

## Construction of an Online Examination System with Resumption and Randomization Capabilities

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### Abstract

Online Examination is an essential ingredient in electronic and interactive learning, however, in educational environment most of examinations are done in the classical paper-based way due to the lack of resumption capability when power/network/physical computer's component failures. For this reason, adopting and developing an online examination system acts as an active research area in recent years. This paper reviews the state-of-the-art and the-art-of-the-practice for nine general-purpose online examination systems found in the literature, as well as, some dedicated industrial systems based on seven elected intertwined features; namely: secure login, resumption capability, multi-instructor, random question selection, random questions distribution, random choice distribution, and portability implementation method. Even though, the implementation of these systems is promising, however, these systems have some bleeding points. For instance, by practicing the existing examinations system, some challenging features are found and others are missing. Among these features; namely: the resumption capability and the combination of randomization features are missing in the reviewed systems. Fix and build from earlier works, this paper proposes an Online Examination System (OLES) that addresses all the elected features to facilitate adopting online examination. OLES is based on spiral model and TCP-IP client/server networking and implemented using Java programming language and Derby database. Finally, a comparison of the proposed OLES versus other related works to distinguish its unique features, and some recommendations for future work are provided.

**Keywords:** E-learning; distributed learning environments; architectures for educational technology system; online examination system; software engineering; Resumption; cross-platform; client/server; TCP-IP socket.

### 1. Introduction

In education, the concept of E-Learning (Electronic Learning) has grown rapidly from distance learning to virtual classrooms towards the online courses and online examinations. Associations are trying to move from a paper-based environment to a paperless environment. People today through big and small tests, with test having become frequently faced issue. In addition, the testing system merits at being fair and open. With the increasing of Internet applications scope, computer net-assisted teaching is becoming a focus of current educational reform; online examination system because of its easy to use, time-intensive, forms and other features has more attention [1-2]. Online exam can improve the standards of student's examination whereas in the traditional examination systems pen and paper are used which require more effort on the part of students and instructors. Online examinations are considered an important source for university exams [3-14]. Moreover, the development of network technologies has given the possibility to deliver the exams online. Thus, education can benefit from these services [3]. There are many benefits for adopting online examination system; some of essential, but not exhausted, involve: E-Learning remote exam [4] [5]; Digital evolution [8] [12]; Utilize available resources [8] [5]; Supplementary and helpful for disabled people [7]; Ease of use and archive [8] [12]; Clarity and credibility of check and grading [12]; Time saving especially in case of huge number of students [8] [11] [15]; and the beneficial effect of the E-Learning that made students break the barriers of the distance learning and expensive courses [16-18].

The process of switching from paper based work to a fully computerized work is not without difficulties. As a result, many systems have been developed in the recent years. The purpose of online examination systems is to take online exams in an efficient manner and save time consuming in checking, marking, return back the paper. The main objective of online examination systems is to efficiently evaluate the candidate fairly through a fully automated system. This system is not only saves a lot of time, but also gives swift results beside the trustiness and credibility that online examination system provides.

Even though, there are valuable online examination systems; however, these systems have vital demerits, which a little bit attention is given in the literature for addressing the power failure and/or network failure and/or physical computer component failure cases during the exam, and the randomness of the questions and their corresponding choices. Addressing above mentioned problems is the main focus of this paper. The remaining of this paper is organized as follows. Section 2 states and describes the features of online examination systems. Section 3 reviews and examines the existed online examination systems and analyzes the obtained results in a form of features requirements to facilitate further enhancements in a form of tabular check list. Section 5 states the specification and the planning of the OLES. Section 6 gives the design and implementation issues of the OLES. Section 6 evaluates the features of the OLES and compares OLES against the existed systems. Finally, Section 7 states the conclusion and gives some recommendations for future development.

## **2. Features of Online Examination System**

The existing online examination systems present a set of features [19-20]. These features are needed in order to make the functionalities of each online examination system meet their requirements to serve their purposes. The following subsections consider these features.

### **2.1 Secure Login**

This feature means that login operation to access the system could not be done without authorization check. Furthermore, users should be registered for have authorization access. The authorization data to be checked are user name and password that specified for each user [6-14]. Some system uses another authorization check such as test access restrictions by groups and Internet protocol (IP) addresses [6], student name and ID [7], matriculation number and password [14]. In addition, other techniques are used to identify the user and check if the person who is logging into the system is the right person or not; various techniques are used like biometric authentication [10], fingerprint or face recognition via webcam.

### **2.2 Resumption Capability**

As the answering exam's questions is a critical operation, any interruption due to failures can cause confusion and frustration for the student as it forces the student to take the exam again from its beginning not just continue it. Coursera [21] is an online site for courses, which provides online free courses with assessments, provides partial continuity to online exams. However, the tests answers are sent to the server to be stored to continue answering after a failure but, only within the exam duration. After the exam duration ended, the answers will be lost even if the examinee did not finish the exam. Furthermore, the student will lose his/her answers when a network failure takes place. Despite of the existing systems did not shed a spotlight on this important feature; this paper will address the resumption capability as an essential feature as far as power and/or network failure and/or physical computer's component failure are concerned. Like Coursera, other certificate issuing system (e.g., CISCO, Oracle, Microsoft, etc) has the same criteria as far as resumption capability is concerned.

### **2.3 Multi-Instructor**

As the online examination system required being structurally solid, it should have multi-instructor feature. Therefore, each instructor has his/her own privileges and tasks. In order to achieve that, the system should consist of an administrator, question builder, and exam builder. The administrator manages and controls the system, and registers the instructors. Question builder, and exam builder are responsible for creating the questions, and exams respectively. The instructor or a Registrar is responsible for registering the

students [8-10] [12-14]. It should be mentioned that according to the scale of the exam and organization, these actors could be same or different entities without the loss of generality.

## **2.4 Combination of Randomization**

The combination of randomization could be featured in online examination systems in three forms namely: random question selection, random questions distribution, and random choices distribution. The following subsections discuss each randomization feature individually.

### **2.4.1 Random Question Selection**

During the build of an exam, questions are selected from the questions tier of a database, random selection of questions is a feature performed for more secure and time saving exam building operation, which randomize the pattern of the set of question selected for an exam [7] [13-14].

### **2.4.2 Random Questions Distribution**

In examination phase, each student login to the system and request for exam's questions, for more secure and robust against cheating, random question distribution is required. In other words, this feature means randomizing the order of questions for each student. Therefore, each student gets a randomly sorted set of questions that differed from any other set of questions received by another student [9-10].

### **2.4.3 Random Choices Distribution**

To ensure security and robustness against cheat attempts during the exam, random choice distribution within each question must be performed. In other words, this feature means randomizing the order of choices within the same question received by different student. Thus, if two students get the same question, the choices of this question are randomly sorted and differed from each other in the order of choices [9].

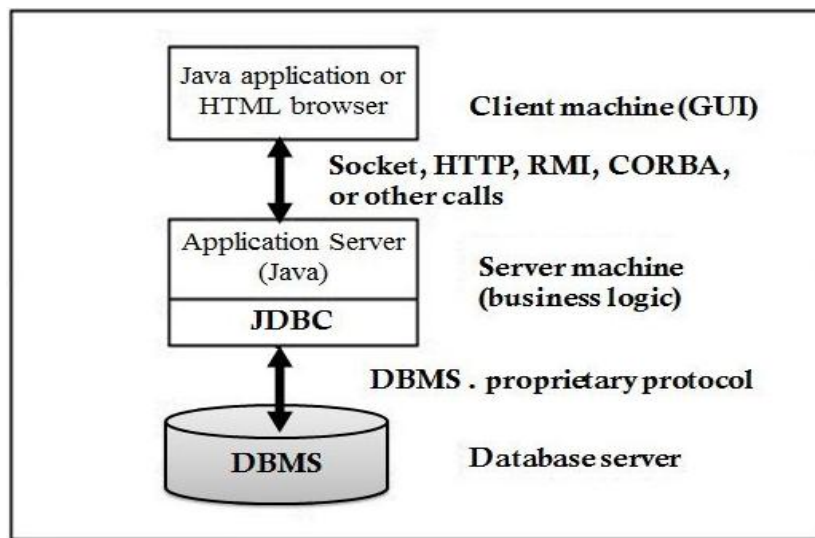
## **2.5 Portability**

This feature means that the online examination system can run on cross platform fashion (i.e., in any operating system and hardware). The online examination system consists of a server part and a client part. The server part is where the exams are created and assigned. While the client part where the examinees take the exam. These part of online examination system could be constructed as web-based [6-8] [13] or application-based [9]. In some cases, a hybrid technique used to build the online examination system, for example, the server part is application-based and the client part is web-based [10-12] [14], the following subsections discuss portability in both of application-based and web-based.

