Research on technical support ability and collaborative planning algorithm in online examination

Zhijie Lu*

Shanghai Municipal Educational Examinations Authority, Shanghai, P.R China

Abstract. Starting from a typical online examination EBMG (Examination Behavior Model Graph), this paper obtains the relationship between the examination effectiveness index and the examinee scale through the probability data of the examiner's examination response behavior, establishes the optimization model of the hardware structure by using the network maximum flow theory, and finds the relationship between the technical support ability and the examinee scale through the analysis of the model. Based on these two relationships, we find a collaborative planning algorithm, which transforms the relationship between the examinee scale and the technical support ability of the system under the same quality of service into the network flow diagram of online examination, and obtains the best cost-effective path of online examination system through the maximum flow algorithm.

Keywords: Collaborative planning algorithm, Examination effectiveness index, Technology support capability, Online examination.

1 Introduction

For online examination, the most important thing is the effectiveness of the examination. Both managers and candidates must optimize the effectiveness index of the examination, and finally obtain stable, accurate and efficient test results. However, with the increasing complexity of online examination hardware, network environment and examination itself, the operation and maintenance cost of online examination is increasing year by year, which has made many projects unsustainable. At the same time, researchers began to pay attention to the relationship between input and output and the collaborative management of online examination. This paper studies the relationship between technical support ability and candidate size, and obtains the technical input value under a given candidate size through a collaborative algorithm. Existing framework models and algorithms in this regard include:

M. Salmela (Salmela, 2002) provides a model to evaluate the business value of information system quality. Different technical support capabilities get different information system quality and have different value.

* Corresponding author: Lzj@shmeea.edu.cn

Jen Yao Chung (Jen et al. 2005) [1] use simpler service-oriented architecture and lower R & D cost to develop web applications more efficiently and reliably. They proposed a service composition framework to support a web services based approach to developing business integration solutions.

Other relevant researchers include Ji Xiaofeng (Ji et al., 2003)[2], Touir A (Touir et al., 2004)[3], Qingcheng Li; Zhenhua Dong (Namcul, 2010), Farhad, Panahifar, Cathal, Heavey (Farhad et al., 2015), Ma Ying, YY Xie (MA, 2018), etc. their research focuses on different technical support capability algorithm models. These models are of great significance for collaborative research of digital applications, and their research work provides us with a good foundation. However, their research pays more attention to the collaborative analysis of process, and does not carry out collaborative management on technical support capability and online concurrency.

Generally, the number of candidates, technical support ability, software development level and QoS (quality of service) are the most important aspects of the online examination effectiveness index. All decisions and predictions should come from the data of these four aspects. Any change in these four aspects will change the online examination effectiveness index.

Due to the huge difference between the technical support ability and the growth rate of the number of candidates, under the same service level, the slight improvement of the technical support ability can support the huge growth potential of the number of candidates.

The technical support ability depends on the ability of Network, CPU and Disk hardware to process software and data. Different hardware utilization brings different technical support ability. On the other hand, the change of candidate scale and online examination demand is also uncertain. Therefore, while determining the examination effectiveness index (EEI), a collaborative algorithm of technical support ability and candidate scale is needed.

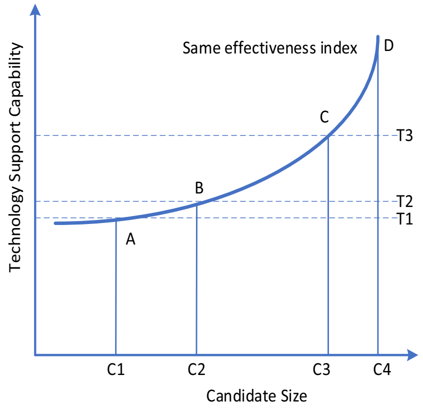

Fig. 1. The relationship of effectiveness index and technology support capability while candidate size is settled.

As shown in Figure 1, managers always hope to obtain the best examination effectiveness index. Under the same service level, they hope to move the point from A to D. however, at point D, the required technical support capacity is greater than point A, which means that investment must be increased to improve the hardware and software infrastructure, which will significantly increase the cost of technical support and ultimately reduce the attraction of online examinations, Considering the dynamic changes of the number of candidates and technical support ability, we can use collaborative algorithm to find out which point is the best position, such as point C.

