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Trust model at service layer of cloud computing for educational institutes

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Abstract Cloud computing is one of those technologies which have revolutionized the modern world. Through this, people can start their businesses without huge investments required for infrastructure like servers, technical staff for maintenance, and purchasing of expensive software, etc. With many advantages, there are few risks involved with cloud computing. There are issues like unavailability of service, i.e., they are down when required. Another issue is of outdated service/stuff provision to the clients by the cloud service providers. Similarly, lacking of effective and quality support services to their customers is another important concern. Moreover, non-capability of cloud

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service provider in honoring the service level agreement is an additional prong in this list. All such issues make cloud service users frustrated. Hence, there is a need of a system which may help the cloud service user to select good cloud service provider. Hence, for the above mentioned issues, in this article, we have proposed a model which will help the cloud service users in finding out the efficient and trustworthy cloud service provider. In put data to the model can be collected from regulatory authorities, performance of cloud service provider in the last one year, and feedback taken from the customers. Moreover, the proposed model is flexible enough to be customized according to the precedence level of aforementioned parameters for the cloud service users, i.e., educational institutes. We have also given a comparative analysis of proposed model with general existing model to portray the importance and requirement of the designed model for the said application domain.

Keywords Cloud service provider · Cloud service user · Service level agreement · Educational institute

1 Introduction

In cloud computing, the services are provided over the network by managing the available resources, i.e., hardware/software. Users can create or customize the environment according to their needs since this is one of the facilities provided to them by cloud computing [1].

In the list published by Talkin' Cloud 100 [2], 'Amazon Web Services' (allows access to their users for data storage and retrieval at any time from everywhere) is undoubtedly ranked at number one for providing the services of cloud computing. "Rackspace" (provides servers for employees, multiple options of operating systems to choose from), San Antonio, TX, USA is ranked at number two, and "Savvis (CenturyLink)", Town & Country, MO, USA is ranked at number three. Other well-known cloud service providers (CSPs) are Salesforce.com, Verizon/Terremark, Google Apps, and Joyent. Although, cloud computing has gained a remarkable progress, there are, however, some weak areas as well with respect to its performance, i.e., Return-on-investment (ROI), Market churn, Privacy, Possible downtime, Security issues, Cost, Inflexibility, and Lack of support, etc. [3].

The Service layer of cloud computing is divided into 3 sub-layers, i.e., Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS) [1]. IaaS is a model in which an organization outsources the equipment used to support operations including storage, hardware, servers, and networking components. The service provider owns the equipment and is responsible for housing, running and maintaining it. The client typically pays on a per-use basis [4]. In PaaS, users can develop their own applications. For the runtime environment of the application, solution stacks and entire computing platforms are offered by the PaaS providers. In SaaS, different vendors or service providers host the applications, and those applications are made available to the customers by using the Internet. This model provides the global accessibility option of the underlying application to its users.

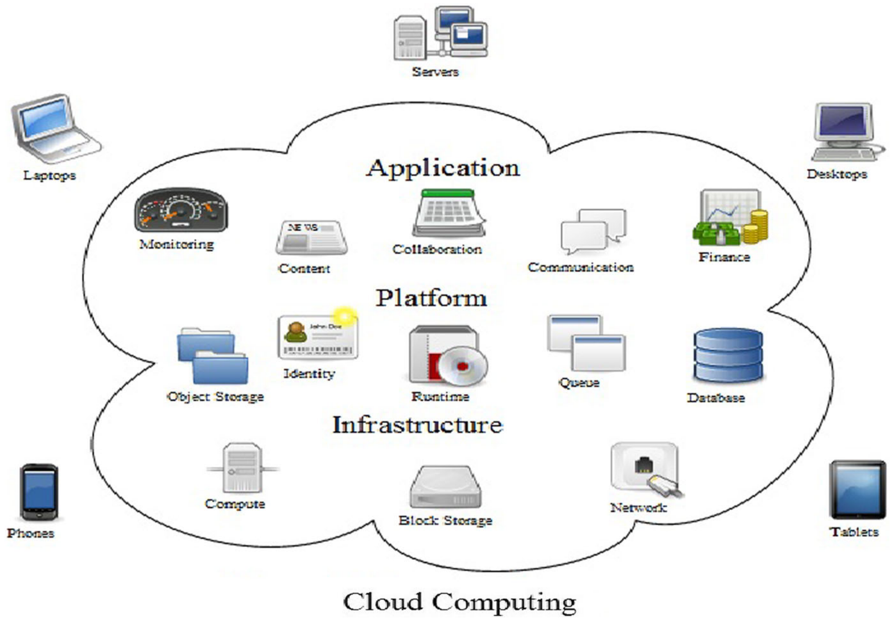

Fig. 1 Basic architecture of cloud computing [6]

Cloud services are generally architectured in one of the following four ways. These models have been recommended by the National Institute of Standards and Technology (NIST) [5]. A simple graphical representation of aforementioned three most renowned service layers of cloud computing is given in Fig. 1.

The deployment models of cloud computing are Private Cloud, Community Cloud, Public Cloud, and Hybrid Cloud [5]. In **Private Cloud,** an organization solely operates this specific type of infrastructure for their requirements to have more control over their data than they can get by using a third-party-hosted service such as Amazon's Elastic Compute Cloud (EC2) or Simple Storage Service (S3) [1]. The organizations or departments which have shared their concerns are grouped together to become a community. The cloud designed for such groups comes under **community cloud. Public cloud** is the cloud service provided by the third party or organization to the large industry group or to the general public. **Hybrid cloud** can be a composition of private, community or public cloud and also acts as an enabler to data and application portability (e.g., between the cloud, the load balancing in cloud bursting). Public cloud deployment model is used for the CSPs to provide services to the common cloud service users (CSUs) like educational institutes (EIs).

1.1 Contributions

Our research work on Trust Model at Service Layer of Cloud Computing for Educational Institutes has following contributions in literature.

(a) Identifying and analyzing the performance parameters for a good trust management system for EIs. Each application has its different types of resources and needs based on which the parameters in the trust model are selected. Similarly, in case of EI, the evaluation parameters should be closely related to the needs and requirement of the EI.
(b) Pinpointing the limitations of any existing trust management system available for EI.
(c) Proposing a new model that helps in the selection of trustworthy cloud provider for EIs.
(d) Selection of CSP based on students' and faculty requirements.

