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Trust Appraisal of Cloud Services using Cloud - Analytic Hierarchy Process

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Abstract

In consuming cloud services, the need for transparency is substantial from the perspective of potential consumers. Consequently, assessment of their trust level becomes indispensable. So, a Cloud – Analytic Hierarchy Process (AHP) based trust assessment system is applied for prioritizing and choosing the most-trustworthy cloud service provider. The objective is to apply the principles and techniques of AHP in the prioritization and selection of trustworthy cloud services among the set of cloud service providers. Discrete experiments were carried out and the results were studied to show the firmness of our system in figuring out the relative efficiency and relative effectiveness of various cloud services through ranking mechanism.

Keywords: *Cloud computing, trust assessment, Analytic hierarchy process, cloud services, cloud theory.*

1. Introduction

One of the main challenges that cloud consumers face today resides in their knowledge and ability to opt the most correct, authentic and consistent cloud service provider from alternatives. Given any relevant information, making this right decision is almost certainly one of the most ambitious challenges for technology. When we think about the ever-changing dynamics of the cloud environment, making the right decision based on adequate and aligned objectives becomes a critical factor.

As cloud consumers cannot prioritize and decide trustworthy cloud services based on values and their own preferences alone, a set of specific criteria and/or objectives have to be employed in this process so that the decisions are efficient and cloud consumers are comfortable.

In order to facilitate cloud consumers to enjoy trusted cloud services, trust label system has been appreciated in [1]. Positive labels and negative labels convey the corresponding impact on trustworthiness of cloud services. An extensive study of credibility assessment on social media has been presented in [2]. This study proved that a hybrid methodology for the judgment of the credibility. Further, multimedia analysis, semantic analysis, feature extraction and dataset related issues were also discussed. II-Learn based measurement of artificial learning system [3] has been suggested to address the dynamic nature the environment. Challenges always exist in choosing the parameters that can be used to assess the trust in a dynamic environment. With the help of a neural network, actual trust relations are used as samples to assess the unidentified trust relations [4]. Obstacles in trust assessment process are discussed in [5]. If resources are properly made available, trust accuracy will be increased to an acceptable level. As several consumers prefer to use online services, amount of data increases tremendously. Hence assessment frameworks have to face challenges and efficiency issues [6]. Based on the interaction between users in social networks, recommender systems can be developed. Involvement of users with similar tastes offer accurate results. For the assessment of trust among users, a questionnaire is given to users who are willing to respond about the trustworthiness of other users who are availing services from the same provider [7]. When trust evaluation is done by operators, mutuality, asymmetry and event weight issues happen to arise [8]. So, evaluation becomes erroneous. Accessibility, dependability, ability, degree

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and reputation are identified as parameters for identifying trusted cloud services [9]. A three-valued subjective logic based system has been developed in [10]. Using Dirichlet-Categorical (DC) distribution, trust assessment can effectively be done in an arbitrary cloud environment. In real-time scenarios, identity authentication, common social attribute and forwarding capability parameters alone cannot be successfully employed to detect malicious activities in online environments. Hence, it is evident that additional parameters have to be included in this evaluation process [11]. To measure the trust of cloud services accurately, direct and indirect trusts become vital [12, 13].
The idea of this paper is to apply and examine the conventions and techniques of the analytic hierarchy process (AHP) in the prioritization and selection of trustworthy cloud services.

The rest of the paper is organized as follows: Section 2 outlines a brief overview of Analytic Hierarchy Process (AHP). The employment of AHP in cloud trust assessment is discussed in Sections 3 and 4. Results of experiments on ranking mechanism of cloud services by cloud-AHP are presented in Section 5. At last, Section 6 concludes our work.

2. Analytic hierarchy process

AHP is one of the foremost mathematical models which provides fundamental support to decision making. The multi-criteria programming problem made through the use of the analytic hierarchy process is a technique for decision making in complex environments in which many variables or criteria are considered in the prioritization and selection of alternative. The adoption of AHP commences with a problem being broken down into a hierarchy of parameters so as to be more straightforwardly studied and investigated in an autonomous manner. After this logical hierarchy is formulated, the cloud consumers can consistently assess the efficiency and effectiveness indices by making pair-wise comparisons for each of the chosen parameter.

