



An Online Examination Management System for Geographically Dispersed Test Centres to Prevent Question Leakage: A Case Study of Bangladesh

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Authors' contributions

This work was carried out in collaboration between all authors. Author MSA designed the study and led the discussions on the analysis and the implementation of the project. Author MIHBA performed the technical analysis, developed the main portion of the web based software. Author MRHM managed the literature searches and wrote the manuscript. All the authors performed the experiments as well as read and approved the final manuscript.

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ABSTRACT

Aims: In some developing countries, an important challenge of the examination system is the question paper leakage. To address this problem, this research proposes a web-based secure model for examination management system that is robust to question paper leakage. The feasibility of the proposed model is then validated by a practical implementation in the context of Bangladesh, a developing country.

Study Design: The proposed examination management system is a web based solution developed for online question paper uploading and then downloading from different locations. In this system, question papers are made available online to different geographical zones consisting

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of several examination centres, where those papers can only be downloaded after the stipulated time.

Methodology: In the proposed system, user authentication is ensured by a Multi-Factor Authentication (MFA) which is achieved by providing a digital certificate with cryptographic token, matching a traditional password and One-Time Password (OTP) sent to a specified cell phone. To enhance the security further, question papers are encrypted and can be made accessible only when the cryptographic token is plugged in. With the use of digital certificates, question papers are also protected from any sort of tampering. The question papers are then printed in press before being sent to the examination centres.

Place and Duration of the Study: A number of day-long examinations using the proposed model took place in Bangladesh.

Results: The feasibility of the proposed model was validated by deploying the system in a real-life recruitment examination of one million test-takers sparsely distributed in different locations in Bangladesh. The relevant personnel involved in the examinations provided positive feedback indicating successful implementation of the system.

Conclusion: The deployment of such a digital examination system is the first instance in Bangladesh. The challenges faced and the countermeasures undertaken during this practical implementation are also reported in this paper.

Keywords: Bangladesh; cryptographic token; examination management; multi-factor authentication; question leakage; web based software.

1. INTRODUCTION

An examination is a form of assessment to measure the knowledge, skill, aptitude, etc. on a topic among a group of test-takers/examinees. A public examination or a recruitment/job test may be administered on paper or on a computer. For a long time, the traditional system involves printing the question papers centrally and then distributing to different zones including remote areas several days or months before the test. They usually use sealed envelopes containing the question papers which are distributed from the central printing press to zonal offices (ZOs) and from ZOs to the examination centres. This system has many disadvantages which may lead to leakage of question papers at various instances while the envelope is moved from central printing location to examination centres. This happens due to tampering of sealed envelopes and other human intervention performed within the long period between question printing time and exam starting time. In many developing countries, there have been reports of question paper leakages in examinations [1,2]. Sometimes the exams are postponed or cancelled due to allegations of question leakage. In many cases, the information related to question paper leakage is unknown even to the authorities. Hence, some candidates achieve good marks by these leakages and those who had worked hard have to compromise with less marks. These factors create a negative effect on the growth of the education and the

society as a whole. Therefore, there is a need to implement a system which will help to stop this malpractice of leaking of the question papers. One attempt is to have multiple different question papers so that if the original question is leaked, the back-up question papers will be used at the examination [2]. Another attempt recently in use involves distributing the question papers via email from the authority to the examination centres prior to the examination. The local examination centres take the printouts of the question papers and then the examination procedure follows. However, sending through email has security vulnerabilities at the end user level, and therefore is not an ideal choice. Another way to prevent any form of question leakage is the use of full online examination. Nevertheless, in developing countries it is not possible to arrange computers or laptops for thousands of candidates, which are required to take a full online test. A recent research paper has proposed the idea of using sealed electronic box to send question papers to different centres [3]. However, this involves the use of expensive and complicated hardware. Therefore, developing an inexpensive, simple and secure examination management system for a developing country is a challenge.