In the subsequent Sect. 2, we will be describing the trust management in EI comprising a brief and fruitful discussion on trust and the constituents of trust policy, criteria for the selection of a trustworthy CSP, points for the evaluation of provided application by the CSPs to their users, as well as the suggestions for the CSPs to improve their trust among their users. In Sect. 3, a brief view of state-of-the-art closely related research is given from around the various available literature. Proposed solution with subsections from 'A' to 'F' for its detailed description is given in Sect. 4. Comparison of the given proposed solution with the existing work is given in Sect. 5. Section 6 gives the conclusion of the article.

2 Trust management in education institute

In this section, we will be starting our discussion from "Trust" and ending on "Trust Management in EI" though the exploration of various aspects of trust from CSP and CSU ends.

2.1 Relationship between trustee and trustor

The functioning of the information, entities, and people in an expected way is the focal point of the word "Trust." The trust may be machine to human, human to machine, or machine to machine. The negotiation of handshake protocols within certain protocol comes under machine-to-machine trust. On a website, the reviewing of the digital signature advisory notice by the consumer is an example of human-to-machine trust. However, relying of a system with extensive verification on user input and instructions is the trust of machine over human. At a deeper level, security and privacy are the desired outcomes that are ultimately required from "Trust." Hence, we can define trust as "Trust is the belief between two or more entities to provide the ground for establishing a reliable communication between them." Hence, relationship on confidence between two entities (Trustor and Trustee) is known as trust. Trustor is an entity who has the ability to take the decision to trust other entities based on the available information and previous experience received, while Trustee is an entity that has the physical existence like person, organization, etc., and is being trusted by the trustor [7]. Different trust management organizations use different trust management models which also have further different types of trust matrices. The trust matrices may vary

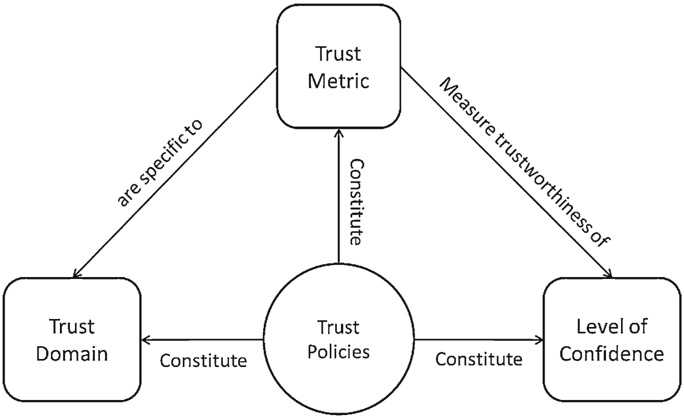

Fig. 2 Typical constituents of trust policy

from model to model. A typical trust model may have one or more than one parameters. Usually, the trust metrics can be calculated on the basis of previous experience and certification awarded. Although, this is a qualitative analysis and does not have any numeric value, yet we can assign the numeric value to the observations from the best to the worst. Similarly, level of confidence is to be measured in percentage between [0,100]. Another terminology used in the trust community is of trust domains. These are all situations and conditions under consideration for the trust policy. Figure 2 shows constituents of a trust policy.

Dropbox (https://www.dropbox.com) has more than four million customers who can upload digital contents, which is permanently synch across a number of their devices. Adam Gross, senior vice president of Dropbox marketing for the storage service said the trust of users is indispensable need for the cloud. He also said that the providers must have the trustworthy relationship with their users as it helps people in storing back-ups of their files with the facility of safety and security. This is totally in contrast to the old models where each personal computer user is responsible for keeping its own data secure and safe. There are two types of trust, which are static and dynamic. Service Level Agreement (SLA) that is signed between two parties is known as static trust. Trust calculated on the basis of previous experience and experience available from other trustors is called dynamic trust [8,9]. There are different parameters in SLA that is signed between two parties, i.e., trustor and trustee. As an example, in the Google apps SLA, downtime, covered services, monthly uptime services, etc., are all mentioned in detailed description form [10]. In the subsequent paragraphs, we will be discussing the trust management from the CSP and CSU perspectives.

2.2 Trust management

Trust management means to manage the trust with respect to the satisfaction of customers against different satisfaction parameters or with respect to different agreed-upon terms and conditions. In short, we can say that “Level of Trust a CSP can maintain with its consumers refers to the term trust management." To maintain the level of trust, the CSP must provide the required services to the CSUs to their demanded level. Although a range of criteria parameters are there for the selection of CSP, yet the ultimate selection of the CSP is based on the preferences that the user is interested to choose for the management of its system. Following are some of the most well-known selection criteria. These all are directly or indirectly related to the trust that the CSP developed with the users.

- Choose a CSP with the help of previous experience with a specific CSP. CSP improves its system day by day on the basis of feedback received from the users. The most important point is getting the feedback and then resolving the problem if there exists any, which is the key to establish the sincerity and reputation of the CSP among the users.
- Quick cloud implementation is another selection parameter. Implementation and starting of the service should be effective and efficient. 'Effective' means that the requirements should be fulfilled completely, while 'efficiency' means that the requirements should be provided in time.
- Avoid electing the lowest-cost cloud option. It is better to scrutinize SLA and security capabilities.

Apart from the generic viewpoints regarding the CSP, the services provided by the CSP should also be evaluated before developing a trust on the CSP. Following are some criteria given for the evaluation of these applications/services.

- How strong the CSP's security processes and standards are with respect to their fault tolerance capabilities? If there occurs any disaster in the system, is then there any alternate solution available to the organization? Is there any availability of backing up to the system and how effectively and efficiently the services are reinstated?
- How flexible the CSP's ability is to meet the need of the user? If a CSU's requirement gets changed or updated time by time or after some specific interval based on its organizational set up or in any emergency situation, then how much the CSP is friendly in making all such changes and updates?
- What is the history of CSP regarding its SLA? How well this is improved, and how does it meet the need of CSUs and their changing requirements? How updated the CSP's current SLA is?
- What are the CSP's business viability and future outlook regarding the technological changes and CSUs' requirements.

The CSPs are the ones to attract the customers to maintain and grow their business. Hence, they must keep their focus on increasing the trust of the current and potential customers. Following are a few of the related points.

- CSPs should avoid being a black box, in particular for 'security' and 'ability' related matters. They should clearly explain their structure/organizational architecture, available resources, policies, planning, mission statements, and their future planning.
- What are the systems and processes in pricing, fault management, maintenance, and other related matters? These must be made clear to the CSUs.
- Improve trust by reducing technical lock-ins.

- When things go wrong, CSPs should be open and honest about them. They must communicate to the CSU about the current situation and expected time to activate or re-activate, recover, or reinstate the system and services.