AHP remodels the comparisons, which are normally empirical, into numerical values that are further processed and compared. The weight of each trust parameter allows the assessment of both indices inside the defined hierarchy. This competence of transforming empirical data into mathematical model is the distinctbenefit of AHP method when comparing with other techniques.

After completing all the comparisons, the establishment of relative weights between each parameter is carried out. This leads to the calculation of numerical probability of each cloud service. Higher probabilities indicate that the corresponding cloud services are better chances for their adoption. The likelihood of each of the cloud services is determined from numerical probabilities of the concerned service.

3. AHP in Cloud Trust Assessment – Level 1

Based on an extensive research, the main criteria or parameter groups are identified and shown in figure 1. Based on these identified parameters, the process of cloud services trust evaluation is carried out.

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Figure 1.Main criteria in Cloud Trust Assessment

Table 1 presents the relative weight data between the criteria that have been determined for the goal of selecting trustworthy cloud services and table 2 portrays the normalized weight data.

Table 1: Comparison Matrix for the goal

	SLA	Performance	Security	User Opinion
SLA	1	1/3	1/5	1
Performance	3	1	1	3
Security	5	1	1	3
User Opinion	1	1/3	1/3	1

Table 2: Comparison Matrix for the goal (after normalization)

	SLA	Performance	Security	User Opinion
SLA	0.100	0.125	0.079	0.125
Performance	0.300	0.375	0.395	0.375
Security	0.500	0.375	0.395	0.375
User Opinion	0.100	0.125	0.131	0.125

The involvement of each criterion to the goal is decided by calculations using Eigenvector. The Eigenvector demonstrates the relative weights between each criterion. It is obtained in an approximate manner by calculating the mathematical average of all criteria and depicted in the table 3. From this table, we observe that the sum of all Eigenvector values is constantly equal to 1. The precisecomputation of the Eigenvector is done only in special cases. Usually, approximateEigenvector is adopted forfacilitating the calculation process. This approximation is mathematically accepted since the difference between the exact and approximate values is always smaller than 10%.

Table 3: Eigenvector Calculation

	Eigen vector	**Percentage**
SLA	0.10725	10.725
Performance	0.36125	36.125

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Security	0.41125	41.125
User Opinion	0.12025	12.025

The Eigenvector values contribute significantly to AHP. They contribute towards the weight of each criterion corresponding to the overall result of the goal. For example, the security criteria have a weight of 41.125% relative to the total goal. A positive evaluation on this factor commits approximately 4 (four) times more than a positive evaluation on the SLA criterion (weight 10.725%).

To come across data inconsistencies, it becomes vital to snatch sufficient information for concluding whether each criterion has been assigned proper weights relative to other criteria. For example, if it is confirmed that the security criteria are more important than the performance criteria and that the performance criteria are more important than the SLA criteria, it would be contradictory to assert that the SLA criteria are more important than the security criteria.The inconsistency index is based on maximum Eigen value (as shown in table 4).

Table 4: Calculation of Maximum Eigen value

Eigen vector	0.10725	0.36125	0.41125	0.12025
Sum	10	2.67	2.53	8
Max Eigen value λ_{max}	4.0395			

The consistency index for our model is calculated as 0.013167 and in order to progress the process, consistency rate needs to be calculated. It is computed as the ratio of consistency index to the random consistency index. The comparison matrix becomes consistent if and only if the consistency ration is smaller than 10%. As it is calculated as 1.463% for the considered model, the comparison matrix of table 1 is found to be consistent.

