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Research Article

# Practices for Clients in the Adoption of Hybrid Cloud

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**Abstract:** Hybrid cloud has received considerable attention in recent years. Many companies all over the world are inclined towards the adoption of hybrid cloud for increasing their efficiency and reducing cost of their IT services. Hybrid cloud reaps the benefits of both public and private clouds by combining the public cloud's cost savings and elasticity with a private cloud's security, control, and customization. However, client organizations should follow the best practices while adopting hybrid cloud. In this research paper efforts have been made to identify the best practices for addressing hybrid cloud adoption challenges from client's perspective. We have performed Systematic Literature Review (SLR) and identified 46 practices for addressing the challenges faced by client organizations in the adoption of hybrid cloud. The identified practices were validated through empirical study in cloud based industry. The results are beneficial to any client organization that is going to deploy hybrid cloud. The identified practices may assist client organizations in mitigation/avoidance of the challenges faced by the clients in the adoption of hybrid cloud.

**Keywords:** Practices/solutions, hybrid cloud computing; client organizations; systematic literature review, empirical study

## 1. INTRODUCTION

Cloud computing (CC) emerges as a modern paradigm where IT resources (applications, storage, and computation power and hardware platform) will be delivered to the businesses on measured basis. Utilizing Cloud computing offers scalability, cost and performance benefits to the business community [ HYPERLINK \l "DKo09" 1 ]. The service models of cloud computing are: software as a services "SaaS", platform as a services "PaaS" and infrastructure as a services "IaaS"2]. Similarly, the four deployment models of cloud computing are public cloud, private cloud, hybrid cloud and community cloud [ HYPERLINK \l "Sar11" 3 ]. Public cloud offers IT resources based on open market offerings. Private clouds are small scale systems compared to public clouds and usually managed by a single organization. Hybrid cloud 4] is the integration and utilization of services from both public and private clouds. Hybrid cloud platform will help practitioners and businesses to leverage the scalability and cost effectiveness of the public cloud by paying only for IT resources consumed (server, connectivity, storage) while delivering the levels of performance and control available in private cloud environments without changing their underlying IT setup. As a result, hybrid cloud computing is receiving increasing attention in recent years. However the major concerns in the adoption of hybrid cloud reported in our previous work [ HYPERLINK \l "Ull14" 5 ] are listed as follow:

- Achieving QoS
- Appropriate cloud offering
- Components partitioning
- Data searching
- Effective management issue
- Integration complexity
- Lack of trust
- Public cloud security concern
- SLA assurance
- Task scheduling and execution

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Amongst the identified list of challenges, eight were marked as critical challenges which are 'achieving QoS', 'components partitioning', 'effective management issue', 'integration complexity', 'lack of trust', 'public cloud security concern', 'SLA assurance', and 'task scheduling and execution' 5]. We conducted a systematic literature review followed by an empirical study in cloud based industry to find the practices/ solutions for addressing the aforementioned critical challenges in the adoption of hybrid cloud from client's perspective, based on the following research question (RQ).

RQ: What are the practices/solutions, as identified in the literature and industrial survey, for addressing hybrid cloud adoption challenges from client's perspective?

The rest of the paper is organized as follows. In Section 2, the background and related work are presented. In Sections 3 & 4, we present the research methodologies. We then present the result in Section 5. In Section 6 overall summary and discussions are provided. Section 7 describes the limitations, followed by the conclusion in Section 8.

## 2. BACKGROUND

The evolution and growth of Cloud Computing (CC) in the current decade is potentially one of the major advances in the field of information technology. "Cloud computing doesn't limit to grid, parallel and distributed computing but it involves power of such paradigms at any level to form a resource pool" [ HYPERLINK \l "Int11" 6 ]. The most commonly used definition of CC, as provided by the U.S National Institute of Standards and Technology (NIST), is "Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction" 7]. The five essential characteristics of cloud computing are:

- On-demand self-service
- Broad network access
- Resource pooling
- Rapid elasticity
- Measured Service

The commonly used service models of cloud computing are [ HYPERLINK \l "Eev12" 8 ].

- SaaS (Software as a Service),
- PaaS (Platform as a service)
- IaaS (Infrastructure as a service)

As cloud computing is still a growing paradigm, the cloud providers are continuously introducing additional/new services of cloud computing. There are four types of cloud deployment model as reported in the literature 9]. These include

- Private cloud
- Public cloud
- Community cloud and
- Hybrid cloud

We are now at the stage when customers are starting to ask whether they should think about cloud computing, but what types of cloud computing are best suited to meet their business needs. The adoption of hybrid cloud is gaining reputation at various organizations at the globe.