Following attributes need to be considered while selecting trustworthy CSP. Hence, on the basis of above-mentioned parameters in the selection of a good CSP, we can draw a list summarizing the performance parameters of Trust Management in Cloud Computing as given in brief hereunder.

- Security measures
  - The different assets that may be in the form of logical or physical or tangible or intangible need security. In case of handing over these assets to the CSP, the main risk is in their illegal use or their misinterpretation with respect to their communication to the allowed ones. The organization (Trustee) that is providing the services to the CSU (Trustor) must guarantee that the assets would be in safe hands and never be misused. Also the privileges given to the stakeholders must be very much defined, and there should never be any lapse in these security services.

- Compliance with regulatory body's standards
  - The regulatory authorities take care of the proper work flow of the organization that also includes the trust of the trustor as its factor of influence. These regulatory bodies define different standards to keep things in the CSP organization to be up-to-date. Hence, a CSP organization that is in compliance to the standards of the regulatory body is and should be preferred by the clients in the selection of getting the services of cloud computing.

- Downtime
  - Keeping the system always active to provide the continuous services to the clients sometimes becomes more and more important when it is direly needed (peak hours). The downtime should be minimized, and if there arises a need for the CSP to get the system shut for upgrading, repair, and maintenance, then that should preferably be preplanned. This is usually called planned outage. The organization that gives minimum downtime in the previous year should be the preferred choice.

- Availability (Uptime)
  - The time of the year when the services of the CSP is available to the users is called uptime. The trustor prefers the CSP that offers the best uptime in the previous year with respect to its availability to the users.

- Customer Support
  - When the customer is in need of the service, support, or help from the CSP, then it should be given in a proper way to resolve the issue of client and to satisfy him. The organization that offers the best experience to the customers with respect to their support when and where needed is preferred to be selected among the CSP organizations.

- Performance of a Specific Service
  - A CSP that has a very good reputation in a specific service is the preferred choice. Hence, it is not necessary that one must use the same CSP for every service; instead, different service providers can be selected for different services according to their past repute.

- Latency (Response time)
  - Once the complaint, request, or query is put to the CSP, it may take time ranging from minutes to hours and even up to days depending upon the severity of the problem, fault, or application. Different tasks may take different times to be resolved. A CSP that takes the minimum time in response to complaint, request, or query is preferred to be the choice as the CSP organization.

Among the aforementioned seven most important parameters, some are preferred for/by one type of CSUs, and some are preferred for/by the other type of CSUs. Hence, each has its own importance with respect to its implementation scenario. Naseer K. et al. have discussed and implemented most of these points at abstract level in [11]. In the subsequent paragraphs, we will be discussing the target domain of this article in detail.

2.3 Trust management in educational institutes

Universities' conventional education system is fast changing in keeping with the research and advancements in the Internet and Information Technology. Students/users use different services like World Wide Web (WWW) service, File Transfer Protocol (FTP) service, Bulletin Board System (BBS), and Simple Mail Transfer Protocol (SMTP). Students who want to use any service on cloud network need to have specific application installed on their mobile, computer, or PDA to access that specific service available on cloud network through internet connection. User service model for libraries that is the key component of any EI has no independent existence. It is closely related with library's information resources, human resources, technology resources, managing resources, and so on. Cloud computing can also be used to improve the current educational service providing techniques by making it more professional and more effective with respect to resource availability and their accessibility. Services of cloud computing in EI are storage, databases, emails, centralized educational applications, and the tools for students/users involved in educational program. Apart from these, there are more advantages of cloud computing in education/mobile-learning like lower costs, improved performance, reduced software costs, instant software update, improved document format compatibility, increased data reliability, universal document access, device independence, etc. [12].

Nowadays, our EIs are suffering greatly due to lack of proper planning, thus facing financial and technical issues. Several aspects are required to be considered for resolving these problems. Out of these problems, cloud computing can help the EIs to reduce their financial and technical issues by providing servers, databases, software, Online library, etc. These facilities do not only help in reducing the expenses of EIs on purchasing new equipment like servers, databases, software, etc., but also in reducing the need for extra space, and manpower for operating and maintaining these systems [13]. For example, when it comes to deploy a network in an EI, then the equipment is purchased. It is not necessary that the purchased equipment is compatible with each other. Even if they are compatible with each other, any upgradation in equipment or system from one manufacturer may result in compatibility issues with the other ones. In such case, the cost on compatibility will also be paid by EI. Hence, to avoid all such tensions and expenses, cloud computing provides the best solution. By availing cloud services, EIs can reduce their effective expenses on upgradation and purchasing of equipment. In this way, institutes get updated software without worrying about compatibility and maintenance issues. Moreover, universities from across the world are now collaborating with each other, but they are working on different systems. For proper coordination, they need compatibility. It would be difficult for universities to tackle this issue, but CSPs can do it easily at low costs. For the said purpose, a few CSPs are not meeting the expectations of customers, and some are cheating also. Hence, the purpose of this research is to help the customers in selecting a good CSP. To avoid a scenario like the one mentioned above, a system is required, such that it can help the customer to select the most trusted and appropriate CSP.

We are now introducing our model that best fits for the assessment of trustworthy CSP for the EI. After a deep analysis of institutional needs and requirements, we propose the new model that appends weight to the attributes. Our model gives the option to EIs for evaluating various available CSPs based on their reputation in market on behalf of their provided QoS and selecting the most-trustworthy CSP. Our analysis further concludes that the selection of "quality of service" as the priority parameter in preference to security measurements is better for the underlying application domain because our focus is on making availability of service and minimizing the downtime in future as it reflects to the insurance against big losses.

3 Literature survey

This section presents the state-of-the-art work that is closely related to the underlying topic.

http://www.crucial.com.au released a white paper in March 2014 [14]. They discussed the cloud computing's application in education sector. They threw the light on CSPs' realization of the fact of adjusting their services according to the needs of EIs. The CSPs are providing customized packages for EIs at low prices. A few leading CSPs which are giving their services to EIs are discussed below.

Microsoft for Education: It is one of those companies whose products have been providing service to the educational sector for more than 20 years. In the following forms, the cloud services of Microsoft are available to the EIs: Business Productivity Online Suite (BPOS), Office 365 for Education, Exchange Hosted Services, etc. Microsoft Office 365 Education: millions of faculty, staff, and students are using this cloud-based communication and collaboration tool.

Google Apps for Education: Google apps for education platform are widely used for outsourcing web-based email and documents for collaborative study. Google has started 2 campaigns to bring improvements in Education Sector. Google's one project is with Malaysian Ministry of Education where they introduced 4G internet access and Samsung “Chromebooks” in 10,000 schools in 2013. The other one is “Tablets with Google Play for Education.” Through this many useful applications are available to students. Moreover, it also help teachers to implement latest technology solutions in classrooms.