In this paper, we demonstrate a suitable way to make question papers available online only to a group of authorised users, which are then printed in different locations hours before the examination. This implementation is carried out

for the recruitment of Assistant Teachers under the Directorate of Primary Education (DPE), a government institution in Bangladesh [4,5]. This is demonstrated for more than one million test-takers/examinees in four different days in 61 geographically distant zones. The software implementation is shown to face many hurdles that are likely to be encountered in any future exam. We describe the implementation and evaluation of this software and then make practical recommendations for future exam management systems. The main contribution of this research is the concept and the implementation of a secure online examination management system in the context of a developing country - Bangladesh.

The rest of the paper is organized as follows. Section 2 describes the reasons and ways of question paper leakages taking place in developing countries. Section 3 describes the proposed system model including the techniques used for ensuring security. The detail methodology for question paper uploading is reported in Section 4, while the question downloading technique is described in Section 5. Section 6 discusses the practical demonstration of this method that took place in Bangladesh in 2015 and 2016. The different challenges involved in the real-life implementation are presented in Section 7. The survey form to receive feedback from the users of the online system is shown in 8. The concluding remarks are reported in Section 9.

2. THE PROCESS OF QUESTION PAPER LEAKAGE

There are a number of reasons for question leakages that take place mainly in developing countries. Firstly, questions are leaked due to the lack of law enforcement to punish the criminals involved in the process. Exemplary punishment of the criminals is not often seen and therefore, people do not feel the fear to repeat the same wrong doings. Secondly, the examinations authorities in many cases deny the incidence of question leakage which actually hampers the proper investigation of the leakage. Thirdly, in the traditional examination management systems, there are many steps from setting the question papers to the examination date. This time gap increases the probability of question leakage. The leakage incident may take place at any stage of question paper preparation, question printing, transportation, question preservation,

distribution, etc. Fourthly, achieving monetary benefits is a reason for question paper leakage. In order to get money, some dishonest coaching centres and owners of photocopiers either get involved in the leakage process or in distribution of leaked questions [6].

In order to reduce the chances of question leakages, a drive must be initiated against the group who are involved in this process. It is also important to raise social awareness against the question leakage threat. It is an overall duty of the nation to ensure the students, teachers and everybody have the right moral values so that they are discouraged from involvement in question leakage, distribution or collecting leaked questions. The application of information and communication technology (ICT) in the examination process is also important to reduce the chances of question leakage. The next Section describes the proposed system model that uses the ICT to reduce the chances of question leakage [6].

3. SYSTEM COMPONENTS

The schematic diagram of the proposed system is shown briefly in Fig. 1. It can be seen that the core of the system is the web based centralized software [7] that is used for storing and retrieving questions and other relevant data. This has a role-based security [8] allowing multiple levels of permissions for the users. This software is used by the Examination Conducting Authority (ECA) and the ZOs. The ECA is responsible for providing the managed services for conducting examinations and uploading the questions papers into the web based software. On the other hand, the ZOs placed at geographically dispersed locations, are responsible for downloading the question papers. The other operation performed at a ZO is printing (in press) the hardcopy of the question papers. Each of the exam centres receives the hard copy of the question papers from the respective ZOs few hours before the examination and then conducts the examination in time. For the case of any form of confidential data transmission over the Internet, security is ensured in many different ways depending on the application scenarios [9,10]. In the context of this project, the security and authenticity of this web based system are maintained by following methods:

1. Use of Secure Sockets Layer (SSL) certificate for secure communication
2. Use of encryption to make the database confidential

3. Use of traditional password based authentication for accessing system
4. Use of One Time Passwords (OTPs) as security keys for downloading question [11]
5. Use of cryptographic token as digital certificate container [12]
6. Use of certificate based authentication for accessing the system
7. Use of digital certificates for encryption and decryption of the question papers
8. Use of a digital certificate for signing the question papers

These methods are described in the following:

In the proposed system, SSL certificate is used to implement Secure Sockets Layer (SSL) or Transport Layer Security (TLS), a cryptographic protocol to provide a secure connection between the server and the clients. It ensures both privacy and integrity of the data exchanged between two parties. In the server, the confidentiality of the contents of the database is ensured by encrypting the database.