2 Research methods

Our research will be carried out from three aspects: 1) the relationship between candidate size and EEI; 2) The relationship between technical support ability and the size of candidates when determining the service level (*QoS*); 3) Collaborative algorithm of technical support level and candidate scale.

2.1 The relationship between candidate size and EEI

Generally, the effectiveness index of online examination comes from the integrity of the candidate test process and the scale of candidate. The more complete the test process, the better the effectiveness index of online examination. We use the model of *EBMG* (Examination Behavior Model Graph) to show the relationship between the size of candidates, technical support ability and test effectiveness index. When the service level is determined, the number of candidates covered in the whole process is a function of the total number of candidates, and the examination effectiveness index is a function of the total number of candidates, Figure 2 shows the relationship between the process coverage probability of a typical online examination and the total number of candidates through the *EBMG* model. Each pane in Figure 2 represents the process state. Based on the output of each pane is equal to 1, we can use equation (1) to get the values of different states. For example, $V1$ = 0.39, which means 0.39 unit time of the total test time is occupied. ASL means the average test length, which is also equal to the total test unit time in the process. *PCR* is the process coverage ratio. We know that the value of *PCR* is 47%, which means that only 47% of the processes are covered by the candidate on average in the end, that is, these processes are important bearers of the examination effectiveness index.

$$\begin{bmatrix} 1 & -0.93 & 0 & -0.05 & -0.02 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.93 & 0 & 0.99 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0.99 & 0 & -0.25 & -0.72 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.05 & 0 & 0.25 & 0.10 & -0.85 & 0 & 0 & 0 & 0 & 0 & 0 & -0.05 & 0 & 0 & 0 \\ 0.02 & 0 & 0.72 & 0.85 & 0.03 & -0.9 & 0 & 0 & 0 & 0 & 0.3 & 0 & 0.85 & -0.02 & 0 \\ 0 & 0 & 0 & 0 & 0.9 & 0.01 & -0.85 & -0.07 & 0 & 0 & 0.3 & 0 & 0.02 & -0.05 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0.85 & 0.03 & -0.6 & -0.3 & 0.2 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0.07 & 0.6 & 0 & 1 & -0.94 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0.3 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & -0.2 & 0.94 & 0 & 0 & -0.65 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & -0.3 & -0.3 & 0 & 0 & 0 & 0.65 & 0 & 0 & -0.4 & 0 & 0 \\ 0 & 0 & 0 & 0.05 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -0.95 & -0.05 \\ 0 & 0 & 0 & 0 & -0.85 & -0.02 & 0 & 0 & 0 & 0 & 0.4 & 0 & 0 & -0.05 & 0 \\ 0 & 0 & 0 & 0 & 0.02 & 0.05 & 0 & 0 & 0 & 0 & 0 & 0.95 & 0.05 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.05 & 0.07 & 0 & -1 \end{bmatrix} \times \begin{bmatrix} V_1 \\ V_2 \\ V_3 \\ V_4 \\ V_5 \\ V_6 \\ V_7 \\ V_8 \\ V_9 \\ V_{10} \\ V_{11} \\ V_{12} \\ V_{13} \\ V_{14} \\ V_{15} \end{bmatrix} = \begin{bmatrix} 0.93 \\ 0.05 \\ 0.02 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix} \quad (1)$$

We assume $E0$ is the examination effectiveness index at present, $E1$ is the next examination effectiveness index goal, we get that,

$$E_0 = \frac{Sessions}{sec} \times PCR \times AverageTimes \times \text{Seconds} \quad (2)$$

When the size of candidates change, the EEI will also changes, for example, from $E0$ to $E1$, the factors that influence this kind of change including sessions of each second and each examination, process coverage ratio, average process coverage ratio of each examination and the service level (Qos) and so on.

$$E_1 = \frac{Sessions1}{sec} \times PCR1 \times AverageTimes1 \times \text{Seconds} \tag{3}$$