### **2.5.1 Application-Based Systems**

As the online examination system works on an Operating System (OS) platform like: Windows, Linux, UNIX, and Mac. Thus, the online examination system should be compatible with the platform that it is running on. Therefore, the online examination system depends on the platform, and that determined by what programming language and technology used in the concrete system implementation [22]. When the development of client/server model is based directly on Transmission Control Protocol/IP (TCP/IP) protocol stack, the server and the client parts build using programming languages like Java, Visual Basic, C, C++, and C#. In this case, the developed system is called application-based network system. In application-based systems, the developers are responsible for developing the client and the server sides. In addition, the developer designs the protocol handlers on both sides.

For historical and security reasons, the client is not allowed to interact with a database server directly. Instead, the user interacts with the client side, the client interacts with the server, and the server interacts with the database server. This network architecture is called multi-tier architecture [23] as shown in Fig. 1.



**Fig. 1** Multi-tier Architecture for Data Access.

When a system is implemented with Java programming language, it works on any platform, otherwise, a compiler required to perform the compatibility [24]. Java compiler translates Java source code into byte codes which represent the tasks to be executed in the execution phase [25]. Byte codes are platform independent and executed by the Java Virtual Machine (JVM) a part of the Java Development Kit (JDK) and the foundation of the Java platform. JVM is a software application that simulates a computer, but hides the underlying operating system and hardware from the programs. Any applications that JVM executes can be used in any platforms. The JVM becomes one of the most widely used virtual machines [25].

Unlike Java, if a system is built using the Microsoft's .NET, it works perfectly on Windows, but could not work on other platform, unless a specific compiler used to run the system, which implies the availability of the source code, and the compilation on each host before running the client or server application on the hosting machine [24]. Furthermore, the compiled code may be incompatible when different hardware is used (e.g., 32-bits Central Processing Unit (CPU) or 64-bits CPU).

### 2.5.2 Web-Based Systems

When the server and client parts are built using any of the following technologies and frameworks: Hypertext Markup Language (HTML), Extensible Markup Language (XML), Active Server Pages (ASP), P Hypertext Preprocessor (PHP), Java Servlet, Java Server Page (JSP), and Java Server Face (JSF), this system is called a web-based system. Normally, these frameworks and technologies are contained in a web-server. In a web-based system, the user interacts with the server through dynamic web-pages. These web pages work on web browsers. These frameworks support portability. However, it is based on HTTP over TCP/IP protocol stack.

The HTML pages can contain a script language (like VBScript, JavaScript) or special compiled Java class (Applet). The main difference between Scripting languages and Java is that they achieve portability in different ways. Normally, the scripts are interpreted each time the code run by a browser or a web-server. In Java the compiled code (byte codes) is interpreted by JVM to a native code by using Just in Time (JIT) compilation technology. Thus, Java achieved the portability of scripting language and the performance of native codes (i.e., hits the both side of the same coin).

In short, application-based examination systems are faster than web page, in addition, unlike the web-based examination systems, the client side has more resource available at the client side, and thus, can perform other functionalities like resource access, creation, update, manage temporary storage. On the other hand, web-based systems are easy to deploy to the client under the restriction of sand-box permission.

### **3. Literature Survey**

This section examines the related works on the online examination systems. In order to judge the desired features in practice, these systems are subjected to the elected features discussed in the previous section. The following subsections contain a brief description and features for existing online examination systems.

#### **3.1 SIETTE**

Guzman and Conejo (2005) proposed an online examination system called System of Intelligent Evaluation using Tests for Tele-education (SIETTE) [6]. SIETTE is a web-based environment to generate and construct adaptive tests. It can be used for instructional objectives, via combining adaptive student self-assessment test questions with hints and feedback. SIETTE supports secure login and portability features. On the other hand, the other features: resumption capability, multi-instructor, random question selection, random questions distribution and random choices distribution are missing.

#### **3.2 WETAS**

Henke (2007) proposed a web-based Test, Examination and Assessment System (WETAS) [7]. WETAS is a web-based system designed for integration into existing Learning Management Systems (LMS); this system provides an examination environment and assignments as well to facilitate database supported e-Learning Test, suitable for the pre- and post- tests of Reusable Learning Objects (RLO) as well as the remote lab entry test. WETAS is implemented using Java Applet and PHP scripts for file handling. The Applet for Knowledge Testing in Laboratory Courses (AKTLC), in contribution with a task assembler, provides tasks from (a randomly selectable) text file and performs an evaluation of the student's result, furthermore WETAS built to make new types of tasks implemented perceptively by using simple and common available text editors. It is also possible to place additional graphics inside the text of the tasks. WETAS supports secure login, random question selection, and portability features. On the other hand, the other features: resumption capability, multi-instructor, random questions distribution, and random choices distribution are missing.

#### **3.3 EMS**

Rashad et. al. (2010) proposed a web-based online examination system called Exam Management System (EMS) [8]. EMS manages the examination and auto-grading for students exams and supports conducting exams, collects the answers, auto mark the submissions, and produce the reports for the test. EMS supports secure login, multi-instructor, and portability features. However, the other features: resumption capability, random question selection, random questions distribution, and random choices distribution are missing.

#### **3.4 iEMS**

Vasupongayya et. al. (2010) proposed an interactive Examination Management System (iEMS) [9]. iEMS is a web-based application test management system, with ease of uses, rich features, flexibility, and extensibility. The iEMS supports secure login, portability, multi-instructor, random questions distribution, and random choices distribution features. However, the other features: resumption capability and random question selection are missing.

#### **3.5 WONES**

Sheshadri et. al. (2011) proposed a web-based Online Non-choice-based Examination System (WONES) [10]. WONES is an effective solution for massive education evaluation; it employs special authentication protocols to ensure transactions between the examination server and the students. WONES supports secure login, portability, multi-instructor, and random question distribution features. However, the other features namely: resumption capability, random questions selection, and random choices distribution are missing.

### **3.6 NOES**

Raj et.al. (2012) developed National Online Examination System (NOES) [11]. NOES can handle a huge number of students for administering questions on various subject, and offers dynamic paper generation. Adobe Flex, Spring, and Hibernate frameworks are used for development of the system. NOES supports secure login and portability features, the other features :multi-instructor, resumption capability, random question selection, random questions distribution, and random choices distribution are missing.

### **3.7 SBPES**

Satav et. al. (2012) proposed a Structure Query Language (SQL) Based Paperless Examination System (SBPES) [12]. SBPES is a web-based system that can present a descriptive exam format for SQL and Description Model Language (DML) statements. This application requires presenting a highly maintainable, secure platform which provides high robustness, reliable, scalable, and updatable in order to acquire new features to improve user acceptability. SBPES supports secure login, multi-instructor, and portability features. On the other hand, the other features namely: resumption capability, random question selection, random questions distribution and random choices distribution are missing.

### **3.8 OESBC**

Islam et. al. (2013) proposed an Online Examination System in Bangladesh Context (OESBC) [13]. OESBC is a web-based, efficient, flexible, and adaptable. OESBC can provide an open mode of examination meeting the needs of various Academic and Non-Academic organizations. The examination contains different types of multiple choice questions. The answers are checked and the marks obtained are stored in the database while the examiner can get the results immediately from the system in various forms such as general mark list and ranking of participants. OESBC supports secure login, multi-instructor, random question selection, and portability features. However, the other features namely: resumption capability, random questions distribution, and random choices distribution are missing.