A Two-Factor Authentication (2FA) is used in the proposed system to avoid unwanted users. The first one is the traditional password based authentication where each user has his/her own username and password. He has to login to the system with his own credentials before doing any authorized action. However, the commonly used static passwords have some security drawbacks. For example, a static password can be forgotten, written down and stolen, guessed, etc. The second one is an OTP which is used to authenticate a person to access the question paper. An OTP is a more secure than traditional passwords since it is valid only for a single session or transaction and this secured key is passed to a designated device for example a designated cellular phone.

In the proposed system, digital certificates are used to authenticate the online system, to encrypt/decrypt the question papers, and to sign the question papers. For these, a cryptographic token is used where the hardware token contains a user's digital certificates- both the private and public key. With the help of this token, certificate based authentication can be used in addition to the traditional password based authentication. In this case, a user must use his digital certificate to access the system. Only valid certificate holders can access the system and then can login by their credentials. These digital certificates provide an opportunity for the transmitted message to be encrypted using an encryption

algorithm. By using corresponding decryption technique, the message is recovered at the receiver end. In this system, public key encryption is used where digital certificate plays the role of the key. Such a certificate, also known as a public key certificate, is a document that is provided by a known authority (a certificate authority or CA) and settles any dispute arises between sender and receiver. In this interaction, the public key of the certificate is used for encryption and the private key is used for decryption. Note that the public key is known to the public and the private key is held securely by the owner by the said token. First, the sender uses receiver's public key to encrypt the message (in this case the question paper) and sends it. Then the receiver uses his private key which is stored in his token to decrypt received file to obtain the actual question paper. This is also termed as asymmetric (or public) key encryption [13]. Fig. 2 shows an asymmetric encryption technique while Fig. 3 illustrates a cryptographic token. The digital certificates also enable the use of a digital signature - a popular way to sign digital data. In the case of a digital signature, a sender first signs the data (i.e. question paper) he wants to send with his private key. Next, the data files are sent to the receivers where each of the receivers uses the sender's public key to verify the originality of the file. Fig. 4 shows the concept of digital signature. One vital function of digital signature is to ensure data integrity. Secondly, this certificate forces anti-deniability. Using public key cryptography algorithm, the sender cannot deny that he has sent the message since only he has the private key. This also ensures that receivers cannot forge message that is claimed to be from the sender.

A number of alternative solutions of the above security measures are possible. This is described in the following. An alternative of SSL based http (https) is the use of virtual private network (VPN). A VPN provides virtual tunnelling, authentication in addition to SSL or other encryption features. However, the complete setup of VPN for an examination system will require VPN appliances such as routers, firewalls and VPN client software. Therefore, VPN is more complex and expensive compared to SSL based https. One alternative of 'one time password (OTP) send as SMS' is the time-based one-time password (TOTP) that computes a one-time password from a shared secret key and the instant time. TOTP is based on hash-based message authentication code (HMAC). Another alternative is an automated

voice call spelling out the password after PIN code verification. The conventional OTP system may be dependable if reliable SMS service is contracted with mobile phone carriers. OTP is a simple but effective solution in the context of a developing country like Bangladesh. Some of the hardware alternatives of cryptographic (hardware) tokens are debit card, smartcard, etc. Another alternative is software token where software is installed on the device, usually in the form of a mobile application popularly known as an 'app'. One advantage of hardware token over mobile phone based scheme is that the

hardware token is only used for the examination time with special care. On the other hand, the mobile phone is used all the time and thus may be more vulnerable to hackers. The use of biometric data, such as fingerprint, retina, iris, etc. can also be a different approach to ensure security. The digital signature embedded in the downloaded question paper is checked to verify whether the question paper has been tempered or not. However, more reliability can be added by the use of the messages authentication codes like HASH, message digest (MD) and hash-based message authentication code (HMAC).