The literature reveals that many researchers have addressed some of the aspects of hybrid cloud. Mahdi et al. [ HYPERLINK \l "iKa12" 10 ] proposed a cost model for hybrid cloud which is useful for enterprise utilizing their own internal and external resources. Majda et al.11] evaluated the availability of service in hybrid cloud architecture and developed a model to justify that service availability can be improved through protection service. Neal Leavitt [ HYPERLINK \l "Placeholder1" 12 ] discusses the need for hybrid cloud and highlights some of the obstacles of hybrid cloud, the author also discusses some of key components and implementation model of hybrid cloud. Géczy et al. 13] discovered some relevant aspects of hybrid clouds and proposed appropriate strategies for their efficient management. Sujay [ HYPERLINK \l "RSu11" 14 ] highlighted some of the basic idea of cloud computing and also discussed the current state of hybrid cloud. The author also suggests that user will embrace hybrid cloud, if the cloud vendors solve the trust and security issue.

Solanke et al. 15] suggest that the security issue in cloud can be solved through the use of hybrid cloud, which offers the opportunity to keep critical data in private cloud and less critical data in public cloud. Emilija [ HYPERLINK \l "Ris12" 16 ] argued how to use public cloud in conjunction with private clouds and also suggested that how to use mass customization and its association in hybrid clouds.

However, there is a notable scarcity of studies about hybrid cloud adoption best practices in literature and relatively less empirical studies have been conducted in this domain. This research work aims to cover this gap and provide some best practices for assisting client's organizations for the mitigation of hybrid cloud adoption challenges.

We have used two methodologies (SLR and empirical study) to answer our research question. We reviewed the existing literature through systematic literature review (SLR) process for the identification of practices for addressing hybrid cloud adoption challenges. After the SLR, we conducted questionnaire survey. Our intent was to validate findings of the SLR through industry practitioners and to find any new practice apart from the identified ones. The details of both research methodologies are given in the following sub-sections.

## 3. SYSTEMATIC LITERATURE REVIEW (SLR)

A Systematic Literature Review (SLR) process was used for data collection, because it is more thorough, less biased, and rigorous as compared to ordinary literature review17]. Systematic literature review has become an important methodology and the number of SLR studies, being published, is rapidly increasing [ HYPERLINK \l "Jam13" 18]. SLRs rely on well-defined and evaluated review protocols to extract, analyze, and document results. Protocol development is the first phase of the SLR process and it describes planning of the review.

Systematic review protocol was written first to describe the plan for the review. Details of the various steps in our SLR methodology are available in our SLR protocol. The protocol can be provided on request. We used the following digital libraries for searching the relevant literature

- IEEE Xplore: (http://ieeexplore.ieee.org )
- ACM Portal: (http://dl.acm.org)
- Spriger Link: (www.springerlink.com )
- Science Direct: (www.sciencedirect.com )
- Cite Seer :(www.citeseer.ist.psu.edu)
- Google Scholar: (www.scholar.google.com)

The data sources searched, the total number of publications found at each resource, primary selection and final selection is shown in Table 1. The data synthesis phase was done by the primary reviewer (the primary author) with the help of secondary reviewer (the co-author).

We found a sample of 90 articles as our final selection, attached in Appendix-1. From the total primary studies, 31 (34%) were identified in IEEEXplore, 6 (7%) were identified in ScienceDirect, 18 (20%) were identified in ACM, 16 (17%) were identified in CiteSeer, 6 (7%) were identified in Springerlink, 13 (14%) were identified in Google Scholar. In the data extraction phase of the SLR, the following data were extracted on the predefined form for each of the finally selected paper/article.

- Article Title
- Publishing Year
- Authors Name
- Journal/Conference Proceedings/Others
- Database searched
- Research Methods
- Practices for hybrid cloud adoption challenges

The data was recorded into an Excel sheet and SPSS. All the data was collected and formatted in a tabulated fashion to allow for data synthesis. The relevant data identified from the finally selected papers was synthesized for answering the research questions. The extracted data on the specified data extraction form were grouped together and initially 55 categories in total were identified. These categories were reviewed by the secondary reviewer and it was merged to 50. These were further reviewed by external reviewers and finally the categories were merged to a total of 46 as classified in the subsequent tables.