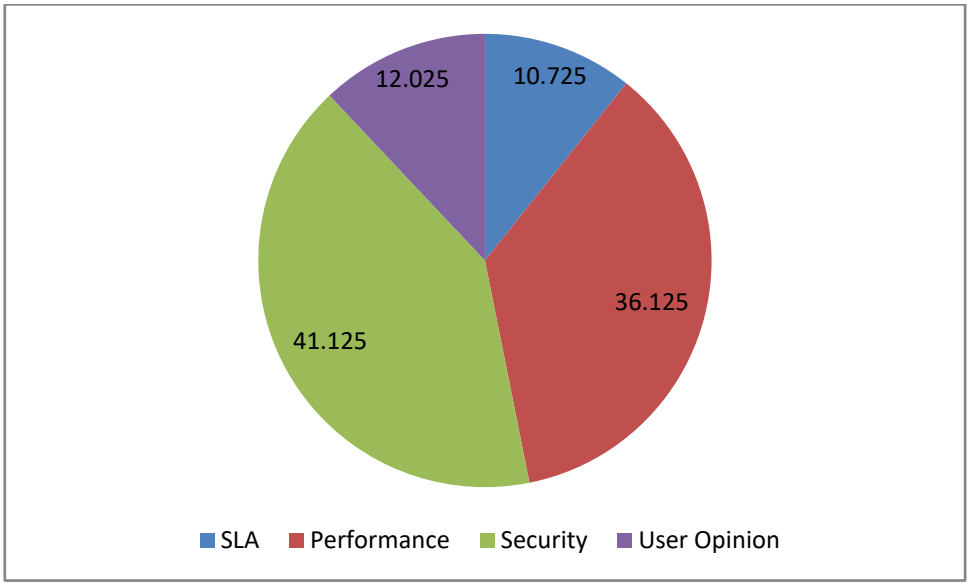

Figure 2. Results of the Comparison Matrix for Criteria Group

Figure 2 illustrates the contribution of each first-level criterion to the goal. From figure 2 and tables 3 and 4, it is noticeable that the security criterion contributes 41.125%, performance criterion contributes 36.125%, user opinion criterion contributes 12.025% and SLA criterion contributes 10.725% to the goal of assessing CSP trustworthiness.

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4. AHP in Cloud Trust Assessment – Level 2

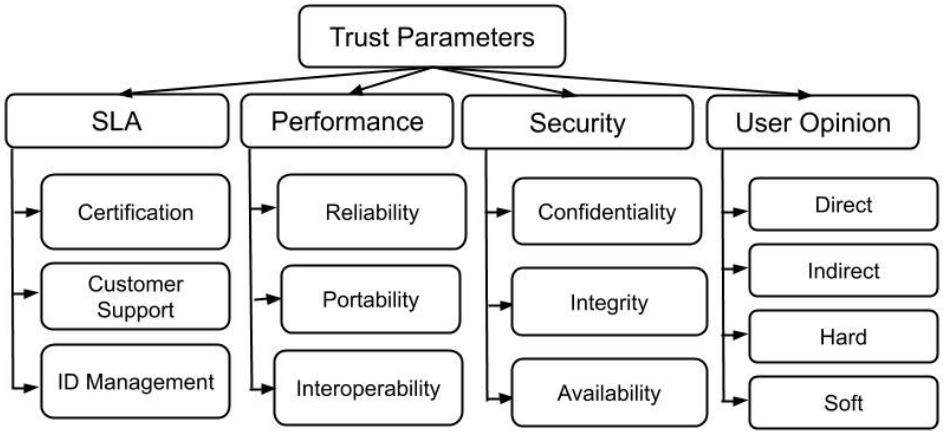

Figure 3: Hierarchy of Criteria for the CSP Trust assessment, highlighting the Second Hierarchy Level

Table 5: Comparison Matrix – SLA Criteria

SLA			
	Certification	Customer Support	ID Management
Certification	1.00	1/5	1/3
Customer Support	5.00	1.00	1.00
ID Management	3.00	1.00	1.00

Table 6: Comparison Matrix – Performance Criteria

Performance			
	Reliability	Portability	Interoperability
Reliability	1.00	7.00	5.00
Portability	1/7	1.00	1/3
Interoperability	1/5	3.00	1.00

Similar to the grouping done for the assessment of CSP trustworthiness, the criteria's relative weights are evaluated for the second hierarchy level. Figure 3 shows the sub-criteria at second level. AHP process is continued for those sub-criteria and tables from to show the comparison matrices for them with pair-wise comparisons. Tables from 5 to 8 presents the relative weight data between the sub-criteria at level 2 of main criteria SLA, Performance, Security and User Opinion, respectively, that have been determined for the goal of selecting trustworthy cloud services.