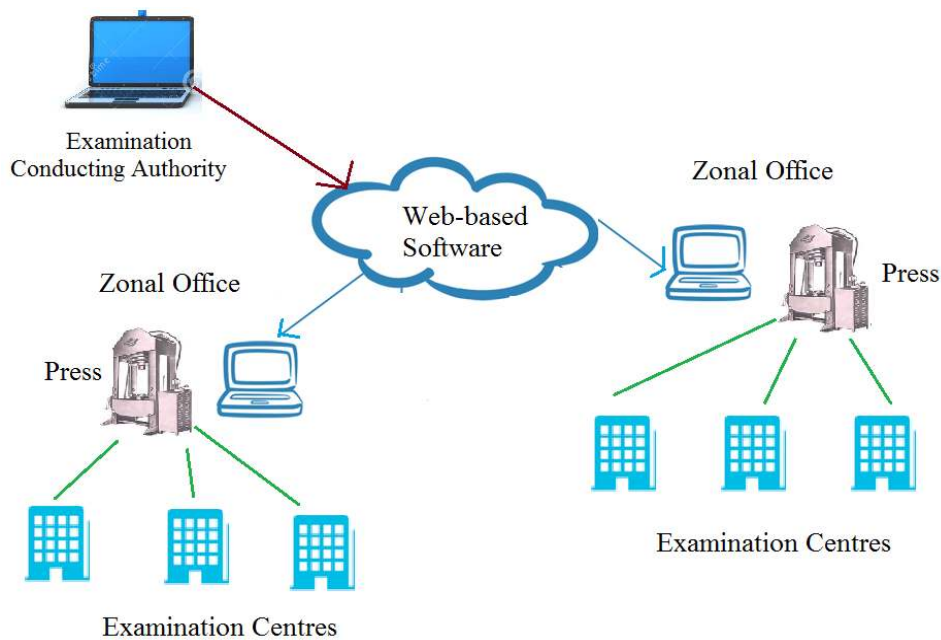


Fig. 1. Schematic diagram of the web-based examination system

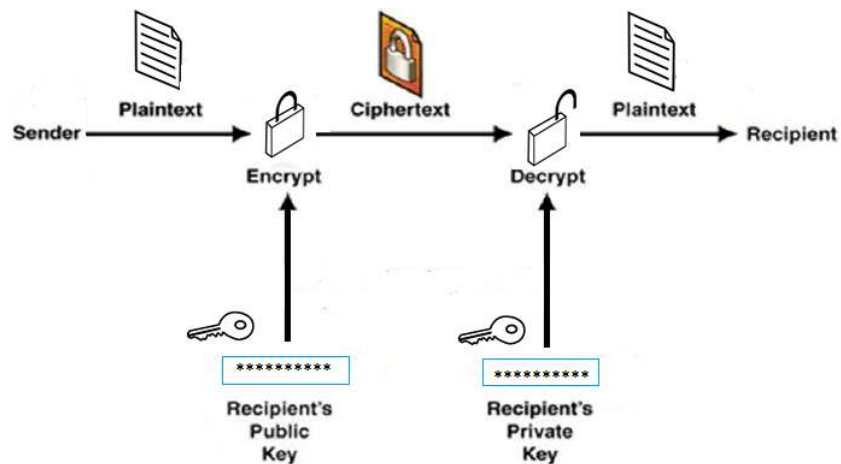


Fig. 2. An example of an asymmetric encryption/decryption algorithm



Fig. 3. A cryptographic token [Manufactured by Gemalto]