**Table 1.** List of data source searched for practice.

| | Total Result Found | Primary Selection Resource | Final Selection |
|---|---|---|---|
| IEEEXplore | 150 | 60 | 31 |
| ScienceDirect | 100 | 20 | 6 |
| ACM Portal | 130 | 50 | 18 |
| CiteSeer | 150 | 30 | 16 |
| Springerlink | 100 | 24 | 6 |
| Google Scholar | 200 | 36 | 13 |
| **Total** | **830** | **220** | **90** |

**Table 2.** Summary of online cloud professionals groups.

| S. No. | Group Name | Members | Date |
|---|---|---|---|
| 1 | Canada Cloud Network | 681 | 14 April, 2015 |
| 2 | CLOUD Architect and Professionals Network | 6,354 | 14 April, 2015 |
| 3 | Conversations On Cloud Computing | 10,132 | 14 April, 2015 |
| 4 | Cloud Computing Best Practices | 7,950 | 14 April, 2015 |
| 5 | Hybrid Cloud User Group | 66 | 15 April, 2015 |
| 6 | SAP Cloud Computing (Private, Public or Hybrid) | 1,531 | 15 April, 2015 |
| 7 | TalkinCloud | 1,010 | 15 April, 2015 |
| 8 | Windows Azure & Microsoft Cloud | 10,467 | 16 April, 2015 |
| 9 | Cloud Computing – Microsoft UK | 11,088 | 16 April, 2015 |
| 10 | IEEE Cloud Computing | 5,719 | 16 April, 2015 |

**Table 3.** Summary of software companies in Pakistan.

| S. No. | Software Company name (code) | Date of Request Sent |
|---|---|---|
| 1 | S.E.C, Pakistan | 14 April, 2015 |
| 2 | H.I.C.IT, Pakistan | 14 April, 2015 |
| 3 | P.A Pakistan | 14 April, 2015 |
| 4 | D.S.IT, Pakistan | 14 April, 2015 |
| 5 | Macro, Pakistan | 15 April, 2015 |
| 6 | X.C Pakistan | 15 April, 2015 |
| 7 | X.S Pakistan | 15 April, 2015 |
| 8 | O.T Pakistan | 16 April, 2015 |
| 9 | Tec, Pakistan | 16 April, 2015 |

## 4. SURVEY DESIGN

We have used questionnaire survey in cloud based industry for empirical validation of the findings of the SLR. The main motive for using survey method is to target a wide range of population in cost effective way [19]. There are many techniques for data collection using survey [20]. We choose to utilize structure questionnaire due to available resources and different scope of respondent.

We have designed online questionnaire using Google Form. The questionnaire contains practitioner detail, demographic information, and practices identified through systematic literature reviews divided in three sections. Every section also contains some open ended questions to find any other challenge which was not mentioned. Seven point Likert scale, i.e., 'Extremely Agree (EA)', 'Moderately Agree (MA)', 'Slightly Agree (SA)', 'Not Sure (NS)', 'Slightly Disagree (SD)', 'Moderately Disagree (MD)', 'Extremely Disagree (ED)', was used to find the view of the respondent about the criticality of the identified challenges.

We also conducted a pilot survey for the validation of the questionnaire, before sending and posting it on the web. Testing of questionnaire survey before sending to the participant is important. Piloting survey can help to find/rectify those questions that are ambiguous and don't make any sense to the participants, or lead to a biased answer. Five members of the SERG_UOM (Software Engineering Research Group) at University of Malakand were selected for pilot survey, and the

**Table 4.** Practices for addressing public cloud security.

| CC #1 Public Cloud Security Concern | | | |
|---|---|---|---|
| | | SLR Vs Empirical Study | |
| **S. No.** | **Practices for addressing Public cloud security concern** | **Frequency of Practices via SLR (N=90)** | **% of Practices via Empirical Study (N=30))** |
| **CCP#1.1** | Cloud security should be controlled by the client organization and not by the cloud vendor | 2 | 65 |
| **CCP#1.2** | Provide effective authentications for users on the basis of access control rights. Only the users those are authorized to access private cloud can be directed to private cloud they can also access public cloud, rest users those are not authorized to access private cloud can be directed to public cloud they can access public cloud only. | 8 | 71 |
| **CCP#1.3** | Client organization should use third party tool to enhance the security | 2 | 61 |
| **CCP#1.4** | Client organizations should utilize their private (own) resources as much as possible and outsource minimum tasks to the public cloud to maximize security. | 2 | 58 |
| **CCP#1.5** | Client organization should carefully manage virtual images in hybrid environment using tools like firewall, IDS/IPS, log inspection etc | 4 | 51 |
| **CCP#1.6** | Data should be encrypted by client before outsourcing to cloud computing. | 6 | 74 |
| **CCP#1.7** | On-premise gateway should be used in hybrid cloud for controlling the applications and data that flow from each part to the other | 6 | 55 |
| **CCP#1.8** | Categorize the data into two parts i.e. sensitive and non-sensitive. Place the sensitive data in the on-premises side (Private cloud) whereas non-sensitive data should be kept in public cloud. | 16 | 77 |