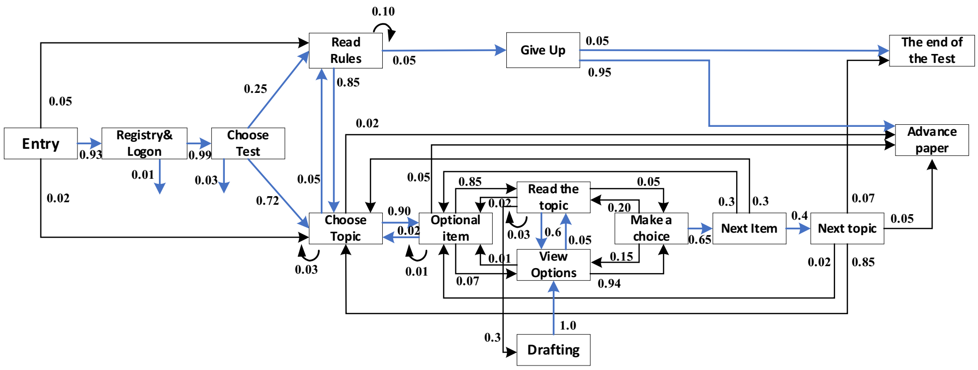

Fig. 2. Examination Behavior Model Graph of a typical online examination.

We suppose just the Process Coverage Quantity change, the others are all settled, and we can get the result of sessions of each test of the E1 as Eq.(5),

$$\text{(Average Process Coverage Ratio) } APCR = \sum_{k=1}^{n-1} V_k \times p_{k,i} \tag{4}$$

$$\frac{Sessions1}{sec} = \frac{E_1}{PCR \times AverageTimes} \tag{5}$$

$$PCR = PCQ \,/\, TSC \tag{6}$$

where PCQ is Process Coverage Quantity and TSC is Total Size of Candidates. From Eq.3 and Eq.5, we get Eq.(7),

$$E_1 = \frac{Sessions1}{sec} \times \frac{PCQ}{TSC} \times AverageTimes1 \times \text{Seconds} \tag{7}$$

For each test, we get Eq. (8) as follow,

$$\frac{E_1}{sec} = \frac{Sessions1}{sec} \times \frac{PCQ}{TSC} \times AverageTimes1 \tag{8}$$

Eq.(8) shows the relation of size of candidates and EEI while the service level is settled.

2.2. The relation between technology support capability and scale of candidate while the service level (Qos) is settled.

Online examination system's Services quality (QoS) has many performance metrics, For candidate, the absence of any non software failure in the examination system within the specified time is an important indicator to measure the service quality of the online examination system, so we choose the Service Response Time and Service Pause Time are

 https://doi.org/10.1051/itmconf/20224702034

used as indicators to measure the service level of online examination system’ s technology support capability, Service Time includes three parts, show as Eq.(9),

$$ServiceResponseTime = CD\_Time + 2 * NetworkTime + SD\_Time \tag{9}$$

$$ServicePauseTime = \text{System Downtime} \tag{10}$$

$$ServiceTime = ServiceResponsePauseTime + ServicePauseTime \tag{11}$$

where CD_Time denotes the Client Disposal Time, SD_Time denotes the Server Disposal Time. NetworkTime means the network transport time, DownTime is the probability time of system downtime, Show as Figure.3,

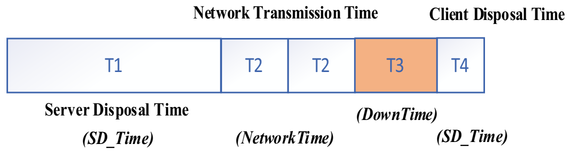

Fig. 3. The main parts of service time.

From Figure.3, There are four time parameters in total. Generally , the processing time of the server is higher than that of the network transmission time and the client. The network transmission time is related to the amount of concurrency, that is, it is related to the scale of online candidates; The downtime disposal time is related to power guarantee measures. From the perspective of server, the server processing time is related to Load Balancer, Server hardware, Service application software architecture, Server database software service, etc; Network transmission time is related to network architecture, network bandwidth and the size of candidates.

For online examination, because of fairness, the system service time of each candidate should be basically the same when the average process coverage is the same. In order to do this, we must find a balance between the scale of candidates, hardware investment, service quality and the effectiveness of examination.