### **3.9 CBTS**

Fagbola et. al. (2013) developed a Computer Based Test System (CBTS) [14]. CBTS is a web-based online examination system developed to address issues such as lack of timing flexibility for automation candidates log-off upon expiration of allowed time, result integrity, guaranty, stand-alone deployment, need for flexibility, robustness, designed to support the examination processes and overcome challenges framing the conduct of examination, auto- marking, auto- submission , and generation report of examination result. CBTS supports secure login, multi-instructor, and random question selection features, the other features such as resumption capability, random questions distribution, random choices distribution, and portability are missing.

Table 1 demonstrates a summary of comparison among the systems reviewed according to the features discussed in the previous section.

**Table 1** A Comparison among the Existing Online Examination Systems.

✓ ✗	Supported Feature	Elected Features							
	Not Supported Feature	Secure Login	Resumption Capability	Multi-Instructor	Combination of Randomization			Portability	Web-Based/ Application-Based/ Hybrid
	Random Question Selection				Random Questions Distribution	Random Choices Distribution			
	Online Examination Systems								
	SIETTE [6]	✓	✗	✗	✗	✗	✗	✓	Web-Based
	WETAS [7]	✓	✗	✗	✓	✗	✗	✓	Web-Based
	EMS [8]	✓	✗	✓	✗	✗	✗	✓	Web-Based
	iEMS [9]	✓	✗	✓	✗	✓	✓	✓	Application-Based
	WONES [10]	✓	✗	✓	✗	✓	✗	✓	Hybrid
	NOES [11]	✓	✗	✗	✗	✗	✗	✓	Hybrid
	SBPES [12]	✓	✗	✓	✗	✗	✗	✓	Hybrid
	OESBC [13]	✓	✗	✓	✓	✗	✗	✓	Web-Based
	CBTS [14]	✓	✗	✓	✓	✗	✗	✗	Hybrid

#### 4. Specification and Planning of the OLES

In order to satisfy the elected features discussed in section 2, this section describes the OLES specification , and the planning phase for the OLES.

##### 4.1 OLES Specification

The following list specifies what the OLES is supposed to do.

1. The instructor can enter the questions into the system through Question building phase.
2. The Instructor can set the exam through examination building phase. In addition, the OLES interacts with the student automatically.
3. The OLES offers combination of randomization features.
4. The OLES should provide the resumption capability in case of network/power/components failures.
5. The OLES supports multi instructors, with privileges for each individual instructor.
6. The OLES manages the system to build the exams for general purpose regardless of the subject.
7. Database is used to store and retrieve the questions and exam's information.

8. Secure login to the system, by three parties: administrator, instructor and student; this system tend to be used within educational facility, thus a superintendent required check student IDs of the students before the exam.
9. The OLES should support cross-platform and scalability functionalities.
10. The OLES should be adaptable for any enhancement and requirments.

## **4.2 OLES Planning**

Before going to the architectural design, it is necessary to plan the design and selection of modules to be involved in the development. As the online examination requires software applied to works over a network in order to serve the function of remote exam, the OLES consists of hardware and software pre-requisites.

### **4.2.1 Hardware Prerequisites**

1. Server and clients computers: server computer is the central computer to be connected to the other computers that act as clients.
2. Reliable network: the network connects the clients to the server needed to be active and to lower the chances of network failure and ease detect and recovery from a network failure. This implies that the organization should have a network infrastructure available.

### **4.2.2 Software Prerequisites**

1. A server and clients OSs are required to work on the server side and client side respectively. In addition, some administration setup is required to run the OLES in these machines.
2. Java programming language is proposed for concrete system implementation to realize the system. Thus, each client and server machine has a per-requisite of Java Runtime Environment (JRE) to be installed in the system. As such, the OLES supports cross-platform functionality [25-26]. In addition, Derby distributed database management system is integrated with Java Oracles Netbeans IDE version 8.0.2, which facilitates the development of the whole product using available free tools for academic research using single development environment.

### **4.2.3 Development Approach**

To establish a robust and an adaptable system, a development strategy must be taken which wrap up the process. This strategy is often referred to as a process model [23]. A process model for OLES is chosen based on the spiral model and socket TCP/IP protocol.

The spiral model is followed for the proposed OLES. The spiral model is a software process model which combines the iterative nature of prototyping with the systematic and controlled aspects of the waterfall model. It gives the potential for rapid development of increasingly more complete versions of software. During early iterations, the release might be a model or prototype. Through later iterations, gradually more complete versions of the system are realized [23] [27]. As the OLES is a network based system, the development of OLES involved socket. Socket enable communications between the clients and server, and could be either connection oriented which is TCP or connectionless which is Universal Datagram Protocol (UDP). Since, the exam requires reliable data transfer, OLES will use TCP Socket.

## **5. OLES Design and Implementation**

This section presents the architectural design, the actors, the networking protocol, failure toleration, and randomization formula.

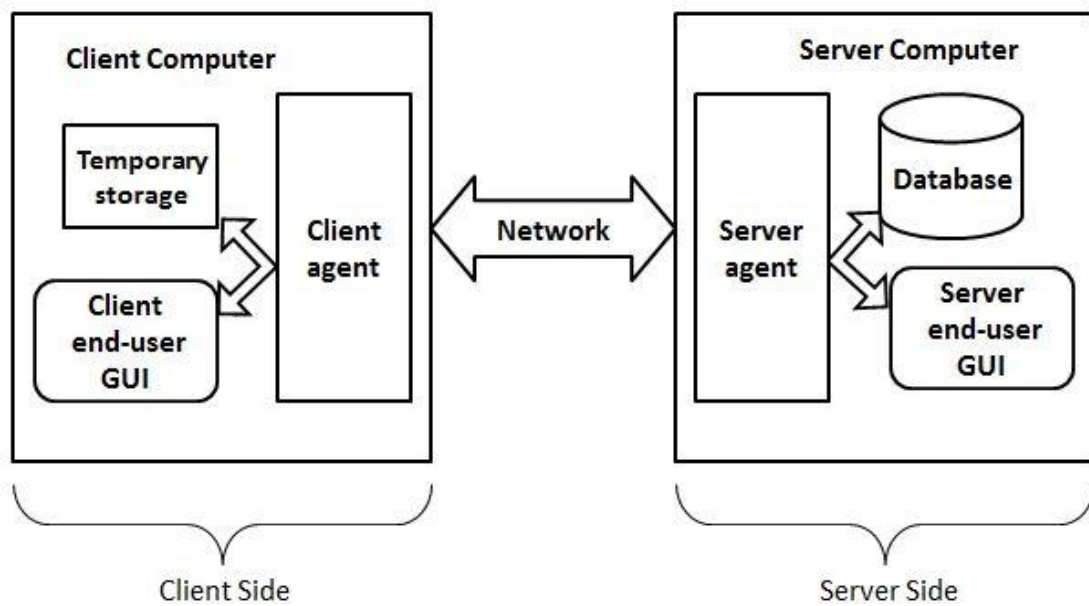
### **5.1 Architectural Design of OLES**

The main portions of OLES are the server side and the client side. Server side consists of server agent, database, Graphical User Interface (GUI), and network. Client side consists of client agent, temporary storage, GUI, and network.

Server agent controls the OLES operation phases in the server side. Similarly, the client agent controls the OLES operation phases in the client side. The client and server agents play the protocol handlers



of the system and connected via the network. Fig. 2 shows the system portions and interprets the control of both server agent and client agent.



**Fig. 2** Block Diagram of the OLES.

## 5.2 Actors in OLES

The proposed OLES performs different functions, these functions are executed by specific actors. The actors in OLES are Administrator, Instructors, Server agent, Client agent, Students, Superintendent, Database, and Temporary storage. The Administrator and the Student interact with the Client Agent through a GUI. Similarly, the Administrator and the Instructor interact with the Server Agent through a GUI.

