OAES: Scalable and Secure Architecture Online Assessment and Evaluation System

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OAES: Scalable and Secure Architecture for Online Assessment and Evaluation System

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***Abstract*—The emerging issues identified for online education are the role of the teacher, student participation and assessment. Conducting effective assessments in a large-scale environment for online education is one of the biggest challenge. Quality of examination gets affected by issues emerging from assessment instrument quality and evaluation centered errors. Online Assessment and Evaluation System (OAES) proposed in this paper is developed to assess students abilities using diverse assessment methods using 15 unique item types which can be automatically evaluated. OAES provides unified management of five modules of an examination system which includes item authoring, examination administration, examination, evaluation and data transfer. OAES is designed using a scalable architecture enabling expanding of users and roles in an extremely manageable way. The transfer of data among modules is handled by an unique encryption and decryption process. Preliminary testing and self evaluation using ISO 9126 quality model is conducted. OAES has shown the potential to be well received by administrators, instructors and students.**

I. Introduction

Online education is an emerging part of today's education system which is adapted for two scenarios: merging it with classroom teaching (blended learning) and offering courses for distance learning (distance education and massive open online courses). It has varied advantages over traditional classroom education which includes flexibility, autonomy, convenience, high degree of self management and efficiency [1]. Computer based assessment is used for online education. The issues related to computer based assessment are addressed by the following questions:

- What sort of learning can be assessed?
- How should students be authenticated so that the correct student's work is being assessed?
- What can be done to prevent cheating during examination?
- How can we ensure the security aspect of the entire examination system?
- How much of the evaluation can be automated?

Our proposed online assessment and evaluation (OAES) system tackles each of these questions by incorporating additional item types for better learning, authentication for validating student's identity, using assessment items randomization for preventing cheating and using an unique encryption and decryption process for ensuring security of OAES. This paper discusses the existing online examination systems, their features and drawbacks followed by a detailed explanation for OAES architecture.

II. Existing Online Examination Systems

Although featured with varying names in the literature, existing online examination systems (OES) comprises of authoring module consisting of items, item banks and assessment instruments (question papers), examination administration module that takes care of authenticator appointments and student enrollments, examination where students submit responses and evaluation where the grades of the students are calculated. Table I shows a brief description about the existing OESs.

Most of the existing systems assess students using only conventional item types (objective questions) [refer Table I]. It is essential to assess student's abilities using diverse assessment methods and partial credit. Therefore, there is a need to design item types which are automatically evaluatable and at the same time are able to assess student's abilities using non-conventional item types. Also, existing systems are built using two or more modules. For such systems, there is a clear demand for design and implementation of distributed and flexible examination system architecture.

III. Key Innovations Related to OAES

Following are the important innovations for OAES as compared to existing online examination systems:

- OAES is built using distributed architecture, where each module scales up independently based on the load.
- Item authoring is performed using 15 unique item types which enables diverse assessment methods.
- Transfer of data among all four modules is handled using highly secure data encryption mechanism.
- OAES has highly configurable examination settings.
- OAES integrates an authenticator for validating student's identity.
- OAES is compliant with ISO 9126 quality model [14] for product assessment.

IV. OAES Architecture

Any examination system typically consists of five discrete steps: designing items and assessment instrument, setting examination using designed assessment instrument, sending assessment instrument to examination centers, conducting and evaluating examination. These steps are addressed in the design of proposed OAES in the form of following five primary modules as shown in Fig 1.

OES	Modules	ItemTypes	Subject	Data and User Security
QUIZIT [2]	Examination admin, Examination, Evaluation	Objective	Generic	Authentication layer, database model that supports locking
ASSYST [3]	Examination, Evaluation	Programming exercises	Computer courses	-
WBE System [4]	Authoring, Examination admin, Examination, Evaluation	Objective	Generic	Common gateway interface
PILOT [5]	Examination, Evaluation	Graph based	Algorithms and Graph theory	Student logs, Time stamps
Test Editor [6]	Authoring, Examination, Evaluation	Objective	Generic	-
Operational skills examination and evaluation system [7]	Authoring, Examination admin, Evaluation	Programming, editing documents using MS Windows	Computer courses	DCOM
CBE-B/S Structure [8]	Examination admin, Evaluation	Objective (Multilanguage items)	Generic	Secure browser,Timing function
Mobile agent based OES [9]	Authoring, Examination admin	Subjective	Generic	Mobile agents
Agent-based System [10]	Authoring, Examination admin, Evaluation	Objective	Generic	Software agent technology
ZOSMAT [11]	Authoring, Examination admin, Evaluation	Objective	Generic	-
OES using web services [12]	Evaluation	Objective	Generic	-
OPES [13]	Authoring, Examination admin, Examination	-	Generic	Identity confirmation, question database security