AWS in Education: Amazon’s AWS cloud is providing cost effective solutions to EIs. It is providing storage and computing resources to their users which contribute to the creation of flexible IT infrastructure in EIs.

In their paper, Yang, et al. [13] gave the detailed survey of recent research advances in different fields and cloud computing in e-science. They included, e.g., business model, computing model, and programming model in e-science. They kept the focus of their survey on cloud computing. Various opportunities and challenges while implementing cloud computing to service computing were discussed. They also discussed in detail the computing-based cloud and storage based cloud in this paper. They said that for achieving successful application, complete understanding of scientific domain in addition with good coordination of domain experts and computational scientists, is required.

In their paper, Durao et al. [4] discussed the increasing numbers of users and thus increasing demands for the applications and services by the customer. They discussed the effects of the above mentioned issues on the service providers and their handling of the applications. They wrote that increasing demand brought up the QoS competition among different service providers. Hence, they worked on Cloud Computing Service Composition. They studied and compared different proposed algorithms and extracted all of the considered QoS parameters. Rating the parameters as most significant and least considered. They also calculated the important parameter percentages. They did a detailed survey of the research been done. In literature they found that most researchers have considered QoS parameters for Service Composition. They found 14 different QoS parameters. Among which “Service Cost” (24 %) and “Response Time” (22 %) are the most repeated ones. For future work they suggested that for preparing an environment that can compare the proposed algorithms, comprehensive QoS dataset along with a set of differently sized, standard problem is required.

Coutinho et al. [15] discussed elasticity and cloud computing in their paper. They said that the property of the system which can add or remove the resources on the fly to handle the variations in the load is known as elasticity. Hence, they said that it is good for cloud computing systems where there is on-demand service provisioning is done. They also pointed that detailed analysis/research on cloud computing is done, but very rare work is done on the elasticity. That is why authors done a systematic review on the various aspects of the elasticity. They presented their findings and future works’ directions in their paper.

Nunez and Hierons [16] discussed the cloud computing and threw the light on the efforts of the researchers in this field/domain. With that they also highlighted the flaws/loopholes that are present in those researches. They said that researchers try to cover all the areas, but still there are few left in virtualization of resources, policies of resource provisioning and underlying cloud architecture. Hence, there always remain the doubts whether the observed behavior in those simulations is correct or not. That is why authors of the paper proposed a new methodology which combines the simulation platform for cloud computing with their testing methods. This helps in checking the correctness of the behaviors of ‘cloud computing models’ suggested by researchers.

Chen et al. [17] said that the IT industry is changing fast due to the role of new cloud computing technology and its infrastructure. They said that the cloud is used as the metaphor for the Internet. They wrote that data/information of users is stored at data centers around the world. Connectivity is provided by the internet and data accessed by the user temporarily on their computers, laptops, and mobiles, etc. They also highlighted the advances in the mobile communication and users’ demand of applications and high speed internet. Mobiles phones are always limited in resources so the computational support has to be provided by the cloud computing for many media-rich applications. For that purpose authors have discussed “Mobile Cloud Computing (MCC)” platform that can work and overcome the problems that hinder the joint/collaborative working of both mobile and cloud computing. The authors have done a comprehensive survey on many issues of MCC that were discussed/addressed by many other researchers in their researches.

Jaikar and Noh [18] discussed the scientific federated cloud. They proposed the idea to select the cost effective as well as efficient data center for cloud services. They pointed out that CSPs throughout the world have not been able to provide good services because of the geographical locations and resource limitations. They said that there are different types of clouds, and one of them is federated cloud. They also pointed that for dynamic loading support, system should be good enough to select the best location for serving the request with best performance. In this paper they presented the algorithm which selects the best data server to achieve significant performance gains in federated cloud computing environment.

Chunlin and Layuan [19] discussed the Multi-Layer Resource Management in Cloud Computing. They discussed “multi-layer optimization” in service oriented cloud computing so that optimization of the utility function of cloud computing can be done. The multilayer optimization have constraints of an IaaS at resources level, constraints (service provisioning) of a SaaS provider at service layer and constraints (QoS) of cloud user at service level. Authors of the paper suggested that problem of multilayer optimization can be divided into three sub-problems: “user QoS maximization problem”, “SaaS service provisioning problem” and “cloud computing resource allocation problem.” Hence, the authors had proposed an algorithm which decomposes above mentioned constraints/problem into three sub-problems. The performance of cloud multi-layer resource management algorithm was evaluated using four parameters, i.e., revenue of the IaaS providers, user satisfaction ratio, resource utilization and execution success ratio. They compared the performance of proposed algorithm with other related previous work.

Sheikh et al. [20] discussed the selection of trustworthy cloud service provider only based on its SLA and conclude that the selection criteria on SLA are not convincing. He proposed an architecture that is a multi-faceted Trust management system for a cloud marketplace, providing means to efficiently differentiate between good and poor quality providers. This system opens an opportunity for the customers to obtain the trust score by customizing the attributes. Problems diagnosed in the previous work are violation in SLA and lack of transparency. Cloud providers are not willing to share audit reports with any organization. More-over incomplete information, information available at unreliable sources, incomplete knowledge about architecture of system or services are the key problem in previously designed trust models. Attributes those are considered by the author are security, latency, availability, customer support. Proposed model is designed to provide the customize solution based on attributes those will be best suitable for any of the organization.

Noor and Sheng [21] discussed the reliability criteria of trust feedback collected from consumers, as system usually receive malicious behavior from its users, quality of trust feedbacks differs from person to person depends on their experience. He suggested a centralized architecture. He proposed an adaptive credibility model that distinguishes between credible trust feedbacks and malicious feedback by considering cloud service consumers' capabilities and majority consensus of their feedbacks.

Liu and Wang [22] worked on the analysis and design of trusted computing applied into cloud. They state that one of the biggest problems faced by computer technology is data security issues, and it is getting more and more serious as time goes on. Their proposed model of trusted computing added two new modules.

1. Service authentication list management (SAL)
2. Configuration dynamic update module (CUM)

The core discussion in this paper is directly concerned with identity authentication and access control. The proposed model applied for trusted computing into cloud environment is designed as follows.

The identities of the virtual machines which are involved in the model should be authenticated. In case of large system and for some special services, the model may need more than one Virtual Machine (VM). There can be many reasons such as malfunctioning or disaster that some specific virtual machine is no longer working or providing the services. Hence, there should be the submission of this service to the CUM which will take over all the existing working. This CUM receives the application and immediately selects a new VM. This replaces the old one and starts working. This CUM submits the amend information to the SAL. At the end, this service authentication list updates the identity information. In the concluding remarks, this paper depicts the advantages and disadvantages of trusted computing and describes the improvements for addressing the challenges and uncertainties seen by trusted computing.