**5.2.1 The Administrator** can perform privileged tasks in a system in both server and client sides. The tasks of the administrator are to organize the operations of the OLES. In the server side these operations are: register the instructors, and set server's IP address, port number if the organization needs to change. The administrator in client side responsible of setting IP address of the server and the corresponding port's number.

**5.2.2 The Instructor** can perform the following activities: choose the type of the questions; enter the question and the choices; choose an image for the question and for the choices (if needed) and set the question mark if desired; build the exam by choosing the questions and set the total mark of the exam; set the date and time of the exam, and set the allowed exam duration; and register candidate that will take the exam.

**5.2.3 The Server Agent** is a piece of program that controls every operation in the server side. It responds to all commands and events in the server end-user program and performs several operations; each operation has its own classes. These operations are: Login, Question Building, Exam Building, and Examination Handling in corporation with the client agent. It should be mentioned that the Server Agent can be installed on the same server machine or different machine according to the organization roles. Fig. 3 shows the state diagram of the server agent that summarizes its operation phases. The Server Agent is a state-full; which means it can recover its state in the case of failure.

**5.2.4 The Student** can perform the following activities: Enter his/her username and password to login; Take the exam by answering the questions; Submit the answers; and Get the grade.

### **5.2.5 Client Agent**

The client agent is a piece of program that controls every operation on the client side. It responds to the commands and events in the student's GUI and performs four main operations: Communicate with the server for student login and getting started phase; Manage the Examination Phase; Send the answers to the Server Agent for grading, Receive the grading, and display it to the student; and Tolerates power/network/components failure conditions. The state diagram of the Client Agent that summarizes its operation phases is shown in Fig. 4. In addition, the Client Agent is responsible for saving the student's credentials, answers, and examination state in the temporary storage to facilitate the resumption capability in the case of failure.

**5.2.6 The Superintendent** is responsible for students ID checking and superintendence during the exam.

### **5.2.7 Database**

The database is used to store the questions, questions' marks, selected questions for exam, exam mark, date and time of the exam, exam duration, and the candidates' registrations. The database contains group of tables that used in the operation phases of server side these tables are Login, MCMA Questions, MCSA Questions, True/ False Questions, MCMA Exam Questions, MCSA Exam Questions, True/ False Exam Questions, startup Time and Time duration, Candidate, and Grade tables.

### **5.2.8 Temporary Storage**

The temporary storage is a file created at the client side. The life cycle of the temporary storage file can be in one of the following states: create, update, and remove. The client agent creates this file in getting started phase automatically. The purpose of this file is to store exam's information that received from the server agent namely: the questions of the exam and exam's duration. However, this file is updated during the exam by the client agent to store the answers and time left of the exam. After the student finished the exam or the client agent indicated exam timeout, the client agent terminates the examination phase and collects the answers from the temporary storage file. When the client agent receives the grade, the client agent will remove the temporary storage file as there is no use of it anymore.

## **5.3 Networking in OLES**

OLES is a network based system. It runs on connected server with clients machines over a network. When the student login, the client agent send the username and password to the server agent on port number 8056 and handle each connection in a separate thread. The server agent checks the authentication and sends back a reply (either a grant or denied). Next, if the reply was grant, the server agent sends the exam duration and prepares the questions that assigned for the exam, randomizes the questions pattern and choices and encapsulate them, then send them to the client agent on port number 8055. After the student finishes answering exam's questions, the client agent collects these answers and sends them to the server agent for checking and grading. The server agent sends the grade of the exam to the client agent on port number 8056. Finally, the client agent receives the grade, displays it to the student through the GUI, this case is referred to as the happy day scenario. Fig. 5 illustrates the networking and data transfer between client agent and server agent. The sequences diagrams for the OLES operation phases are depicted in Figures 6, 7, 8, and 9.

## **5.4 Failure Toleration**

The most important feature in the proposed OLES is the ability of recovery after a power/network/component failure conditions. In doing so, the exam's resumption capacity is done, when the power and/or network connection is back, the client agent prepare the system to continue from it has left off. Hence, the exam does not need to start all over again. The next subsections discuss the recovery procedures in each case.

#### **5.4.1 Power Failure**

The client agent manages the OLES phases to be ready for the power failure. The procedure that the client agent takes for this management is after the login phase. The client agent checks the temporary storage whether it is created or not and if not then this is the first login of this student onto the system. Otherwise, there is a temporary storage file that means this login is happened after power failure situation. Subsequently, the client agent accesses the temporary storage, load the stored answers in it and display them within their questions on the end-user GUI. In addition, the time left of the exam is also stored in this temporary storage. Thus, the client agent loads the duration of the exam and the time left is still fixed no matter how long the power was off.

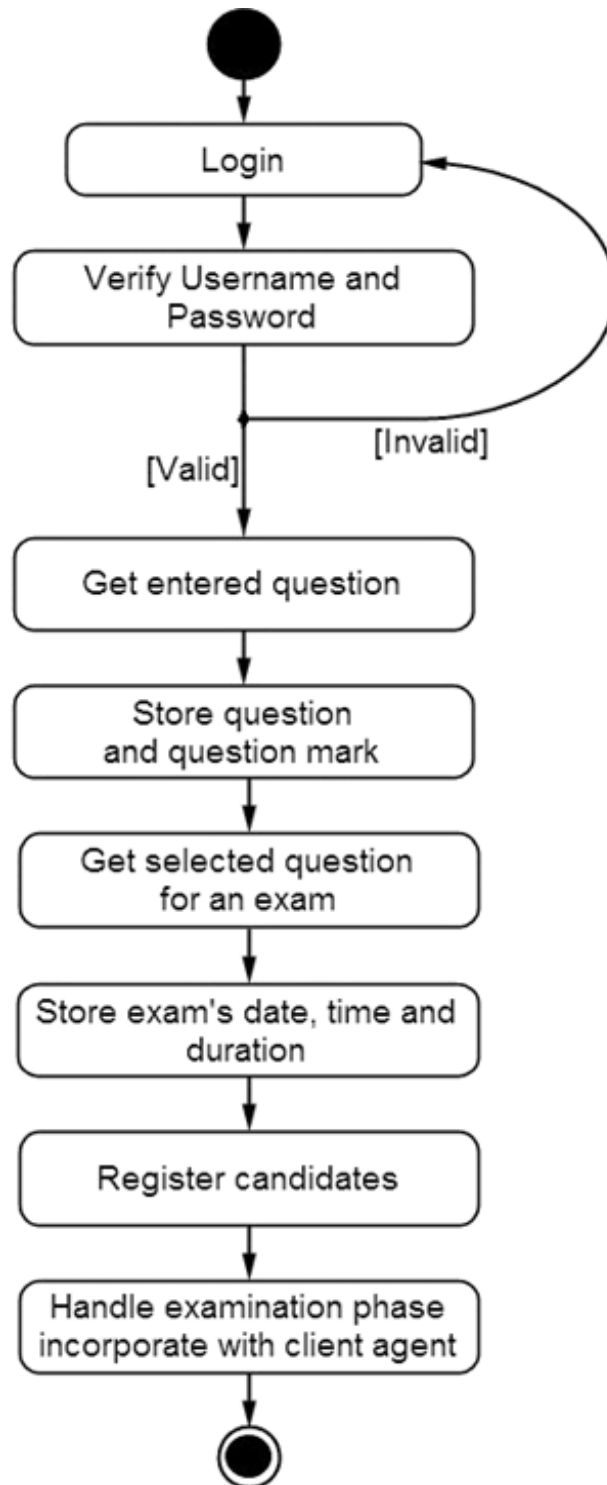
In the server side, the server agent manages the system phases to be ready for the power failure. All of the server agent operation phases involve dealing with database. In each phase, the server agent updates and/or stores data into database. The server agent can load any stored data of any operation phase after the power gets back.