TABLE I
EXISTING ONLINE EXAMINATION SYSTEMS

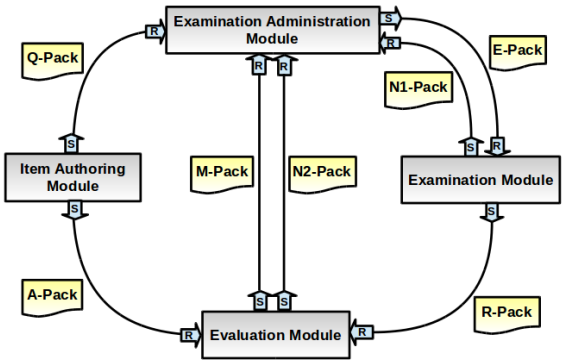

Fig. 1. Primary Modules of OAES with Secure Data Transfer Channels

1) Item Authoring
2) Examination Administration
3) Examination
4) Evaluation
5) Secure Data Transfer

The interaction between the modules is enabled using "Packs", which are information packets that are encrypted and digitally signed. Item authoring module is used for generating assessment instruments using items in the item bank. The assessment instrument (Q-Pack) is sent to the examination administration module while the answers (A-Pack) for the items in the assessment instrument is sent to the evaluation module. Examination administration module is used for sending the assessment instrument to examination centers along with student and examination details (E-Pack). Students appear for examination in examination module and students responses (R-pack) are sent to the evaluation module. Evaluation module is used for comparing A-pack with R-pack and sending marks (M-pack) to examination administration module. Notification packs (N1-Pack and N2-Pack) are used for monitoring purpose by examination administrator. Examination module is designed to be running independently in a separate server for enhancing security. Data transfer module takes care of transfer of packs from sender (S) to receiver (R) module.

V. DESIGN OF OAES

OAES tool is developed for administering examination in online mode using LAMP stack [15]. The user interface is developed in PHP/HTML. The application interacts with MySQL database and uses HTTPS for web-based access by users. All passwords are stored in the database in an encrypted format and all packs are digitally signed. Role-based access is granted to different types of users. Following sub-sections discuss each of the primary modules in detail:

A. Item Authoring Module

Item authoring module is used for creating item bank. An item bank is a collection of assessment items that are used for constructing assessment instruments. An item is created by an item author which is represented by attributes including cognitive level, knowledge category and difficulty as per IMS QTI [16] specifications. Item authors provide sample response which is used for automatic evaluation. Fig 2 shows data flow diagram for item authoring module which includes item author, item reviewer, item bank manager and authoring administrator roles and their actions. Item authoring includes a three step workflow process. Each item created by an item author goes for two rounds of review: technical and pedagogical. Item reviewer verifies the technical details of item created by item authors. Reviewer verifies if the item is aligned with the stated course outcome. An item is stated to be aligned if it belongs to the same or lower cognitive level to which course outcome is mapped to [**?**]. Reviewer also verifies if the item is free of any ambiguity. Reviewed items are sent to item bank manager for pedagogical review if the item is approved by an item reviewer or it goes back to the author with review comments, if it is rejected by the reviewer. Item author