Table 7: Comparison Matrix – Security Criteria

Security			
	Confidentiality	Integrity	Availability
Confidentiality	1.00	5.00	3.00
Integrity	1/5	1.00	1/7
Availability	1/3	7.00	1.00

Table 8: Comparison Matrix – User opinion Criteria

User opinion				
	Direct	Indirect	Hard	Soft

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Direct	1.00	3.00	1	1
Indirect	1/3	1.00	1	1
Hard	1	1	1	7
Soft	1	1	1/7	1

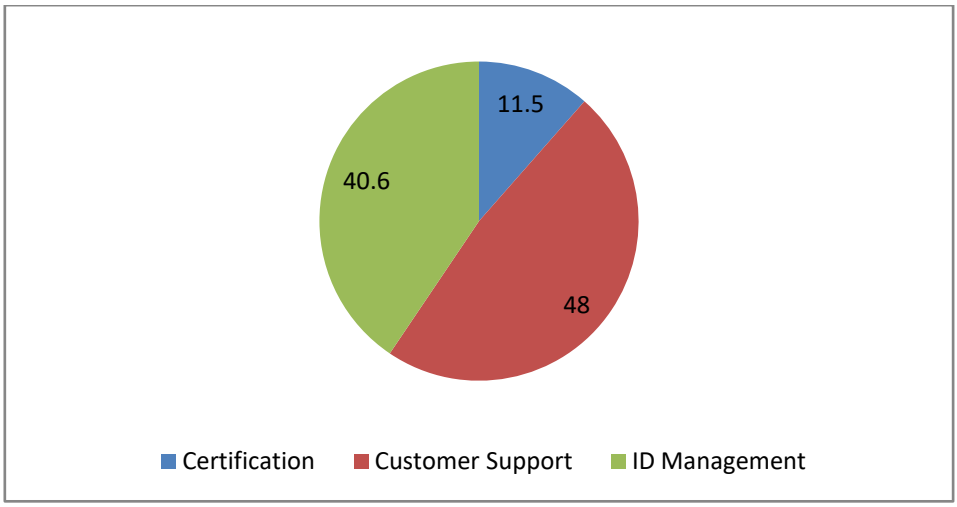

Figure 3: Results of the Comparison Matrix for SLA criteria Group

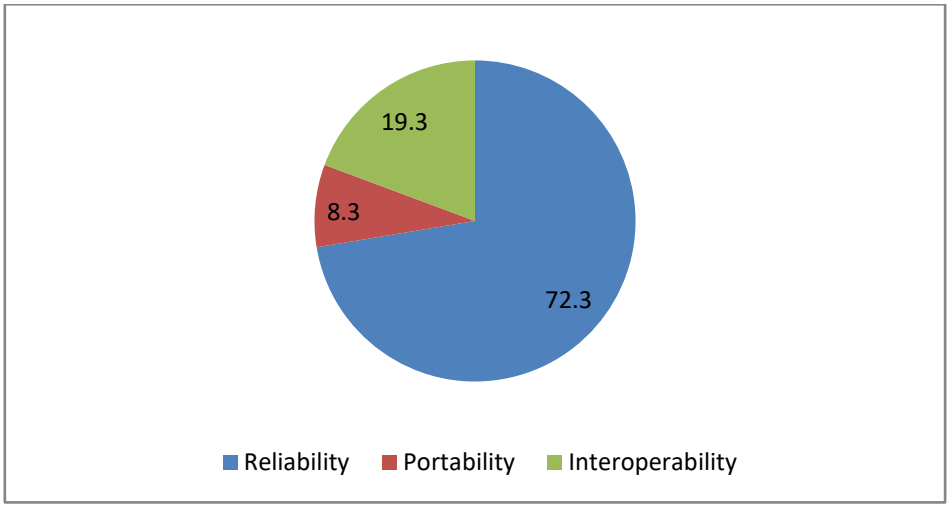

Figure 4: Results of the Comparison Matrix for Performance criteria Group

