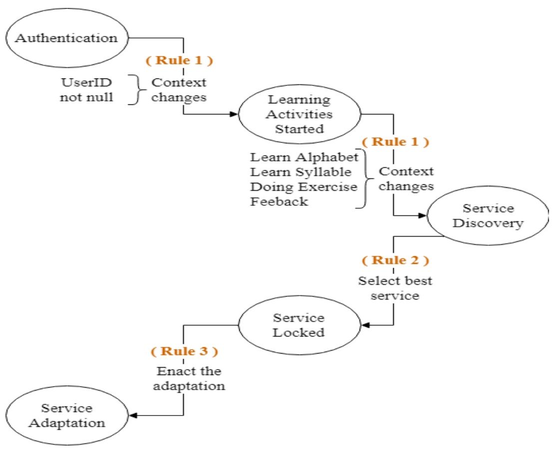

Fig 6: Adapted functional model of CAMCL

7. Conclusion

In conclusion, basic knowledge of dynamic service adaptation of context-aware in mobile cloud learning is represented in this paper. Studies on related work and their gaps are discussed. A conceptual framework is designed and described which an aim to support the service adaptation process by considering two learner's context-dimensions which are intrinsic and extrinsic as well as QoS properties. The semantic-based approach is used to represent the contextual information which is ontology-based-solution and rule-based reasoning. The DACAMoL framework aims to address the research challenges by combining the adaptation approach which is an ontology-based solution and rule-based reasoning to support and enrich context representation. The framework also considers the status of the network, the availability of the device's battery and the correctness of the adaptation process for better learning experiences. As emphasised earlier in the research challenges and the framework, future works could be refined and the framework tested by developing a tool for confirming the concept in the MCL environment.

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