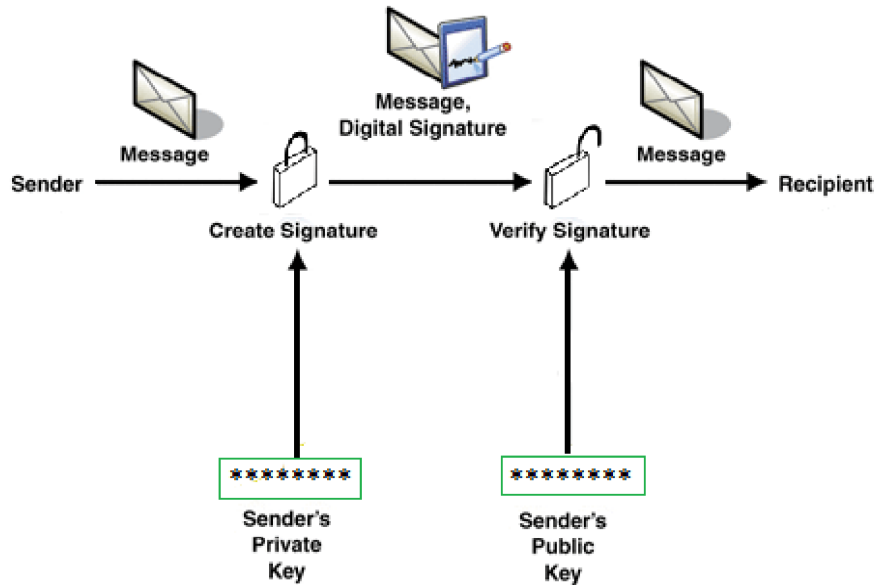


Fig. 4. Schematic showing the concept of digital certificate

4. PROTOCOL FOR QUESTION PAPER SETTING

In the proposed model of automation, the ECA is responsible for conducting and initiating the examination. In the web based system, an authorized person of the ECA initiates the question preparation procedure mentioning a specific date and time for question upload and download processes. The head of the ECA approves this initiation online. He also chooses the number of different question sets for the examination.

The next step in this system is the question paper setting. This is performed through question bank module of the software. The question bank is a large repository of questions in digitized format. Many experts in different fields prepare the questions on different topics. Each question also has a difficulty level: easy, moderate, hard, etc. These questions are then moderated by another team of experts. Afterwards the selected questions are entered

into the question bank. For a particular examination, a set of questions are selected randomly from all the available questions based on some specific criteria such as difficulty level, category of the test – technical/non-technical, etc. The selected set of questions is uploaded into the web based software. In cases where the question bank is not ready with sufficient questions, the questions are prepared manually into a Word/ Excel or an equivalent file format which is later uploaded into the web based software. In the software, the questions are rearranged into different sets. Moreover, within the same question set, questions are arranged in different ways for different zones. This is prepared so that in case there is any question leakage, it can be detected from which zone the leakage has happened.

The ECA also uploads the contact details with cell phone numbers of two authorized personnel of each zone. The cell phone numbers are vital since in the proposed model, secret codes or OTPs are transmitted to the two cell phones for

verification. This is accomplished to prevent any sort of unauthorised users.

5. PROTOCOL FOR QUESTION PAPER DOWNLOADING

The question papers are printed only in ZOs each having 50-100 examination centres. This is because the number of examination centres can be as large as thousands where many of them may not have printing facilities. Authorized personnel of each zone download the question only after the certain date and time has elapsed. However, he has to be authenticated by the system for viewing the question paper. First, the user has to insert the cryptographic token to the computer and go to the URL provided by the ECA. When the token is connected to the computer, the token driver software requires the Personal Identification Number (PIN). Then the user has to enter the PIN of the token if the server identifies the certificate as a valid certificate. After that like any web based system, he has to provide his user name and password to login into the software. When he tries to download the question paper, he is asked to provide the security keys that are actually sent to the official cell phones of two authorised persons. The sending of secret keys to two persons is done in order to reduce the chances of illegally downloading and distributing the question papers. So, both the persons with their cell phones have to be present together in order to download the question paper.

Each of the downloaded question papers is in portable document format (pdf) format. However, the pdf cannot be viewed without a pre-set token prepared for each zone. When the authorized person of each zone tries to view the question paper, the computer reminds the user to plug in the appropriate cryptographic token if the token is not already plugged in. The token for that particular zone contains the private key of the zone which is required for the question paper to be decrypted and displayed. After the PIN for the token is entered, the authorized persons can view the questions. Moreover, it is possible to check whether the question file is indeed free from any tampering by checking signature of the head of ECA embedded in the pdf file.