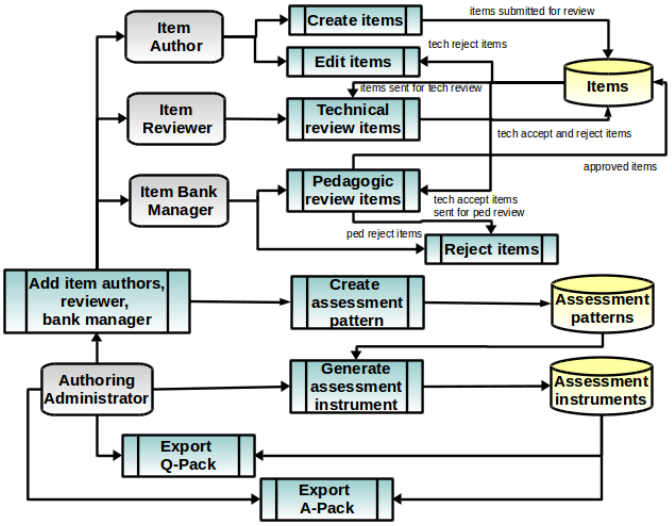

Fig. 2. Data Flow Diagram of Item Authoring Module

again submits the same item after making necessary changes as requested by the reviewer. Item bank manager verifies if the items are tagged properly with metadata which includes knowledge category, cognitive level and difficulty level. Item bank manager can also reject an item if found inappropriate with respect to alignment, equivalence or clarity.

Nineteen types of items can be created in this module, which includes four conventional selective item types and fifteen unique item types amenable for automatic evaluation and providing diverse assessment [17]. Conventional item types are *multiple choice, true or false, match the following and fill in the blanks using given list*. Remaining item types includes *fill in the blanks, short question, use feature of package, reordering, compute, complete the program, correct and complete the program, modify code, programming, compare, complete the block diagram, correct and complete the block diagram, complete the flow chart, correct and complete the flow chart and determine the output*. A thorough analysis of these item types is beyond the scope of this paper.

Authoring administrator creates an assessment pattern which essentially gives the distribution of marks for an assessment instrument across all relevant cognitive level, course outcomes and item types. Authoring administrator generates an assessment instrument automatically using items corresponding to a chosen assessment pattern. A provision is given to change a set of items in the designed assessment instrument. The assessment instrument (Q-Pack) is exported to the examination administration module while the expected response (A-Pack) for the items in the assessment instrument is exported to the evaluation module. It is worth pointing out that Q-Pack sent to the examination center does not include the right answers thus enhancing security and reducing vulnerability.

B. Examination Administration Module

Examination Administration is a very important module and is central to OAES. Fig 3 shows data flow diagram for exam

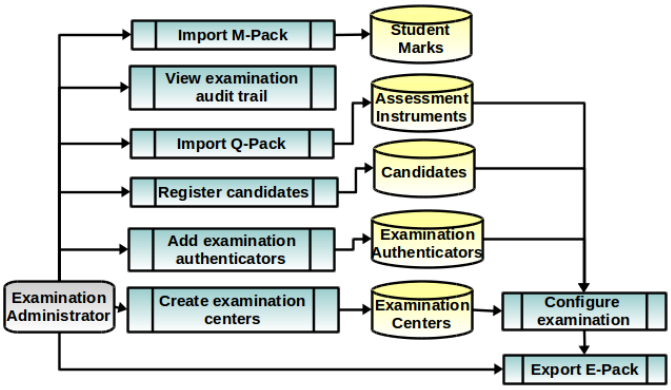

Fig. 3. Data Flow Diagram of Examination Administration Module

administration module which includes examination administrator role and its actions. Q-Pack sent by authoring administrator is imported by examination administrator. Examination centers are added in this module and a unique certificate file is uploaded for each examination center which enables importing of assessment instrument at examination center location.

An examination is created and exported as E-pack to the examination centers. E-pack consist of examination center details, enrolled students in each examination center, examination details and assessment instrument. Enrolled students and authenticators are mapped to the appropriate examination centers while configuring the examination. The system supports two factor authentication in which authenticator provides the second factor authentication where ever needed. Also, a grace period can be allotted to students by authenticators for valid reasons which includes browser issues, server failure and network problem. Following is the detailed description of examination configuration setting:

- *Authentication Mode:* Examination administrator can select any one of the three modes for authentication: one factor, two factor and two factor for reattempt. One factor is chosen when no external authentication is needed for the student. Two factor is chosen in case authenticators need to validate the identity of students before starting the examination for the first time and for special circumstances which includes restarting the examination in case of browser issues, server failure and network problem. Two factor for reattempt is chosen when authenticators are required to validate students identity for special circumstances.
- *Schedule start time:* After this time, the examination is accessible to students for making attempt.
- *Schedule end time:* After this time, the students will not be able to start new attempt. Answers for individual student will be submitted for evaluation.
- *Grace Period:* Occasionally, authenticator may extend schedule end time from the scheduled end time for valid reasons by grace period.