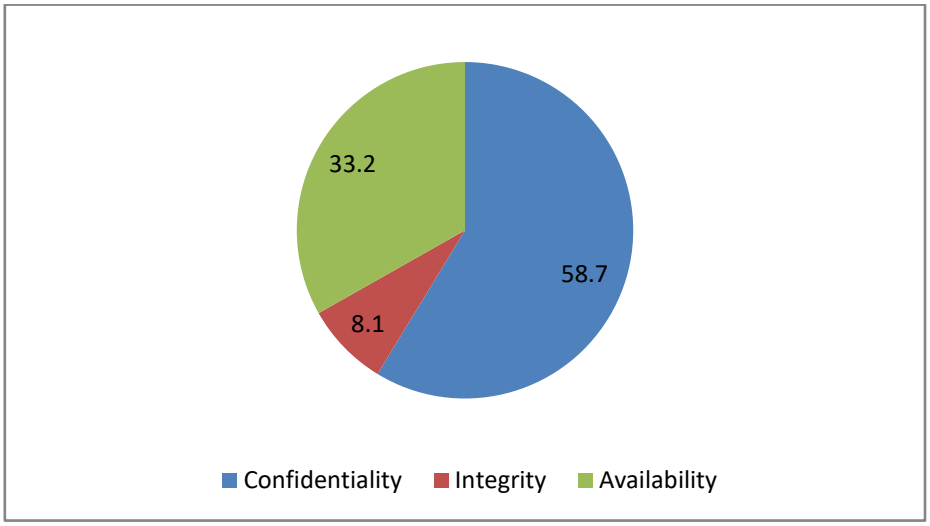

Figure 5: Results of the Comparison Matrix for Security criteria Group

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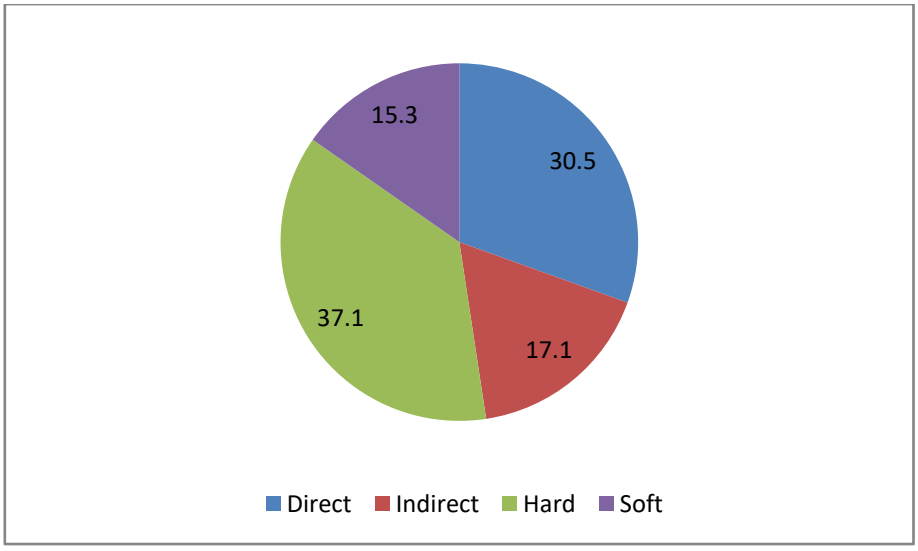

Figure 6: Results of the Comparison Matrix for User Opinion criteria Group

Figures from 3 to 6 reveal that, it is noticeable that the Customer support, Reliability, Confidentiality and Hard trust are the major-influencing sub-criteria in SLA, Performance, Security and User opinion criteria, respectively, in contributing to the goal of assessing CSP trustworthiness.