As the increasing of scale of candidates, service request increasing rapidly, the utilization of the Online examination system’s server also increasing quickly, at the same service level (Service Time), more hardware investment will be made in the online examination system to ensure that the service time provided to candidates under the same process coverage is the same, and at the same time, to ensure that the database system of the server does not have blocking downtime. The use of a certain range and scale without cutting off the power supply will be needed.

Figure.4 shows the hardware network structure of a typical online examination system, it include several virtual layers structure, each layer achieves different functions, and we can use a Flow Network Model to denote their micro services structure, shows as Figure.5.

Our method is to combine software and hardware for analysis, that is, the hardware architecture diagram and software data flow diagram are combined to form an online examination network flow diagram, which includes all factors that may affect network traffic, such as hardware factors (including hardware equipment performance, network architecture, load balancing, etc.) Software factors (including software architecture, code compilation efficiency, data query algorithm, storage algorithm, etc.) and candidate factors (candidate scale, misoperation probability, etc.), and then according to the method of network maximum flow on the premise of unchanged service quality.

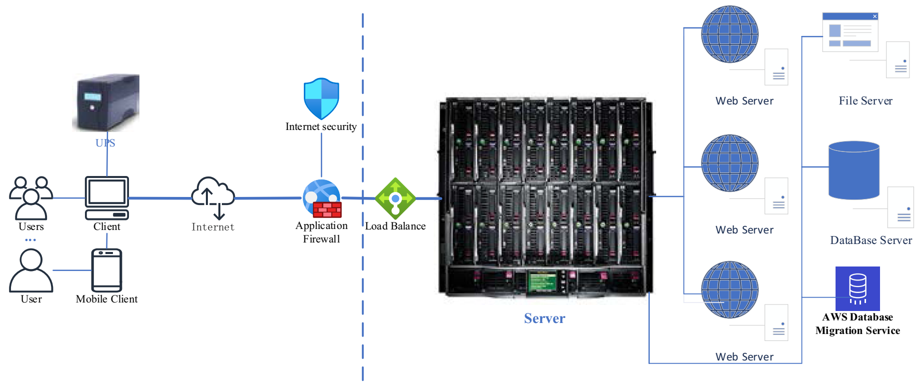

Fig. 4. Structure Figure of hardware network.

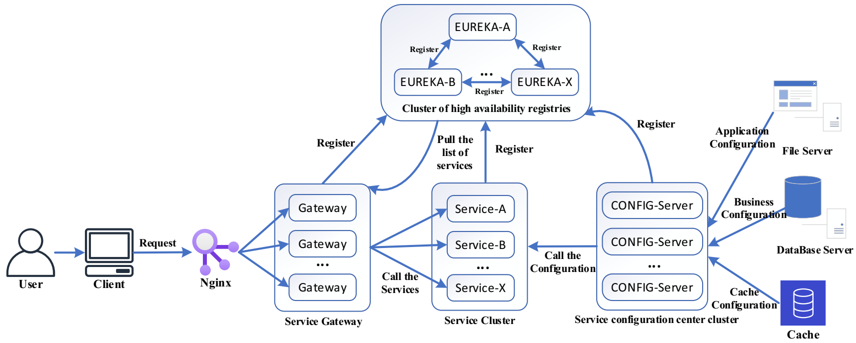

Fig. 5. Diagram of online exam data flow model.

Figure 2 shows a simple network flow diagram, but it is only a part of the online examination system interface. If it is combined with the whole technical support system (including hardware, software and network), it can form a complete online examination network flow diagram integrating Figure 4 and Figure 5, shows as Figure. 6.

In Figure 6, S represents the beginning of the exam, E represents the end of the exam, and V represents each node that will consume time in the exam process. Some nodes are not considered because the consumed time is negligible. Each link represents a possibility, but also a constraint and capacity. When the quality of service requirements are the same, the relationship between candidate size and technical support ability has become the Biggest Flow Problem of online examination network flow diagram.