6. EXPERIMENTAL DESIGN, RESULTS AND ANALYSIS

The software was designed and developed in the first six months of the project. Before and during

the software development, input/feedback was collected from the DPE officials. The application side of the web based software was developed using Java with Struts 2 framework [14]. One difficult task in the software development with Java was to bring the local language (Bengali) font properly in the question paper. Oracle [15] which is a modern Relational Database Management System (RDBMS) was used for data storage. In the data centre, a network firewall was used to prevent the servers from unwanted traffic. Another important task before the start of the examination was to configure the cryptographic tokens. Each cryptographic token was manufactured by Gemalto [16], an international digital security company, and supplied locally by DataEdge Limited [17], a Certificate Authority in Bangladesh. The tokens with the private key and PIN were sent to the corresponding zones.

A few days before the actual exam date, there was software training sessions with the users, i.e. DPE officials. Each of the users received a letter and an email containing a prerequisite checklist (e.g. compatibility with computer operating system, token driver installation, administrator rights, etc.), PIN of the token, personalised user details including a username and password, and a step-by-step user manual. After several trials and testing, the proposed model was implemented for the recruitment examination of Assistant Teachers of 61 zones (each zone in this case was a district of Bangladesh) under the DPE in Bangladesh. The first phase of examination was held for 5 zones in June 27, 2015. The second phase was held for 17 zones in August 28, 2015. In September, 2015 the examination took place for another 22 zones. Finally, the last part of examinations took place in October 2015 for the remaining 17 zones. Later the same model was applied in the recruitment examination of 100 thousand test-takers at 61 zones simultaneously on 29 October 2016. In all the cases, the sequence of operations was the same. For each of the above mentioned four phases of examinations, the following operations were performed:

Table 1 shows the officials who played the main roles in the ECA and ZOs.

The Additional Director General (ADG) and the Director General (DG) of the DPE played the main roles of the ECA. Firstly, in the web based software, the ADG initiated the question preparation procedure mentioning a specific date

and time, in particular the start and the end time for question upload and download were specified. The ADG also selected the zones where the examinations were going to take place. The DG then approved the initiation. The DG also provided his digital signature/certificate. In all the above examinations, no Question-Bank were used rather questions were prepared by different subject experts under the ECA only few hours before the examination. The questions were prepared in Microsoft Excel. When the certain date and time elapsed, the DG uploaded the Microsoft Excel file containing the questions into the web based system. The DG then entered the number of question sets which was either 4 or 5 in those phases of examination.

The questions were ready for download by the ZOs 8 hours before the test. The DG was able to monitor the full download process from the software dashboard. The District Commissioners (DCs) of each district (i.e. zone) were responsible for the download. In order to access the online software, the DC had to use the token and had to enter the associated PIN. Next, each of the DCs provided his user name and password to login into the software.

While clicking the download option, the software prompted for generating two security keys, i.e.

OTPs. When the keys were generated, one of these was sent to the official cell phone of the DC and the other to that of the District Primary Education Officer (DPEO). Therefore, both the DC and the DPEO with their cell phones had to be present together in order to download the question paper. Both of them entered their keys into the software in order to validate the authentication. After the completion of the validation process, the questions were enabled for download. This is shown in Fig. 5.

Since, all sets of the question papers were grouped into a single zip file, the zip file was unzipped first. Each of the downloaded question papers was in pdf format. However, the pdf files were not viewable without a pre-set token prepared for each zone. When the authorized person of each zone tried to view the question paper, the computer asked the user to plug in the appropriate cryptographic token. This is shown in Fig. 6. When the token was connected to the computer having the downloaded question, the token driver software required a PIN which was also pre-set prepared for each zone. Once the PIN was entered, the question paper was decrypted and displayed. Moreover, it was possible to check whether the question file was indeed free from any tampering by checking the digital signature embedded in the pdf file.