5. Ranking mechanism of cloud services by Cloud-AHP

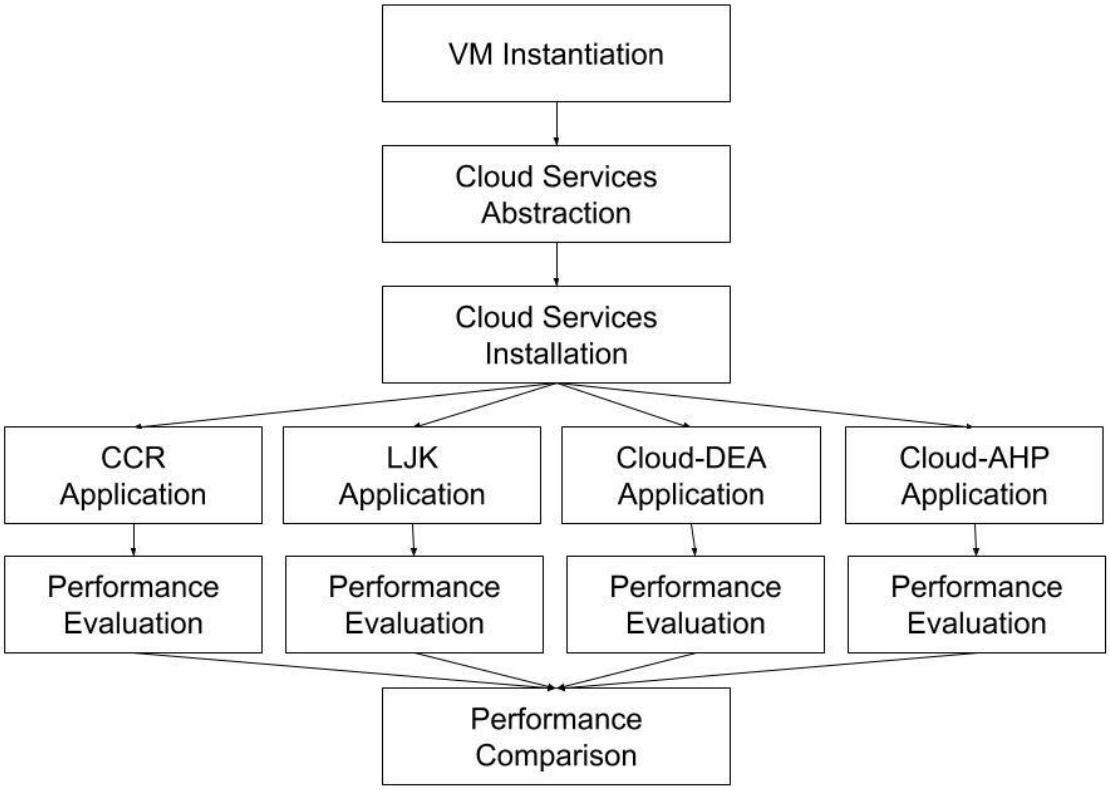

Figure7. Ranking mechanism of cloud services

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Figure 7 shows the order of execution of our work in the trust assessment of cloud services.Cloud theory has been adopted for converting each qualitative significance degree into a cloud-oriented quantitative value. After converting the 3-level qualitative attribute values of the input parameters SLA, Performance, Security and User Opinion into quantitative values, as given in table 9, the proposed *C*loud – *AHP* based trust estimation framework works out the efficiency and effectiveness indicesfor each of the cloud services. The corresponding 5-level qualitative and quantitative values of the output parameters are given in table 10.