In Figure 6, the flow on each arrow cannot exceed its maximum capacity (capacity). At the same time, for each node, the algebraic sum of inflow and outflow is equal to zero. In addition, the total outflow at the starting point and the total inflow at the ending point are also equal. Because the feasible flow of an actual network flow graph always exists, the maximum flow algorithm in the network flow system is to find a path flow f covered by the average process in a given capacity network to maximize its flow v(f). The following linear programming mathematical model can be established for the maximum flow problem of online examination.

$$\max v(f) = \sum_{v \in V} f(s, v)$$

$$s.t.\begin{cases} \sum_{j} f_{ij} - \sum_{i} f_{ij} = 0, & i \neq s, t \\ 0 \leq f_{ij} \leq c_{ij}, & \langle v_i, v_j \rangle \in E \end{cases}$$

Model.1 linear programming mathematical model

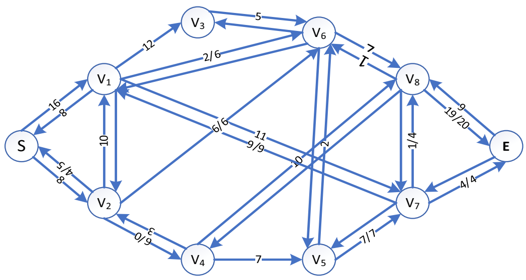

Fig. 6. Conceptual model of online exam network flow diagram.

According to the linear programming theory, the solution $f = \{f_{ij}\}$ satisfying the above constraints is called the feasible solution, that is, the feasible flow in the online examination network flow. The corresponding flow in the feasible flow is an important reference in the hardware configuration, software setting or network setting of the online examination system.

2.3 The collaborative planning arithmetic of the technology support capability and the scale of candidates

After research, we find that the maximum flow problem of online examination network flow can be transformed into the problem of augmented chain. That is, if there is a feasible flow f in the network flow, as long as it is determined whether there is an augmented chain about the feasible flow in the network. If there is no augmented chain, then the flow f must be the maximum flow. If there is an augmentation chain, the flow of feasible flow f will be continuously improved and increased, and finally become the largest flow in the network. We use the labeling method to solve the linear programming model shown in Figure 6 and listed in Model 1.

Step1: Find an initial feasible flow $f_{ij}^{(0)}$. If there is no feasible flow in the online examination network flow, make the flow of all arrows zero, $f_{ij}^{(0)} = 0$.

Step2: Mark the docking points and find an augmentation chain.

Starting point label (∞);

Select a point Vi to search for a link to the end point along the arrow labeled at one end and not labeled at the other end;

(a) If the arrow is forward and $f_{ij}<C_{ij}$, then label $\theta_j=C_{ij}-f_{ij}$.

(b) If the arrow is backward and $f_{ij}>0$, then label $\theta_j=f_{ij}$.

When the end point has been labeled, it indicates that the augmented chain should be found, and an augmented chain can be obtained by reverse tracking according to the label of Vi. When the end point cannot be labeled, it indicates that there is no augmentation chain, and the calculation ends.

Step 3: Adjust flow:

(1) Find the minimum value of the Vi label of the point on the augmented chain to obtain the adjustment quantity number $\theta = \min_j \{\theta_j\}$

(2) Adjust the flow as follows:

$$f_{ij}^{'} = \begin{cases} f_{ij} + \theta, < v_i, v_j > \in \mu^{+} \\ f_{ij} - \theta, < v_i, v_j > \in \mu^{-} \\ f_{ij}, < v_i, v_j > \in \mu \end{cases}$$

Get a new feasible flow $f_{ij}^{'}$, remove all labels, and return to the second step. Label again from the starting point to find the augmented chain until the ending point cannot be labeled.