Sule [23] discussed the deployment of data centers in the EIs. He stated that it has some major concerns. This paper presented a work on deployment strategy of cloud infrastructure in higher EIs; deployment should be as a community cloud named as CIaaS framework. The provision of opportunity is to share the resources and to collaborate in work together. Such framework of community cloud is most feasible.

Hui et al. [24] introduced a well-defined E-Learning environment in EIs for distance learning that opens the opportunity for researchers to work around. By considering the "Google collaborative platform" as a case study in E-learning environment, it provides the platform for collaborative learning platform.

Xiaona and Lingyun [25] presented their work on application of cloud computing in university library user service model. The application of cloud computing in libraries, problems are discussed and solved in this research article. Here the authors proposed public cloud among many university libraries that can converse library resources. It can also be the source of user satisfaction those are interested to use the library resources.

Ghazizadeh [26] publish her work on cloud computing benefits and architecture in E-Learning. In that paper, they discussed about cloud computing benefits and services for mobile and electronic learning. Services which can be accessed through mobile devices and applications available for mobile users are provided by cloud providers. Cloud computing can help in providing services and storage to its users. Useful data and multiple applications are available at datacenters. Cloud computing made the things easy as compare to the traditional systems. In E-learning, cloud computing has many benefits, providing the platform, centralized data storage, virtualization, and educational services.

In view of the aforementioned work on cloud computing, its application in EIs from various perspectives, a research gap was found for the evaluation of CSPs for their selection to give services in EIs. To bridge the said gap, a model is proposed that is explained in detail in the next section.

4 Proposed solution

In EIs, availability of service is very important especially during the time of research, online exams, and lecture hours, etc. Consider a scenario where labs are established and lectures are to be delivered then any interruption in service will lead to a big loss. Similarly a scenario where service suffers cutoff by any reason during online examination, will be unbearable. Moreover, in seminars and important meetings, there is a need of continuous service, and and no downtime is acceptable. Minimum downtime leads to the benefits that results in continuity of work and reduce loss. Hence, the backup plans for quick recovery and fault tolerance precautions should be considered before the selection of CSP. Trust management system consists of many attributes as shown in Fig. 3. A simple but comprehensive article on Identity Management and Trust Services in foundation of Cloud Computing is given in [27]. For EIs, the core attributes ondowntime which we focused are downtime, uptime, customer support, fault tolerance capability and application update frequency. Downtime is the time duration when service is not available (users could not access the cloud). The proposed model includes high precedence to the CSP that have minimum downtime history during last one year. So CSP with minimum downtime should be selected. Uptime clearly defines maximum time when services are available. Efficiency of any CSP can be determined from its uptime, especially when designing the model for an EI where uptime is focused on high priority. Hence, a CSP with good efficiency should be selected. Value of customer support experience accomplishes big importance to trust upon the CSP. Hence, a CSP with better ranking in customer support should be selected. Fault occurrence can happen in any network service where multiple devices constantly work together, but all service providers must have their back plans, either battery banks or generators for power backup and data connectivity with other online servers for data backup. Hence, a CSP with alternate power plans and back-up facilities should be selected.

The proposed solution comprises of the five main factors which are the proven attributes for any CSP to provide the services to EI. These attributes are of great importance for EIs (in selection of CSP). One of the main things that is differentiable features of our proposed solution is its customized and flexible approach. The user (the

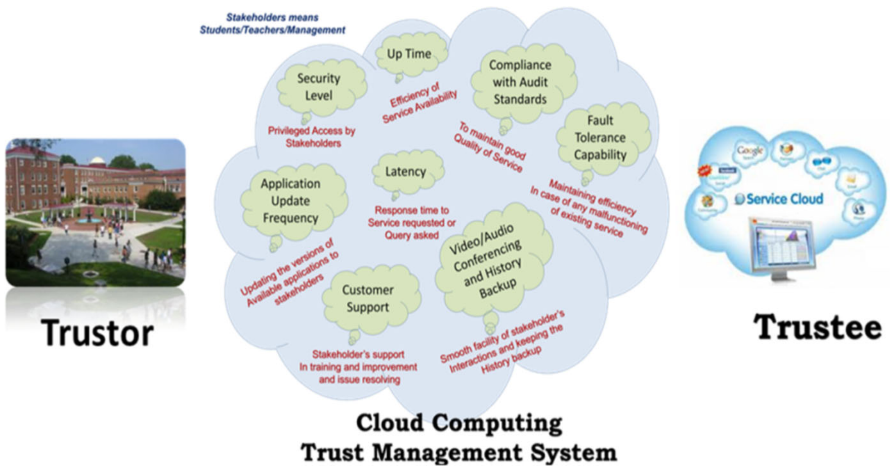

Fig. 3 The constituents of a typical cloud computing-based trust management system for EIs

EI management) can prioritize the most appealing and required feature over the other four features or the precedence level of the solution parameters can be set according to its requirements and need by just giving the highest weight to the most important parameter and the lowest weight to the least important parameter. In the subsequent paragraphs, we have done a detailed discussion on the given scenario in theoretical and mathematical way.

4.1 Parameters discussion

The detailed description and the mathematical modeling of these evaluation parameters have been discussed below.

4.1.1 Downtime

The proposed model calculates the downtime of available CSPs for last one year. We counted the number of times service was down during last one year due to some known and unknown reasons. We named them as planned and unplanned outage respectively. We also considered time of outage as well. Outage in peak hours is disliked more compared to outage in off-peak hours. The equation provides us the efficiency level of any particular CSP. Higher number of outages decreases more efficiency of a CSP compared to the CSP who suffers lower number of outages.

Planned outage is that outage which is planned before its occurrence and users have information of it in advance. While unplanned outage is unexpected and users are not aware of its occurrence before their occurrence. In our criteria, planned outage is better than unplanned outage. Similarly, timings are divided into Peak Hours and Off-peak Hours. Peak hours are those hours in which demands for services are very high. For EIs like universities, they are normally working in both morning and evening. Hence,

Table 1 A representation of different parameters of downtime

Outages	Downtime			
	Planned outage		Unplanned outage	
Weightage	Peak hours POP (0.2)	Off peak hours POO (0.9)	Peak hours UOP (0.1)	Off peak hours UOO (0.5)
CSP-1	2	3	3	1
CSP-2	1	0	2	1
CSP-3	0	0	4	2

we took peak hours for our model from 8:00am to 8:00pm. In our criteria, off-peak hour's outages is better than peak hour's outage.