Table 1. Designated persons of ECA and ZOs

Office	Designation of Persons
Examination Conducting Authority (ECA)	1. Director General (DG) 2. Additional Director General (ADG)
Zonal Office (ZO)	1. District Commissioner (DC) 2. District Primary Education Officer (DPEO)

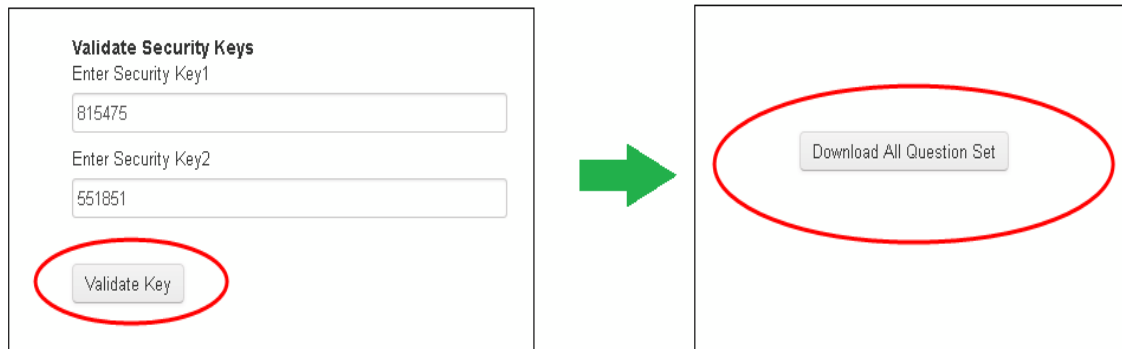


Fig. 5. Snapshot showing validating two security keys

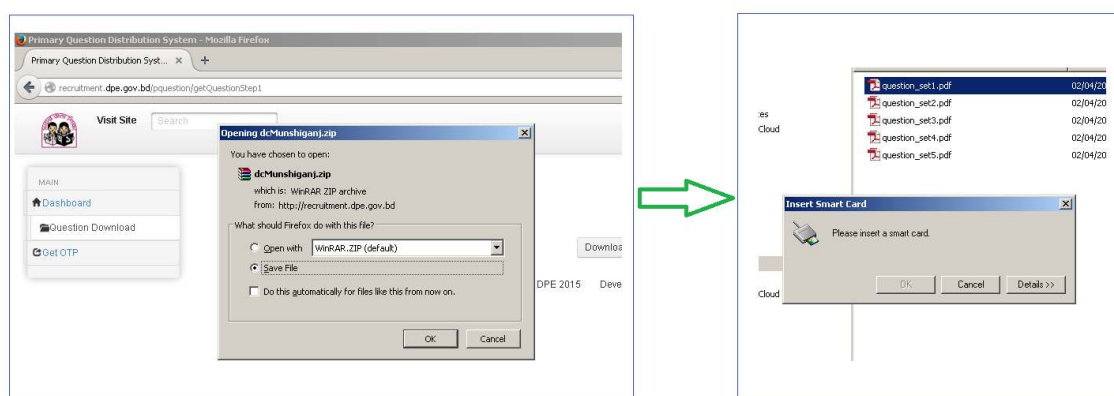


Fig. 6. Snapshot showing downloaded zipped file and list of pdf files which requires the token

In most examinations, the questions were uploaded at 5:00 AM and downloaded at 6:00 AM. The downloaded question papers were printed and photocopied from 6:00 AM to 2:00 PM while the examination started at 3:00 PM. It can be noted that for the zone with the largest number of examinees (40,000), it took 7 hours to print and distribute the questions.