The augmented path algorithm program based on Ford & Fulkerson method is as follows:

```
#define Maxn 120
#define INF 0x7f7f7f7f
int cap[Maxn][Maxn],flow[Maxn][Maxn];
int pre[Maxn],res[Maxn];
int Edomonds_Karp(int start,int end)
{
    int Maxflow=0;
    Memset(flow,0,sizeof(flow));
    Memset(pre,0,sizeof(pre));
    queue<int> q;
    while (ture)
    {
        Memset(res,0,sizeof(res));
        res[start]=INF;
        q.push(start);
        while(!q.empty())
        {
            int u=q.front();
            q.pop();
            for (int v=1;v<=end;v++)
                if (!res[v]&&cap[u][v]>flow[u][v])
                {
                    res[v]=min(res[u],cap[u][v]-flow[u][v]);
                    pre[v]=u;
                    q.push(v);
                }
        }
        if (res[end]==0) return maxflow;
        for (int u=end; u!=start; u=pre[u])
        {
            flow[pre[u]][u]+=res[end];
            flow[u][pre[u]]-=res[end];
        }
        Maxflow+=res[end];
    }
}
int main()
{
    Memset(cap,0,sizeof(cap));
    for (/**/)
    {
        int u,v,s;
        scanf("%d %d %d",&u,&v,&s);
        cap[u][v]+=s;
    }
    return 0;
}
```

By modeling the software and hardware of the online examination system, and then using the network maximum flow collaborative planning algorithm, we find the relationship curve between the examination effectiveness index and the size of candidates in the online examination system (under the same service quality). Based on this curve, we can effectively manage the promotion and Application of the online examination system.

Via the real network data, we get the Figure.7 as follow,

With the increase of the scale of candidate, in order to ensure the effectiveness index of online examination, we must improve the technical support ability. Therefore, the investment of online examination system began to increase, and the quality of service (*QoS*) of examination system also began to improve. However, when the scale of candidates reaches a certain level, due to the complexity of the network system and the saturation of the network flow, the service quality of the examination system begins to decline, and the effectiveness index of the examination also begins to decline. Points M and L in Figure 7 correspond to the best service quality point and the scale of candidates with the best effectiveness of the online examination.

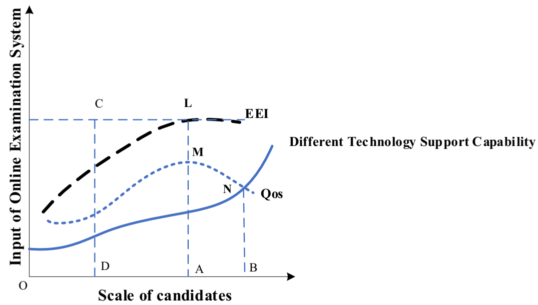

Fig.7. The relationship between Scale of Candidates, online examination investment and Examination Effectiveness Index.

3 Conclusion

This paper focuses on the relationship between the size of online examination candidates and technical support ability. Candidate scale is an easy data to collect, while technical support ability is a variable that is difficult to quantify. In this paper, through candidate examination behavior model diagram(EBMG), online examination hardware network architecture diagram and software data flow diagram, the evaluation index of technical support ability is transformed into the maximum flow of network flow diagram, and the problem is solved through collaborative programming algorithm, Supported by real data, this paper analyzes the relationship between the technical support ability of online examination system and the size of candidates.

In the follow-up research, we will further refine the network flow diagram and further optimize the algorithm, so as to provide more effective data support for the scientific planning of online examination.

References

1. Jen-Yao Chung. A Web services-based framework for business integration solutions. *Electronic Commerce Research and Applications*, (2:1), 2003, 15-26.
2. Ji XiaoFeng, Xu Junhua, Zhu Hua et al. A realizable intelligent agent model applied in dynamic e-business. *Information Reuse and Integration*, IEEE International Conference on IRI 2003, 27-29 Oct. 2003, Pages: 1-7.
3. Touir A, Mathkour H, Al-Naeem T. BizArk: a reusable e-business architecture based on pattern-oriented technology. *Computer Systems and Applications*, IEEE International Conference on ACS, 14-18 July 2003 Pages: 54.
4. S Eliott. Electronic Commerce: B2C Strategies and Models. *European Journal of Information Systems* (12:1). 2003, p. 72.
5. CC Pan, KH Yang, TL Lee. Secure online examination architecture based on distributed firewall. *IEEE International Conference on E-technology*. 2004-03.
6. QF Zhao, YF Li, Research and Development of Online Examination System. *Advanced Materials Research*. 756-759,2013-09,1110-1113.
7. CR Weeramuni, *ONLINE EXAMINATION SYSTEM*, 2016. http://dl.lib.mrt.ac.lk/handle/123/ 11705.