#### **5.4.2 Network Failure**

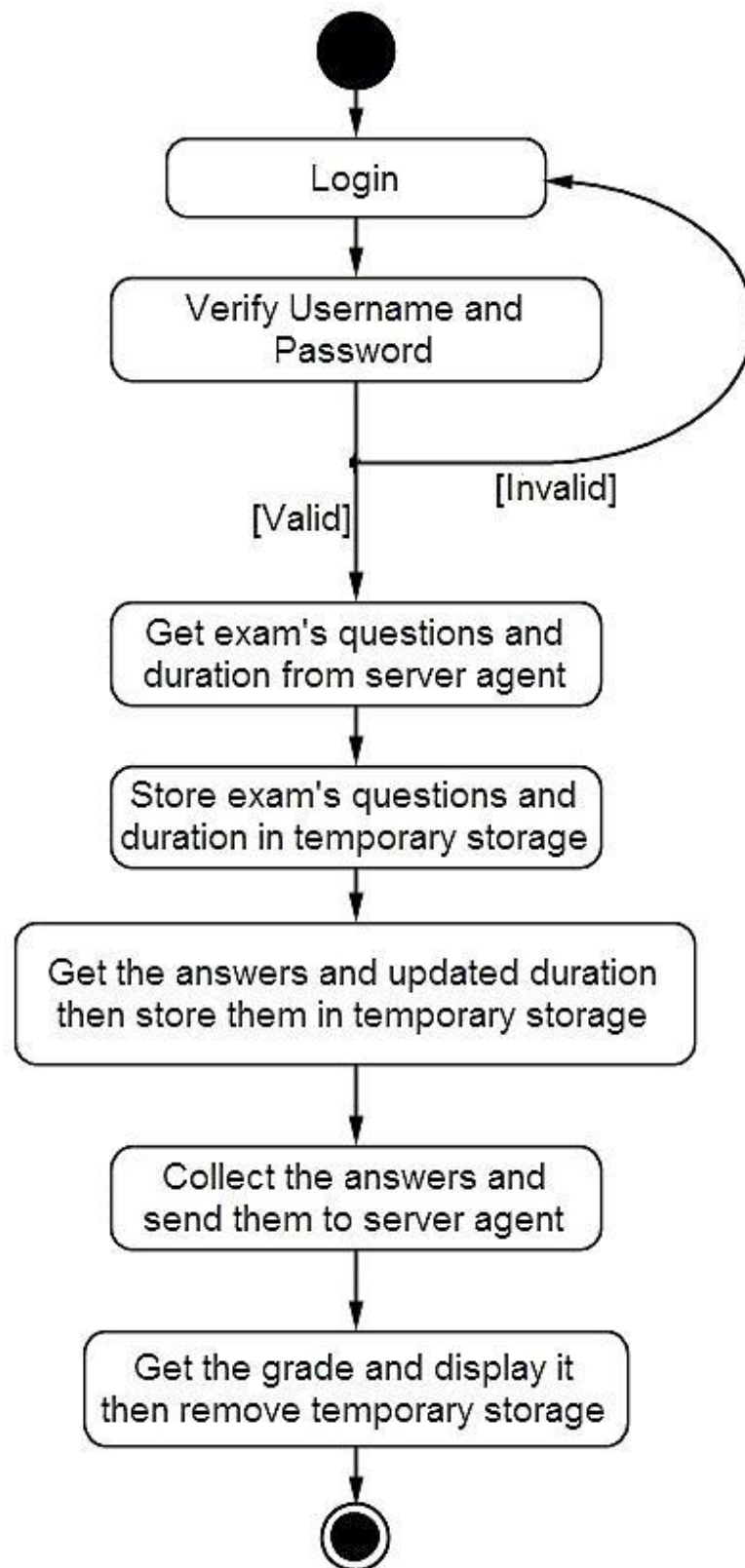
In case of network failure, the client agent and server tolerates it according to which phase this failure is occurred.

If a network connection failure is occurred during the client agent sending the student's username and password and the login information lost as shown in Fig. 10, in this case, if this acknowledgement did not received due to the network connection failure, the client agent will inform the user to this failure, login information is kept with client agent until the failure repaired, then the client agent will reconnect and resend data for login and resume the protocol operation.

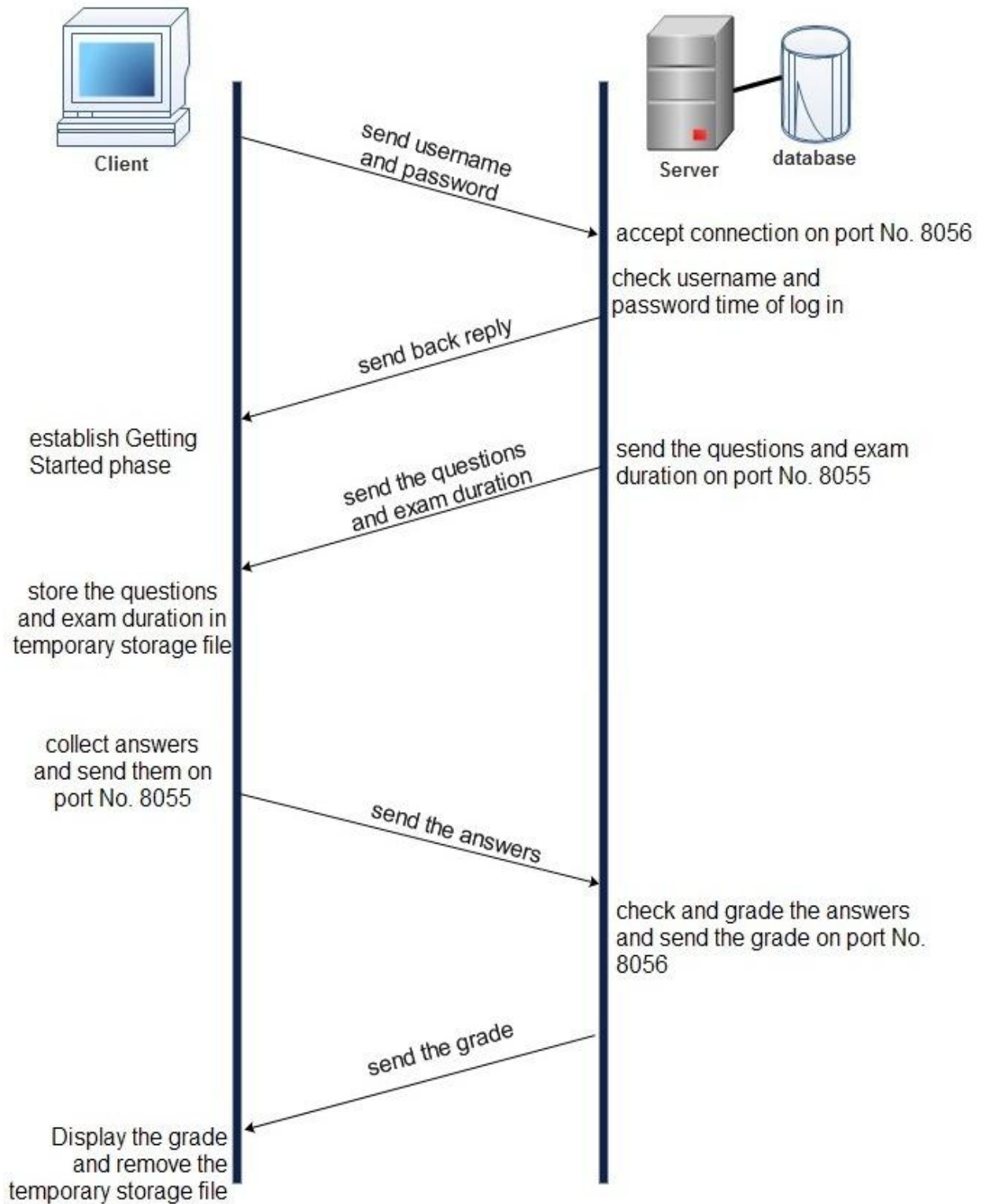
If a network connection failure occurred during the server agent is sending the login reply to the client agent or during the server agent is sending the questions and duration of the exam, as shown in Fig. 11a or the questions and duration of the exam are lost as shown in Fig. 11b. In these cases, both the client agent and the server agent will indicate this failure, and the client agent informs the student about the failure, and resends the login information when the connection is repaired, next, server agent will provide of the reply and exam's duration and questions after the repairing of the connection failure.