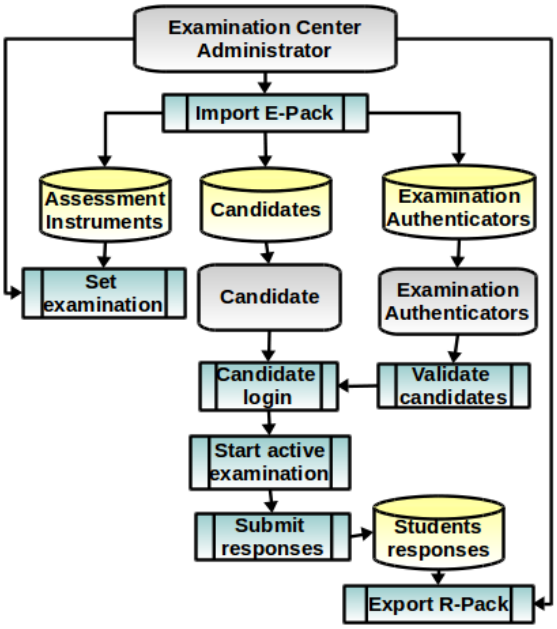

Fig. 4. Data Flow Diagram of Examination Module

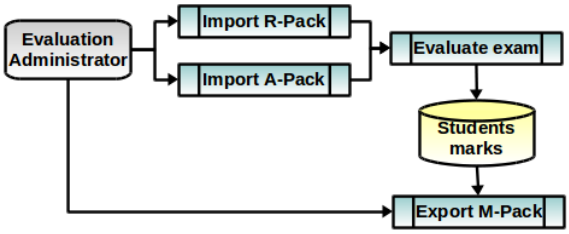

Fig. 5. Data Flow Diagram of Evaluation Module

Examination administrator can track examination flow in each examination centers, individual student's attempt and the timing based on their log in time using notification messages in N1-Pack. N1-Pack essentially consist of exam and student level notifications. The examination results, students-marks for an examination center and individual student marks, can be viewed in this module after importing the M-Pack sent by the evaluation module. N2-pack sent by evaluation module consist of exam level notification related to evaluation.

C. Examination Module

Fig 4 shows data flow diagram of examination module which includes student (candidate), examination center administrator and examination authenticator roles with their actions. Examination center administrator imports the E-pack and sets examination for the center using the assessment instrument provided. Each student uses a unique login user id and password which is sent as a part of E-Pack. A list of examinations for which the candidate is enrolled and the date at which the examination is active is displayed after the student logs into the examination module. An active examination is an examination

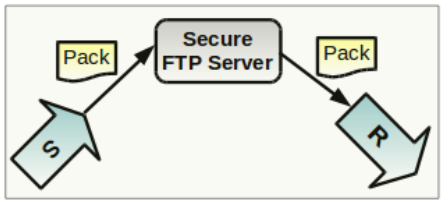

Fig. 6. Secure Data Transfer Module

for which a student has enrolled and the date and time of the examination set by the examination administrator matches with the date and time of the examination at the time student logs in to the examination module. Examination authenticators validates the identity of students as per the settings chosen by examination administrator. All students responses are exported as R-Pack to evaluation module.

D. Evaluation Module

Fig 5 shows data flow diagram for evaluation module with evaluation administrator role and its actions. A-pack and R-pack are imported in this module. Student's responses are compared with the expected responses as given by item authors and marks are estimated. All student marks are exported by evaluation administrator as M-Pack.