We have divided outages into following four categories:

- Planned Outage in Peak Hours
- Planned Outage in Off-Peak Hours
- Unplanned Outage in Peak Hours
- Unplanned Outage in Off-Peak Hours

We know that unplanned outage is more harmful than planned outage. Similarly, peak hours' outage is more harmful than off-peak hours' outage. Hence, on these bases, we will be discussing the above four categories in detail. Planned Outage in Off-Peak Hours is the best in all the four categories, and Unplanned Outage in Peak Hours is the worst category.

We have assigned different weights to these categories in such a way that any outage will result in reduction of points. For example, in case of no outage, the points for specific CSP will be full. However, in case of any outage, those points will reduce. One planned outage in off-peak hour will result in less reduction in points compared to the one unplanned outage in peak hours. Our model selects the CSP with the highest points.

Data provided by regulatory bodies is found in both compiled and raw form. Our model caters for both types of data.

Table 1 given below shows the all kind of outages. Each kind of outage is also assigned different weights according to the needs of model.

For raw data, we sum up all planned outages that came in the peak hours, and in case of compiled data, user can simply enter the sum of planned outages in peak hours. We divided the assigned weight by the sum of all planned outages in peak hours. Number of planned outages in peak hours is represented by "A." Mathematical modeling of the said description is given below:

Equations 1 or 2 is used to calculate the number of planned peak hours downtimes entered by the user.

$$A = D_{pph(i)} + D_{pph(i+1)} + \cdots + D_{pph(n)} \tag{1}$$

OR

$$A = \sum_{i=1}^{n} D_{pph(i)} \tag{2}$$

Table 2 A representation of different parameters of downtime

Planned peak hour downtime		
Sr. # (i)	Date	Number of outages $(D_{pph(i)})$
1	10.1.2013	1
2	17.2.2013	1
3	3.3.2013	2
:	:	:
:	:	:
:	:	:
N	24.6.2013	1
		A = $\sum_{i=1}^{n} D_{pph(i)}$

Data entered by the user is shown in Table 2.

Number of Peak Hours Planned Outages = A

*Points for **P**lanned **O**utage **P**eak Hours Downtime* (***POP***):

$$\begin{aligned} &\{ \\ &\quad If\ \boldsymbol{A} = 0\ then \\ &\quad \boldsymbol{POP} = 1 \\ &Else\ \boldsymbol{POP} = \frac{1}{A} 0.2 \\ &\} \end{aligned}$$

For planned off peak hours data collection and the calculation thereof accordingly is same as in that of planned peak hours.

Equations 3 or 4 is used to calculate the number of planned off-peak hours downtimes entered by the user.

$$B = D_{poh(i)} + D_{poh(i+1)} + \cdots + D_{poh(n)} \tag{3}$$

OR

$$B = \sum_{i=1}^{n} D_{poh(i)} \tag{4}$$

Number of Off-peak Planned Outages = B

*Points for **P**lanned **O**utage **O**ff-peak Hours Downtime* (***POO***)

$$\begin{aligned} &\{ \\ &\quad If\ \mathbf{B} = 0\ \text{then} \\ &\quad \mathbf{POO} = 1 \\ &\text{Else}\ \boldsymbol{POO} = \frac{1}{B} 0.9 \\ &\} \end{aligned}$$

For raw data, we sum up all unplanned outages that came in the peak hours, and in case of compiled data, user can simply enter the sum of unplanned outages in peak hours. We divided the assigned weight by the sum of all unplanned outages in peak hours. Number of unplanned outages in peak hours is represented by "C." Mathematical modeling of the said description is given below:

Equations 5 or 6 given below is used to calculate the number of unplanned peak hours downtimes entered by the user.

$$C = D_{uph(i)} + D_{uph(i+1)} + \cdots + D_{uph(n)} \tag{5}$$

OR

$$C = \sum_{i=1}^{n} D_{uph(i)} \tag{6}$$

No of Peak Unplanned Outages = C

Points for ***U****nplanned* ***O****utage* ***P****eak Hours Downtime* (***UOP***)

{
If **C** = 0 then
UOP = 1
Else $\boldsymbol{UOP} = \frac{1}{C} 0.1$
}

Data collection and its collection accordingly for unplanned outage peak hours downtime is same as that of for unplanned outage peak hours.

Equations 7 or 8 is used to calculate the number of unplanned off-peak hours downtimes entered by the user.

$$D = D_{uoh(i)} + D_{uoh(i+1)} + \cdots + D_{uoh(n)} \tag{7}$$

OR

$$D = \sum_{i=1}^{n} D_{uoh(i)} \tag{8}$$

Number of Off-peak Unplanned Outages = D

Points for ***U****nplanned* ***O****utage* ***O****ff-peak Hours Downtime* (***UOO***)

{
If **D** = 0 then
UOO = 1
Else $\boldsymbol{UOO} = \frac{1}{D} 0.5$
}

Marks for any CSP with respect to its downtime are calculated using the Eq. 9:

$$D_T = \frac{(A + B + C + D)}{4} \quad (9)$$

Maximum points which can be assigned to any CSP using above equation are 1.

4.1.2 Uptime

Uptime clearly defines maximum time when services are available. Efficiency of any CSP can be determined from its uptime, especially when designing the model for an EI where uptime is on high priority. These two parameters downtime and uptime are inversely proportional to each other. If value of one increases the other one will decrease and vice versa. Our model assumes to pick up the random values of fifty days in the last one year and used those for uptime calculation. It is important to note that in downtime we used all the downtimes that occurred in last one year, but here we are picking up only 50 random days (as shown in Table 3) because it is very difficult to enter all values for 365 days of a year.

Points for ***Uptime*** (*UT*):

$$UT = \left(\sum_{i=1}^{50} \frac{U_t}{24}\right) \Big/ 50 \quad (10)$$

Equation 10 shows the uptime points. We have selected 50 random days in a year and checked that how many maximum hours' services were available. Maximum point which can be assigned to any CSP using above equation is 1.