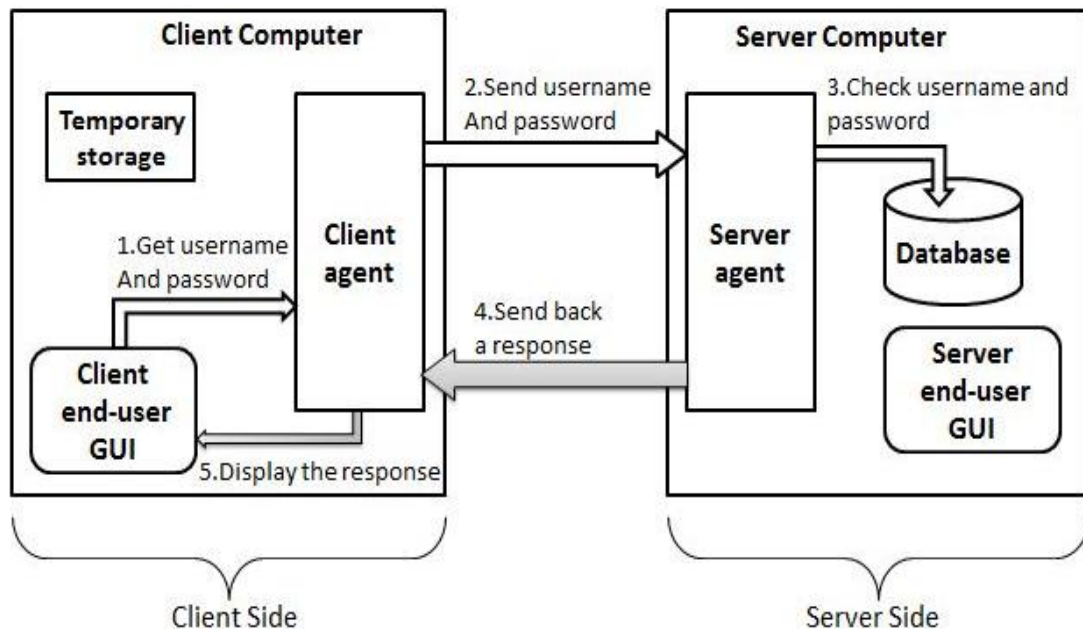
**Fig. 3** State Diagram of the Server Agent.



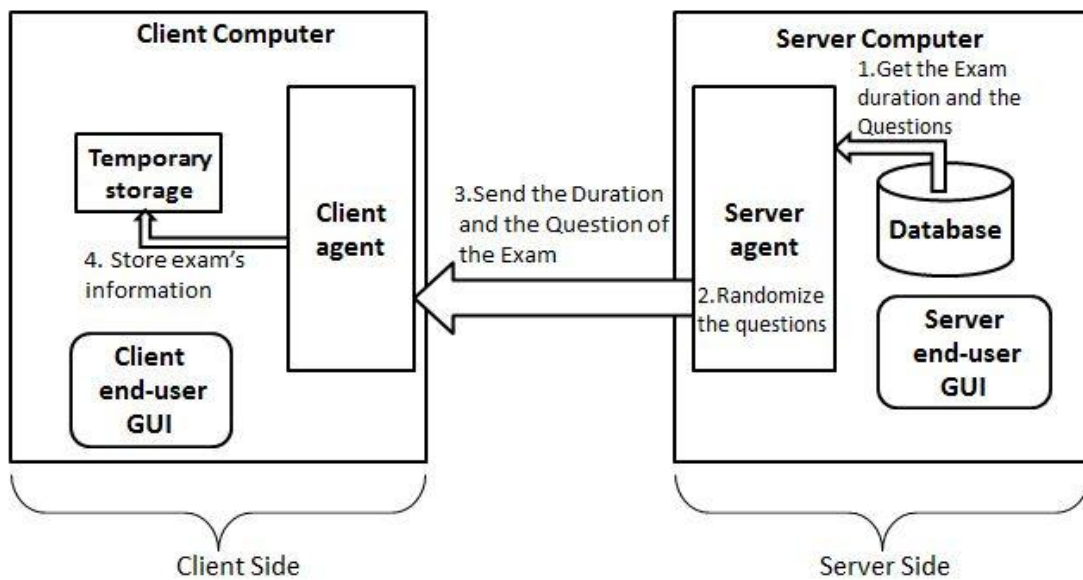
**Fig. 4** State Diagram of the Client Agent.



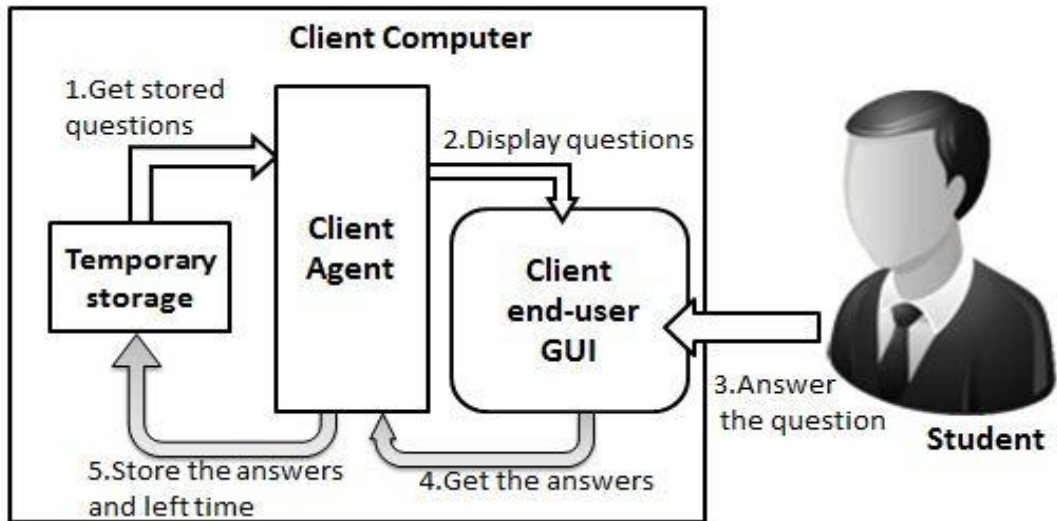
**Fig. 5** Networking between Client Agent and Server Agent.



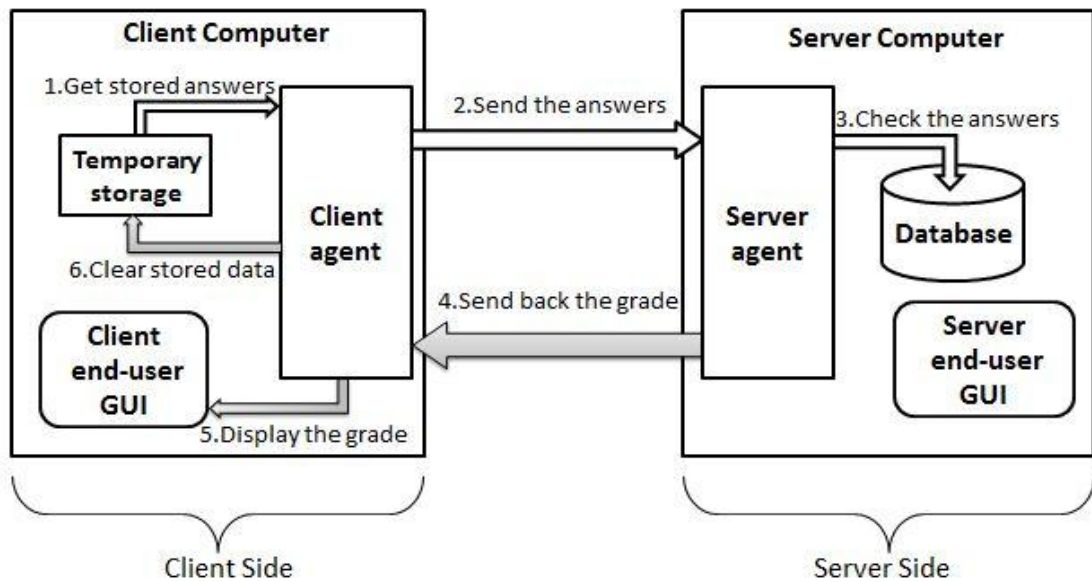
**Fig. 6** Student Login Phase.