E. Secure Data Transfer Module

Data transfer modules transports data between the four primary modules of OAES. Communication between these modules occurs in the form of packs. This module has three parts: a sender (S), a receiver (R) and an FTP server to which the sender uploads pack and from which the receiver downloads them as shown in Fig 6. Table to table data transfer from source to the receiver database is performed in addition to encryption and decryption of data, providing a mechanism for acknowledgements, adding metadata, signing verification and uploading to/downloading from FTP server. The end to end operation of creating and uploading a pack by a sender for all the intended receivers is called 'export' and that of downloading the pack by a receiver is called 'import'.

1) ***3-file Set****:* A pack contains one or more 3-file sets; each set is meant for a particular receiver. It contains a data file (df), a metadata file (mdf) and an empty acknowledgement file ($ackf$). A set in a pack is always meant for a particular receiver. If a pack is meant for two receivers, there will be two 3-file sets in the pack making it 6 files in total. Following pack is designed for two receivers: the first set is meant for receiver 1 and the second is meant for receiver 2.

$$\text{Pack} = [df1, mdf1, ackf1, df2, mdf2, ackf2]$$

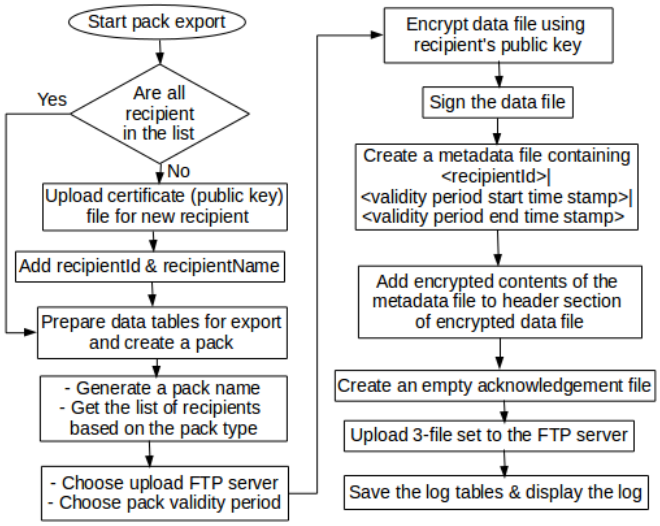

Fig. 7. Secure Data Transfer Sender Module

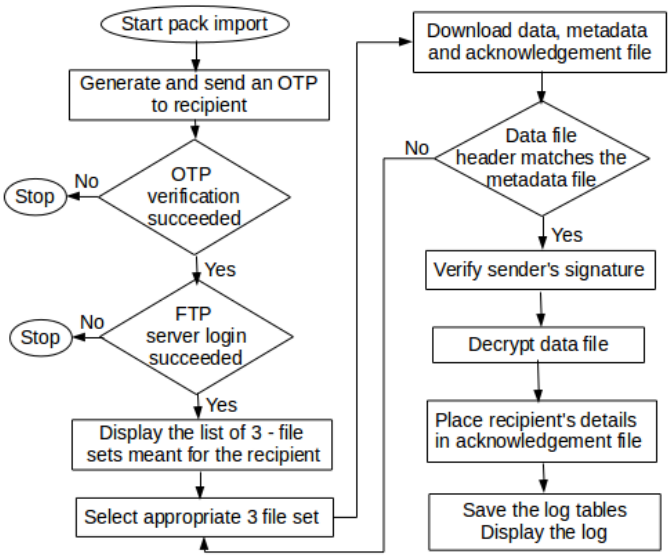

Fig. 8. Secure Data Transfer Receiver Module

- The ***data file*** contains SQL dump of the required rows in required tables in the source module's database and metadata from the metadata file. It is encypted using receiver's public key which means that a sender has to have its intended receiver's public key to be able to encrypt a file for it.

- The ***metadata file*** is a plain text file which contains the unique ID of the receiver (recipientId) and the 'from' and 'to' timestamps which specify the validity period of the pack. Outside this period, the receiver will not be able to see the pack on the FTP server. This metadata is also present in the data file in an encrypted form, so any tampering with the plain text metadata file will result in a mismatch with its corresponding data file and the import operation will fail at the receiver side.