4.1.3 Fault tolerance

There are many types of faults which can be faced by a system. Sometimes these faults can directly affect the services that are being provided by the CSP. Any interruption in the service is not tolerable, so we have also focused on the "alternate power plans" to ensure the availability of services. Other thing which we also considered in this regard is "back-up facility." By accident data saved on any system can get corrupted or system

Table 3 Sample uptime calculation

Number of samples	Uptime calculation		
	Sample dates	Uptime hours	Average uptime hours
1	2.10.2012	23	$S_1 = 23$
2	10.11.2012	22	$S_2 = 22$
3	21.12.2012	24	$S_3 = 24$
:	:	:	:
:	:	:	:
50	29.5.2013	24	$S_{50} = 24$
		Total average = TA = $(S_1 + S_2 + S_3 +, \ldots, +S_{50})$ /number of samples	

Table 4 Parameter involved in the Fault Tolerance Capability

Fault tolerance capabilities	
Alternate power plan	Backup facility
Yes (10)	Yes (10)
No (0)	No (0)

can crash or data is erased from system. In all these cases, data when required cannot be accessed. This phenomenon is not bearable. Hence, backup is required to ensure its all-time availability. We give full points to CSP if it has alternate power plans, and backup facilities are available as shown in Table 3. Even if there are availability of alternate power plans and backup facilities with CSP, we cannot say that problem will not occur in this regard. We have also considered failures happening with emergency plans. Hence, we put up another option in our model. We will calculate the number of failures occurred while backup plans were implemented for last one year. More number of failures will result in more reduction in points of CSP. CSP with highest points will be selected for the service (Table 4).

Points for ***Alternate Power Plan*** (*APP*)

{
If **APP** *exists* then
{
E = Number of Failures with Alternate Power Plan
If $E > 10$ *then*
$APP = 0$
Else $APP = 10 - E$
}
Else APP = 0
}

Points for ***Backup Facility*** (*BUF*)

{
If ***BUF*** *exists* then
{
F = No of Failures with backup Facility
If $F > 10$ *then*
$BUF = 0$
Else $BUF = 10 - F$
}
Else **BUF** = 0
}
$FP = APP + BUF$

Points for ***Fault Tolerance Capability*** *(FTC)*

$$FTC = \frac{FP}{20} \tag{11}$$

Maximum point which can be assigned to any CSP using Eq. 11 is 1.

4.1.4 Customer support experience

Value of Customer Support Experience (CSE) accomplishes big importance to trust upon the CSP. We added points to the quality of customer support provided by the CSP on the behalf of customer's experience. Efficiency in creating, managing and updating application as per needs of customers directly affects the customer's experience. Similarly, when a customer faces some problem or asks for information when required, the dealing of CSP with the customer affects the CSE. The response time of CSP to any complaint by the user also adds towards the CSE. All such data is easily available from regulatory bodies. The best experience is awarded the highest points, and the worst experience is given the lowest points. Similarly, we are also considering the trend of CSE. We have assigned highest weights to the results of last quarter and lowest weights to the first quarter. Refer to the Table 5, performances are assigned marks as well as quarters are assigned weights. 1st Quarter is assigned least weight and 4th Quarter is assigned highest weight. We did this because quality of service in last quarter is more important compared to the quality of service in first quarter.

MQ1 = Points on performance in Quarter-1
MQ2 = Points on performance in Quarter-2
MQ3 = Points on performance in Quarter-3
MQ4 = Points on performance in Quarter-4

$$\text{Total Points} = TM = 1^{*}MQ1 + 2^{*}MQ2 + 3^{*}MQ3 + 4^{*}MQ4 \tag{12}$$

where in Eq. 12,

'1' is the weight (multiplier) for 1st Quarter
'2' is the weight (multiplier) for 2nd Quarter

Table 5 Parametric values in the customer support experience calculation quarterly

Customer support experience (CSE)	World class (WC)	Exceeding PERFORMANCE (EP)	Solid performance (SP)	Marginal below (MB)	Below AVERAGE (BE)	Poor performance (PP)
Points	5	4	3	2	1	0
1st Quarter (1)	N	Y	N	N	N	N
2nd Quarter (2)	N	N	N	Y	N	N
3rd Quarter (3)	Y	N	N	N	N	N
4th Quarter (4)	N	Y	N	N	N	N

'3' is the weight (multiplier) for 3rd Quarter
'4' is the weight (multiplier) for 4th Quarter.

Points for Customer Support Experience (*CSE*)

$$CSE = \frac{TM}{50} \quad (13)$$

Maximum points which can be assigned to any CSP using Eq. 13 are 1.

4.1.5 Application update frequency

One of the most important features of the service provided to the EI by the CSPs is the availability of the updated applications or software to the students, teachers, and management. If the updated version of the applications under study or work is not available, then the knowledge imparted to the students will be outdated that may affect the grading and reputation of the university directly or indirectly. Also the updated versions of the journals and magazines should be available in time. We are considering this important parameter, i.e., application update frequency, into our proposed trust model at cloud computing service layer for the EIs. As per the SLA, we inspect how frequently CSP provides us the updated application on the server.

The table given below shows the points assigned to a CSP on the basis of their application updating routine. Updating routine of any application provided by CSP is checked. Weekly or less time for updating routine is assigned highest points while yearly updating or more are assigned lowest points for that CSP. It can be seen in Table 6 given below.

Points for ***Application Update Frequency*** (*AUF*)

$$AUF = \frac{UP}{5} \quad (14)$$

where UP is Update Points and maximum points which can be assigned to any CSP using Eq. 14 are 1.

Table 6 Sample table for the application update frequency with awarded points at its efficiency

Application update frequency						
Time for updating	Weekly	Monthly	3 Monthly	6 Monthly	9 Monthly	12 Monthly
Points	(5)	(4)	(3)	(2)	(1)	(0)
CSP-1	N	N	Y	N	N	N
CSP-2	N	N	N	Y	N	N
CSP-3	N	Y	N	N	N	N

4.1.6 Final calculation

We have left few choices to the customer to select the CSP on the basis of his/her requirements. Hence, we added weights to all the five parameters which a user can change according to his/her requirement. For example, if a customer is more interested in CSE then the customer/user can change the weights assigned to that parameter. Higher the weight assigned, higher will be the role of that specific parameter in the selection of CSP. CSP with the highest points will be selected for cloud service.

Final result is dependent on the weights assigned to parameters and parameters' values.

$$\begin{aligned} &\mathit{Final\ Result} = (Wt_1 {*} (\mathit{Downtime}), Wt_2 {*} (\mathit{Uptime}), Wt_3 {*} (\mathit{Fault\ Tolerance\ Capability}), \\ &\quad Wt_4 {*} (\mathit{Application\ Update\ Frequency}), Wt_5 {*} (\mathit{Customer\ Support\ Experience})) \end{aligned} \tag{15}$$

Equation 15 can be written in a mathematical form as follows:

$$\mathit{Total\ Points} = J \times D_T + K \times U_T + L \times FT + M \times C_{SE} + N \times A_{uf} \tag{16}$$

where, value of *J, K, L, M* and *N* may range from 1 to 10, but this is the choice for user to select the value according to their preferences.