Table 9. 3-level evaluation scale cloud system of SLA, Performance, Security and User Opinion

Level	Attribute value				Expectation Ex	Entropy En	Hyper-entropy He
	SLA	Performance	Security	User opinion			
1	Weak	Poor	Low	Negative	0.1667	0.0687	0.0069
2	Moderate	Medium	Medium	Neutral	0.5000	0.0687	0.0069
3	Strong	Good	High	Positive	0.8333	0.0687	0.0069

Table 10. 5-level evaluation scale cloud system of CS trust

Level	Attribute value	Expectation Ex	Entropy En	Hyper-entropy He
1	Complete distrust (Untrustworthy)	0.1	0.0412	0.0041
2	Distrust	0.3	0.0412	0.0041
3	Weak trust	0.5	0.0412	0.0041
4	Moderate trust	0.7	0.0412	0.0041
5	Complete trust (Trustworthy)	0.9	0.0412	0.0041

To assess and demonstrate the efficiency of our proposed system, we have simulated a cloud environment [14] with the 10 cloud service providers: Amazon, Azure, Century Link, City-Cloud, Cloudera, Google Compute Engine, HP, IBM, OpenNebula, and Rackspace. For each of them, 2 or 3 cloud services are considered.

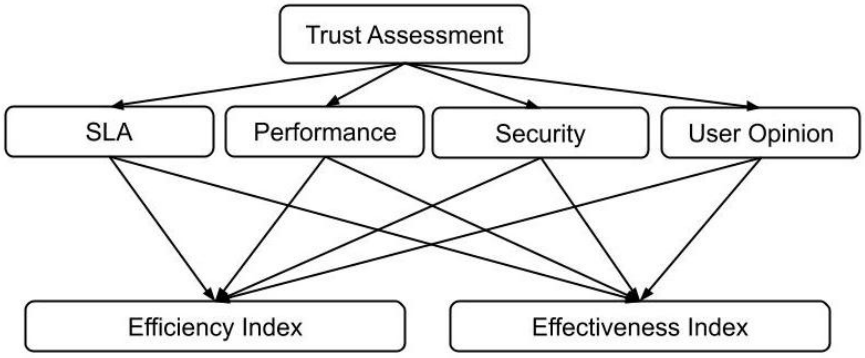

Figure 8. Efficiency and Effectiveness indices

Table 11 shows that how different methods assess ranks for various cloud services based on efficiency and effectiveness (as given in figure 8) using CCR, LJK and Cloud-DEA. We understand that the ranks awarded by CCR and LJK models often differ from each other for the same set of cloud services with the same set of resources and the ranks awarded by Cloud-DEA and Cloud-AHP are having minimum deviation. The comparisons between the consistencies of the all four methods are shown in figure 9 from which we infer that our proposed method achieves minimum deviation and constant results with respect to other methods.

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Table 11. Rate of difference between four methods

	Between CCR and LJK models	Between CCR and Cloud – DEA models	Between CCR and Cloud – AHP models	Between LJK and Cloud – DEA models	Between LJK and Cloud – AHP models	Between CLOUD - DEA and Cloud – AHP models
Based on Efficiency index	0.8462	0.7692	0.730769	0.6538	0.576923	0.076923
Based on Effectiveness index	0.8077	0.7692	0.730769	0.6923	0.615385	0.076923