- The ***acknowledgement file*** is empty initially. Every import operation will cause the receiver to place the logged in users email address in the acknowledgement file along with the current timestamp. That way, the sender can poll it to find out which sets in a pack were imported, by whom and how many times. The sender can see a list of packs it has exported so far and choose at any point in time to delete a pack from the FTP server.

*2) **Secure Data Transfer Sender and Receiver**:* This module is used by item authoring, examination administration, examination, evaluation modules for exporting/ importing Q-Pack, A-Pack, E-Pack, R-Pack, M-Pack, N1-Pack and N2-Pack. Table II shows details about each of these packs. Fig 7 shows the steps involved for exporting a pack and Fig 8 shows the steps involved for importing a pack.

VI. Evaluation of OAES

The standard ISO 9126 is a quality model for software product assessment that identifies six quality characteristics (Q): functionality (Q_1), usability (Q_2), reliability (Q_3), efficiency (Q_4), portability (Q_5) and maintainability (Q_6) [14]. The first three characteristics (Q_1, Q_2, Q_3) and the first sub-characteristic of Q_4 (time behaviour) are easily assessable, whereas the remaining characteristics are difficult to measure except by trained IT professionals. The sub-characteristics for Q_1 are suitability, accurateness, interoperability and security. The sub-characteristics for Q_2 are maturity, fault tolerance and recoverability. The sub-characteristics for Q_3 are understandability, learnability, operability and attractiveness.

A preliminary survey is conducted with a set of item authors, instructors and students to validate the performance of OAES against the quality characteristics as mentioned in Table III. OAES is found to satisfy the quality parameters with sufficient satisfaction of students and instructors. The system has been deployed and in use for internal assessments at International Institute of Information technology, Banaglore, India. A pilot followed by implementation at National level is planned for NIELIT examinations.

Acknowledgment

The work has been supported by Department of Electronics and Information Technology (DietY) and National Institute of Electronics and Information Technology (NIELIT) for Online Assessment and Evaluation System (OAES) Project at International Institute of Information Technology, Bangalore, India.

Pack	Sender	Receiver	Description
Q-Pack	Item Authoring	Examination Administrator	Assessment instrument is sent
A-Pack	Item Authoring	Evaluation	Answers for the items in the assessment instrument is sent
E-Pack	Examination Administrator	Examination	Assessment instrument along with student and examination details is sent
R-Pack	Examination	Evaluation	Students responses are sent
M-Pack	Evaluation	Examination Administrator	Students marks are sent
N1-Pack	Examination	Examination Administrator	Notification about monitoring students attempts are sent
N2-Pack	Evaluation	Examination Administrator	Notification about monitoring evaluation is sent

TABLE II
SECURE DATA TRANSFER PACKS

Quality Characteristics	Domain Specific Quality Criteria for OAES
Suitability	Creating quality items and assessment instruments, Conducting assessments, Evaluating responses, Maintaining assessment records and grades
Accurateness	Evaluating responses, Mapping students and authenticators to exam centers, Recording students responses
Interoperability	Export assessment items, instruments and marks in PDF and Excel format
Security	HTTPS for web pages, Password protection of all users, actions and resources, Role-based access control which determine permission levels which users need to control, manage, and update content, Encryption and decryption of packs using certificate file, Identification and authentication of students
Maturity	Error-free system functions, System validation for security attacks
Fault tolerance	System performance verified for response to invalid input data, Continues to function in the event of browser issues
Recoverability	Remedial action taken in case of error recognized by the system, Resuming attempt soon after a failure
Understandability	Consistent layout, System terminology related to pedagogic theories, Display of error messages on the screen where ever necessary, documentation provided by the system is easy
Learnability	Easy to operate the system, Easy to explore new features by trial and error, Straightforward task performance, Display of help messages on the screen, Supplemental reference materials is clear
Operability	Easy to upload/download resources, Information organization is clear, Sequence of screens presentation is logical and clear, Easy to correct errors, Easy to find required information
Attractiveness	Pleasant and attractive systems interface
Time behaviour	Decent level of performance when large numbers of students are logging into the system at any one time , Appropriate response time provided, Uploading/ downloading files with satisfying speed under stated conditions, Quick location of operations and information

TABLE III
DOMAIN SPECIFIC QUALITY CRITERIA FOR OAES

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