In Table 7 given below, column named "Values" shows the values of the parameters that the CSP is awarded based on calculation given in subsections of section IV from (a) to (f). Column "Weight" shows the values assigned to the related parameter according to their precedence level or required priority to the customer or user.

From Eq. 16

$$\begin{aligned} \mathit{Total\ Points} &= 0.9 \times 9 + 0.9 \times 10 + 0.8 \times 8 + 1 \times 6 + 0.6 \times 7 \\ \mathit{Total\ Points} &= 8.1 + 9.0 + 6.4 + 6 + 4.2 \\ \mathit{Total\ Points} &= 33.7 \end{aligned}$$

In the same way all the other CSPs points can be calculated. Figure 4 shows the main window of developed application for cloud computing trust model at service layer for EIs.

Table 7 Summarized view of all parameters of proposed solution with its final calculation format

Evaluation Parameter	Values	Weight
Downtime	0.9	9
Uptime	0.9	10
Fault tolerance	0.8	8
Customer support experience	1	6
Application update frequency	0.6	7

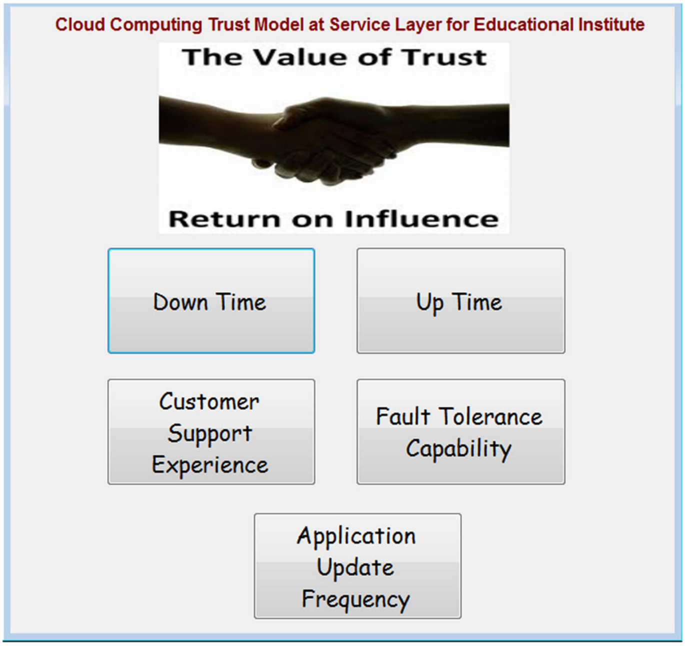

Fig. 4 Main window of developed application for the said model in C#

5 Proposed model versus existing model

After comprehensive review of the literature, it can be concluded that the available solutions don't provide the exact and feasible solutions to the problem for the EIs to avail the facilities of cloud computing effectively and efficiently with respect to cost and service. More-over, the exact and targetable solution does not exist in the literature for the said purpose. The main focus of existing models is based on security parameters and the backup plans in case of system crash. Solutions provided so far are expensive compared to our proposed model because CSPs should have to spend a lot to implement security features and secure backup plans. However, in most cases CSPs hire third party services to implement the security features as per the requirements of an organization, finally additional cost added to the consumers.

Mehbub et al. [13] discussed the selection of trustworthy CSP only based on its SLA and conclude that selection criteria on SLA are not convincing. Their proposed architecture is a multi-faceted Trust management system for a cloud marketplace, providing means to efficiently differentiate between good and poor quality providers. This system opens an opportunity for the customers to obtain the trust score by customizing the attributes. Problems diagnosis in the previous work is violation in SLA and lack of transparency, cloud providers are not willing to share audit reports with any organization. More-over incomplete information, information available at unreliable sources, incomplete knowledge about architecture of system or services are the key problem in previously designed Trust models. Attributes that are considered by the author are

Table 8 Table showing the comparison of the existing solution to the proposed solution at different comparison parameters

	Existing model	Proposed model
Cost effective	No	Yes
Quality of service	Medium	High
Security features	High	Medium
Delay in service	Medium	High
Backup features	Medium	High

security, latency, availability, customer support. Proposed model is designed to provide the customize solution, attributes that will best suitable for any of the organization can be used as per the requirements.

Our model proves high efficiency in selection of trust worthy CSP in terms of cost, service quality, frequent update, and fault tolerance capability compared to the above comparative model. Since after detailed workout on the needs and requirements of EIs, we diagnosed that cost can be reduced by excluding the extra features of security from the requirements and the additional secure backup plans. We have directly focused on the quality of service and the desperate need of the availability of service especially in busy hours by considering the importance of academic body. Keeping in view the above requirements, our model is cost effective, and results provided by our model proved the efficiency in selection of trust worthy CSP. Our model prefers to uptime when services are available and considers inefficiency of the CSP when service are not available. Moreover, we also manipulate the features of peak timings and off-peak timings. Service that should be downgraded during off-peak timings has less inefficiency compared to the service down during peak timings. As an organization it should be unacceptable that service is unavailable during peak timings when consumers are doing their important work. Moreover, we added the feature of planned outage or unplanned outage. Furthermore, we pin point the timings of outages and have it compared with planned or unplanned outages. Outages that are prior declared by the service provider with time length are known as planned outages on the other hand those outages that happens unpredictable are known as unplanned outage. We also added the percentage of CSE of CSP in our trust evaluation model. Fault tolerance and Frequency update frequency are the other features included in our designed model.

Table 8 clearly depicts the difference between the existing model and the proposed model with respect to the cost effectiveness, quality of service, security features, delay in service, and the backup features. Based on these parameters, we have come up with a conclusion about the preference of the proposed solution over the existing competitive solution.

6 Conclusion

After the complete study and detailed analysis of the proposed idea, we have come to an agreed conclusion that the proposed model is the best and the cheapest way to find out the best service provider (CSP) according to the requirements of user (EI). The proposed solution evaluates the CSP in terms of services they are offering and quality of service as well. The key performance evaluation parameters considered in this context are service downtime, service uptime, customer service experience, fault tolerance, and application up-date frequency. These aforementioned five parameters are the proven attributes for any CSP in order to provide the quality services to the EIs. The most differentiable feature of our proposed solution is its customized and flexible approach. The user (the EI management) can prioritize the most appealing and required parameter over the other parameters. One can set the precedence level for the solution parameters according to his/her requirements by just giving the highest weight to the highly precedent parameter and the lowest weight to the least important parameter.

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