The above implementation was performed for a set of specific parameters. The reasons for these parameter values and their implications on the results are briefly described in the following:

The web-based software was developed using Java and Oracle database. These tools are popular and reliable in the ICT sector. The results are unlikely to be changed if other reliable software tools are used. The cryptographic token was manufactured by Gemalto. However, any cryptographic token from any reputed company can work as certificate container. In the project, there were a maximum of 61 zones for question downloading and printing. This is because the practical examination took place in 61 districts of Bangladesh. Increasing or decreasing the zone numbers may not be an issue as long as the number of examinees within a zone does not change significantly. The largest zone in the project had 40000 examinees. If more examinees were within a zone, then printing time and facilities could have been an important challenge. In the project, four or five question sets were prepared and used. More question sets could be prepared. However, if there was lesser number of sets, there would be increase in the probability of examinees looking at others'

answers during the test. The downloading of the question papers was performed approximately eight hours before the examination. If less time was given for printing, then printing facility needed to be increased. After the downloading of the question papers, the digital signature embedded in the question paper was checked to confirm whether any tampering had taken place. Any other means such as using Hashing algorithms could be used to check whether the question papers were tampered or not.

7. CHALLENGES INVOLVED IN THE PRACTICAL SCENARIO

Proper database and user-interface design considerations and quality assurance testing were done so that the software could have overcome a number of challenges in the real world implementation. During testing phase, thorough checking was done at each ZO so that there was no out-dated hardware and poor internet connection which could have led to difficulty in downloading the question papers. High end laptops and Internet connection from cell phone carrier modems were also kept as backup. Load shedding of electricity was also a big threat for question downloading and printing. Since, each of the zones was equipped with large capacity electric generators as back up sources, no electricity interruption was experienced. An important issue during question paper download was the mandatory presence of both the DC and DPEO with their designated cell phones. So, a provision was also kept to display the security codes (sent to the official cell phones of DC and DPEO) in the software if the DG was informed of the fact that any of the two persons is missing at the ZO.

Table 2. Questionnaire of the survey

No	Question
1	The online question distribution system was easy to use.
2	No error/problem was found in the online system particularly in the token/dongle provided.
3	High speed Internet connection was available.
4	The computer/laptop was compatible with the preinstalled software and the online question distribution system.
5	The user manual was helpful and easy to follow.
6	Security codes were received by SMS without much delay.
7	The overall experience with the online system was satisfactory.
8	Making copies of the questions was easy within the given time frame.
9	There was no fear of security risks with the online question distribution system.
10	The training given for the online system usage was useful.

8. FEEDBACK RECEIVED FROM THE USERS

The software performance was assessed by the users 'live experience' during the testing phase and the actual implementation stage, as they (the users) provided feedback to the research team. In order to collect the feedback from the actual software users of DPE, a survey form (a questionnaire form) was designed. The questions of the survey form are shown in Table 2. There were a total of ten (10) questions asking for the opinions of the DPE personnel regarding the online system. Each of the questions was of multiple choice type (MCQ) with five (5) possible answers as shown in Table 3. The survey forms were sent to the relevant personnel of 60 zones via email. The filled in surveys were sent back via email to the authors of the paper. The collected data showed that in general, the software worked very well during the implementation stage. However, there were reports of limitations of the overall system in a number of cases. For instance, some of the users mentioned that they faced a little difficulty in completing the photocopy of the question papers within the time frame due to lack of high-speed photocopy machines. Some users mentioned that they received the SMS after few minutes of delay. The lack of high speed Internet connection was indicated by some users. Moreover, some users did not have up-to-date computers/laptops suitable for the software.

Table 3. List of answers for the questions

No	Multiple choice answer
a.	Strongly Disagree
b.	Disagree
c.	Neutral
d.	Agree
e.	Strongly Agree

9. CONCLUSION

This paper proposes a new model of examination management system where question papers are uploaded and downloaded by a centralized web based system. Moreover, this model is successfully implemented in Bangladesh for a recruitment exam of more than one million examinees. From the information obtained from the practical scenario, the feasibility, reliability and application prospects of the proposed examination system are justified. In general, the user experience of the software was quite satisfactory. Most of the users rated the software as user-friendly, well-functional and well-structured. The success in implementing this model has already attracted widespread attention in Bangladesh. Many organizations in the country have shown their interest in applying this model in several upcoming public examinations. We believe that the adoption of our proposed model can greatly reduce the possibility of question paper leakage and thus can play an important role in maintaining examination privacy and security.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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