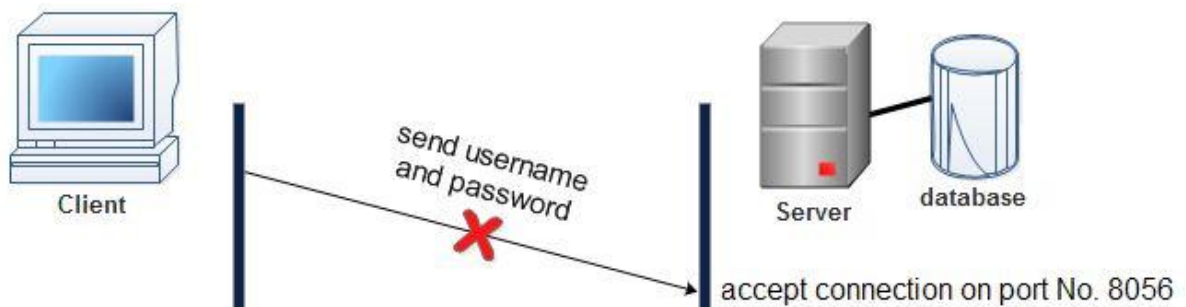
**Fig. 7** Getting Start Phase.



**Fig. 8** The Examination Phase is Managed Locally by the Client Agent, all Questions, and Answers are Stored in the Temporary and Redundant Storage to Facilitate the Resumption Capability.

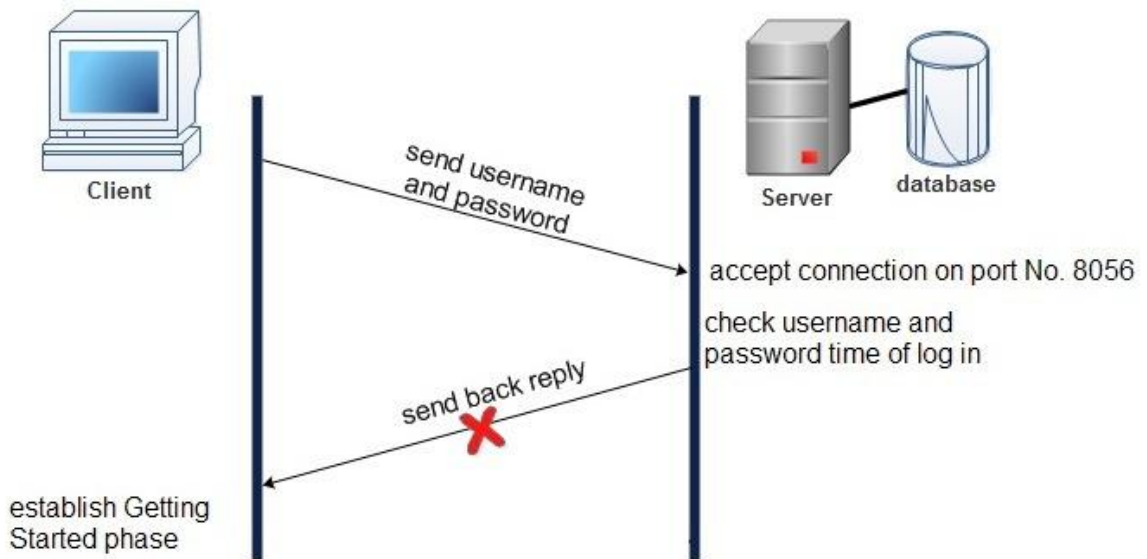


**Fig. 9** Answers Submitting and Getting Result Exchange Phases.

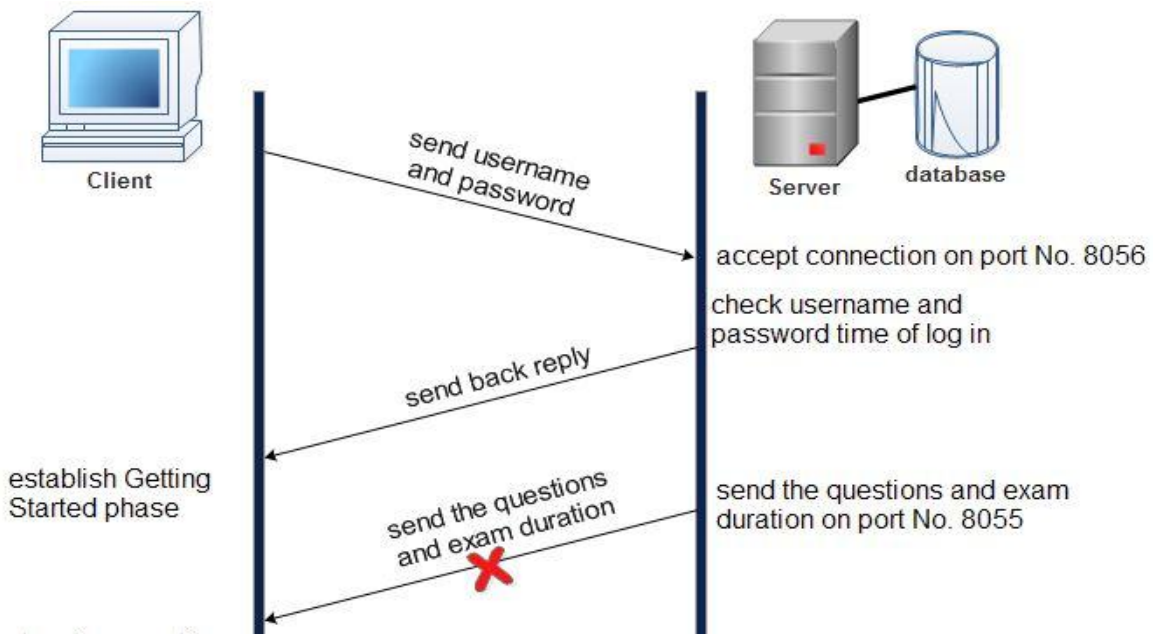


**Fig. 10** Login Information is Lost.





a. Login Reply is Lost.



b Exam's Questions and Duration Segment is Lost.