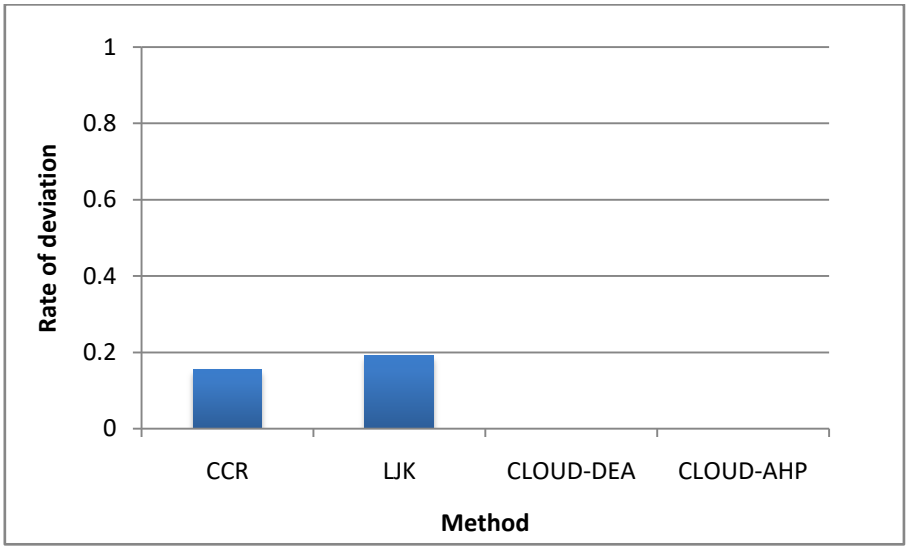

Figure 9. Results of consistency comparison

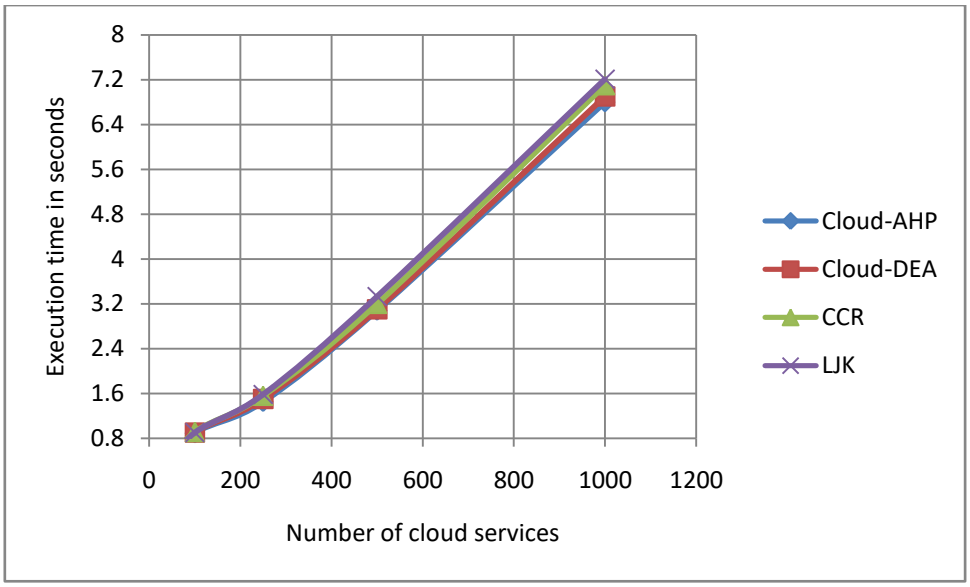

Figure 10. Execution time of various methods for ranking cloud services

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Experiments are carried out to appraise the execution time of ranking for distinct number of cloud services. Figure 10 shows that, for small number of cloud services, all the four methods are almost equal in terms of execution time. But as there is an increase in the number of cloud services increase, they show signs of a difference. Further, even for 1000 cloud services, Cloud-AHP method consumes about 6.8 seconds only, where Cloud-DEA consumes about 6.9 seconds. This shows the sign of competence of Cloud-AHP for ranking cloud services.

6. Conclusion:

In this paper, we have proposed a Cloud-AHP based trust assessment system for a cloud environment, where trustworthiness of cloud service providers is assessed based on cloud theory and analytic hierarchy process. The principles and techniques of AHP are applied for prioritizing and choosing the most-trustworthy cloud service provider. By implying input criteria using a set of 3-level cloud system, trust of each cloud service is graded by a 5-level cloud system. This is followed by the ranking of cloud services through the assessment of efficiency and effectiveness indices. With same set of resources, analogous experiments are conducted using the models namely, CCR, LJK, DEA and AHP to study and contrast the results. The obtained results reveal the integrity of our proposed Cloud-AHP model.

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