**Fig. 11**

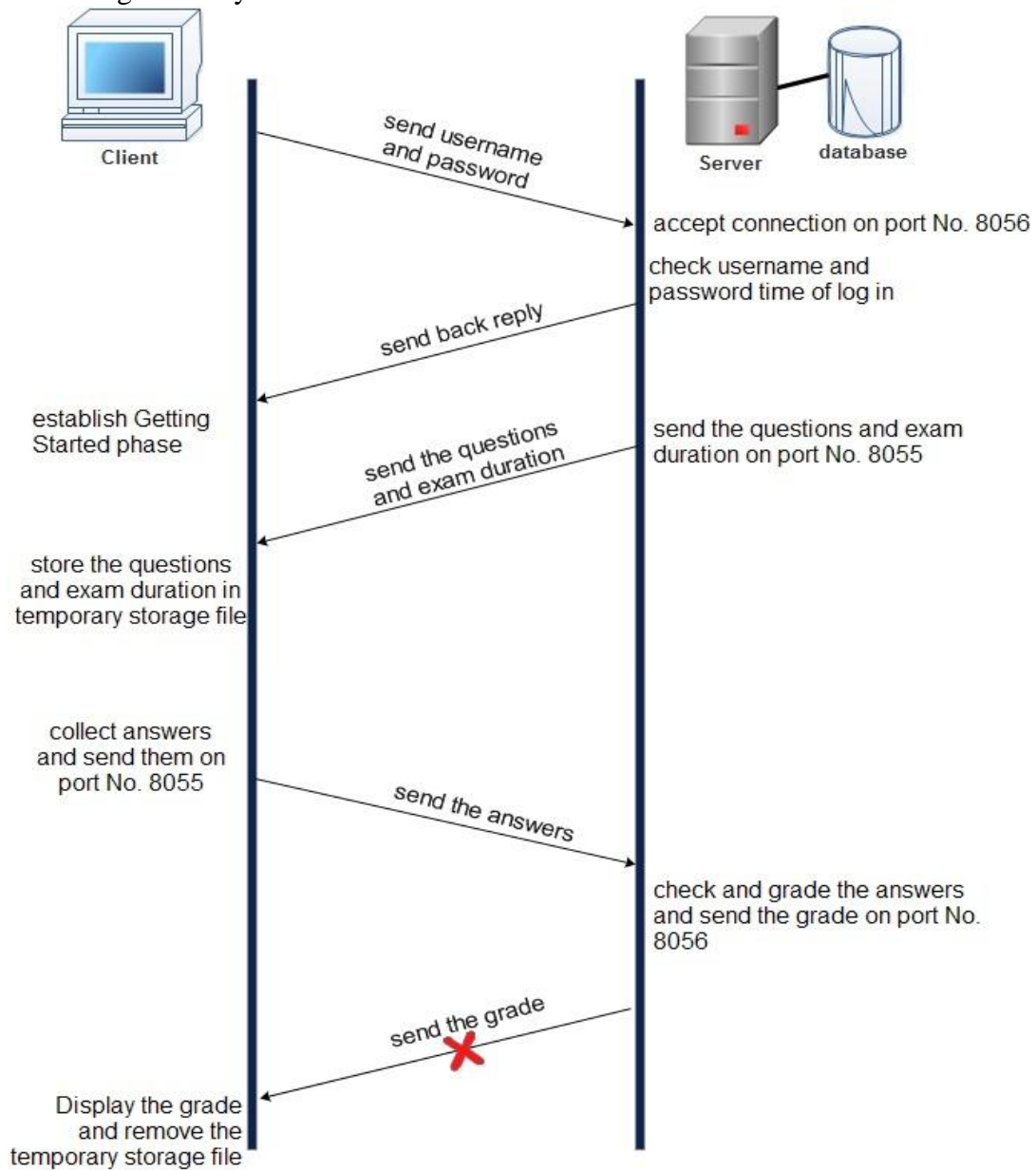
If a network connection failure occurred during the examination phase there is no data transmission during this phase needed. Therefore, no affection to the OLES operation occurred until the exam ended. As such, the student just answers the questions, and the client agent saves the answer in the temporary storage. Thus, the client agent can retrieve the answers and resend them to the server agent after the failure repaired.

Finally, if a network connection failure occurred during the server agent is sending the grade to the client agent as shown in Fig. 12. In this case, the server agent can retrieve the grade from database and resend it after the failure repaired.

### 5.4.3 Computer's Components Failure

There are some scenarios might occurred such as machine failure or hard disk failure. It is important to use reliable warranted computers. These cases will rarely happen. However, if machine failure or hard disk failure is occurred, The OLES enable the student to use a redundant storage (flash disk) to store a redundant temporary storage on the OLES' client side. In doing so, the student can resume the examination using another computer, within resumption from another computer. After the student choose this option, the

temporary storage will be copied from flash disk to the hard disk of the new pc, and the student resumes the exam from this pc. As a result, the OLES decreases the probability of examination failure due to components failure significantly.



**Fig. 12** The Grade is Lost.

### 5.5 Combination of Randomization

The sequence of the distributed questions among the student and the choices in each question is random. Let the probability of students get the same sequence of questions with the same sequence choices denoted by  $P(R)$ . Assume the number of exam's question is  $Q$ , the number of their choices is  $C_i$  for  $Q_i$  (where  $i=1...Q$ ), the number of students is  $S$ , and total number of questions stored in the database for this exam is  $N$  (where  $Q \leq N$ ). Then  $P(R)$  can be determined by Eq. 1.

$$P(R) = \frac{Q * S}{N * Q! * \prod_1^Q C_i!} \tag{1}$$

### 6. OLES Evaluation

Unlike other existing systems, the OLES has two fold as an essential features. The first feature is the resumption capability; which is considered as a novel feature, the OLES provides the resumption capability

of the exam in the case of power and/or network and/or physical computer components failures, thus, the student could resume his/her exam without affecting the remain examination time. In addition, this feature saves the required connection and bandwidth of the network. The second feature is the combination of randomization features (i.e., random question selection, random questions distribution, and random choice distribution), which is also considered as a novel feature. In addition, an equation of the probability of students getting the same questions in the same order for the same exam is derived. Also, the proposed system is oriented for lecturers to build their exam for general purpose regardless the subject. Table 2 demonstrates the features of the OLES compared with the systems discussed in Section 3.

**Table 2** The Comparison between OLES and the Existing Systems.

✓	Supported Feature	Elected Features							
✗	Not Supported Feature								
Online Examination Systems		Secure Login	Resumption Capability	Multi-Instructor	Combination of Randomization			Portability	Web-Based/ Application-Based/ Hybrid
					Random Question Selection	Random Questions Distribution	Random Choices Distribution		
	SIETTE [6]	✓	✗	✗	✗	✗	✗	✓	Web-Based
	WETAS [7]	✓	✗	✗	✓	✗	✗	✓	Web-Based
	EMS [8]	✓	✗	✓	✗	✗	✗	✓	Web-Based
	iEMS [9]	✓	✗	✓	✗	✓	✓	✓	Application-Based
	WONES [10]	✓	✗	✓	✗	✓	✗	✓	Hybrid
	NOES [11]	✓	✗	✗	✗	✗	✗	✓	Hybrid
	SBPES [12]	✓	✗	✓	✗	✗	✗	✓	Hybrid
	OESBC [13]	✓	✗	✓	✓	✗	✗	✓	Web-Based
	CBTS [14]	✓	✗	✓	✓	✗	✗	✗	Hybrid
	OLES	✓	✓	✓	✓	✓	✓	✓	Application -Based

## 7. Conclusion and Future Work

The following conclusions can be drawn from this paper.

1. Resumption capability in case of failure, that is overcome the power /network/ physical problems thereby the students do not have to repeat the exam from the beginning and could resume his/her exam without affecting the remaining examination time. As such, this feature increases the satisfaction of the individuals.
2. Combination of randomness is important in order to ensure the robustness against cheating attempts.

3. Bandwidth usage reduced. The OLES use the network with the clients only during student's login, question providing and grading. Thus, during other operation phases, the organization and server are free to use the network connection for other tasks.
4. The entire network protocols can be distributed further in hierarchy fashion to address the scalability issues. For instance, the database can be in different server that interacts with the server agent.
5. The OLES is a modular system, which can be extended horizontally (by adding new desired features) and can be expanded vertically (by developing another version or variation of the current implementation). As such, the OLES acts as a research vehicle and prototype for future work. From industrial point of view, this is the point of changing OLES from in-house alpha version to specialists' beta version for further research and development as follows.
  - Adding ID checking and superintendence features implementation, beside the username and password, (e.g., face recognition, webcam, or finger print) included as student's registration information that would be checked during student's exam time.
  - Collecting the statistics about student results (e.g., degrees, gender, age) enables organization and researchers to do some machine learning research to improve the method of teaching, exam, and analyze the behavior of the student's learning curve, determining the standard deviation, percent of attendance, class average, issuing certificate, etc.
  - Performing a feasibility study for adopting the OLES in both regional and international academies and organizations.

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