**Table 5.** Practices for addressing management issue

| CC#2. Effective management issue | | | |
|---|---|---|---|
| | | SLR Vs Empirical Study | |
| **No.** | **Practices for addressing effective management issue** | **Frequency of Practices via SLR (N=90)** | **% of Practices via Empirical Study (N=30))** |
| **CCP#2.1** | Use management tools developed by several working groups like Open Grid Forum, Open Cloud Computing Interface (OCCI) Storage Network Industry Association (SNIA) etc to monitor the performance of both internal and external resources. | 2 | 59 |
| **CCP#2.2** | Establish appropriate plan for release and deployment management for utilizing and living cloud environments | 1 | 51 |
| **CCP#2.3** | Place a strong Service portfolio management for Continual Service Improvement Process | 1 | 58 |
| **CCP#2.4** | Set plan for Capacity management (business capacity management, service capacity management, and component capacity management) in order to improve performance relating to both services and resources | 1 | 55 |
| **CCP#2.5** | Implement tools like Ansible, CFEngine, Chep, , Elastra and Rightscale Puppet, Salt etc for addressing for configuration and change management in order to control the lifecycle of all changes which will assist in enabling beneficial changes to be made with minimum disruption to IT services | 1 | 52 |
| **CCP#2.6** | Keep backups of applications and data on on-premises servers and storage devices in order to avoid data loss and time delays in case of failures in the cloud platform. | 4 | 74 |
| **CCP#2.7** | Consider a cost-effective model in order to decide which task is economical on the cloud or on internal resources. | 3 | 65 |
| **CCP#2.8** | Perform efficient planning and implementation strategies before moving to the hybrid cloud. | 2 | 60 |

questionnaire was then revised according to their response and feedbacks.

The main objective of this survey is to collect data regarding hybrid cloud adoption challenges in two ways. Firstly to validate the list of challenges identified in our previous SLR study [5]. Secondly to validate the finding of SLR for practices and to identify any new practice apart from the existing ones. For data collection a request was posted in different groups on LinkedIn as shown in Table 2.

We also sent a request for consent to different companies utilizing cloud services as shown in Table 3 to participate in the questionnaire survey. Our invitation was responded by 60 experts in total by showing their willingness through email for participation. A total of 33 participants participated in the survey. Among these filled questionnaires, 3 were rejected because of our quality criteria. Hence, 30 responses were selected and used for the analysis, showing a response rate of 50%.

For the analysis of the collected data, we used frequency analysis technique. Frequency analysis is helpful for the treatment of descriptive information. Each challenge and practices was analyzed by counting its occurrence in the responded questionnaires.

## 5. RESULTS

The subsequent sections represent the 8 critical challenges (CC) and their respective practices identified through SLR and validated through empirical study/industrial survey.

### A. Public Cloud Security Concern

As Hybrid cloud services are a combination of both public and private clouds, implemented by different providers. Hybrid cloud model transfers selective data between public and private clouds. Data externalization towards services deployed on the public cloud creates security problems coming from data issued by public cloud services [21]. Table 4 presents our identified list of 8 practices for public cloud security concern and graphically represented by Fig. 1. The practice (CCP#1.8) about categorization of data into two parts i.e. sensitive and non-sensitive show high frequency in both SLR and empirical study reflecting that sensitive data should be kept in private cloud and non-sensitive data in public cloud.

### B. Effective Management

Our findings also indicate that without proper management, computational resources could be over provisioned or under provisioned, resulting in wasting money or failing to satisfy service demand. The risk of outsourced services going out of control is high in a hybrid cloud environment and key management becomes a difficult task in such situations [22]. To properly manage hybrid cloud environment, practice CCP#2.6 highly reflect that client organizations should keep backups of applications and data on on-premises servers and storage devices in order to avoid data loss and time delays in case of failures in the cloud platform. Table 5 presents our identified list of eight practices for addressing the management issue and graphically represented by Fig. 2.

### C. Integration Complexity

Integration of one or more public and private clouds into a hybrid system can be more challenging than integrating on-premises systems [23]. A mechanism for integrating private and public clouds is one of the major issues that need to be addressed for realizing hybrid cloud computing infrastructure [24]. Our results indicate that the use of standard API (Application Programming Interface) to integrate applications and data between the private clouds and the public clouds will solve this problem. Table 6 presents our identified list of five practices for addressing the integration issue and graphically represented by Fig. 3.

### D. Achieving QoS (Quality of Service)

Another challenge in the adoption of hybrid cloud is the quality of service (QoS). Different components of the hybrid infrastructure provide different QoS guarantees, efficient policies to integrate public and private cloud to assure QoS target of the users remain a challenging job [25]. Our result indicates that selection of a cloud provider that can ensure high degree of availability of services at all times, offer improved services in QoS parameters/ attributes: such as price, offered load, job deadline constraint, energy consumption of the integrated infrastructure and security overcome this challenge. Table 7 presents our identified list of five practices for addressing the hybrid cloud adoption challenge 'QoS' and graphically represented by Fig. 4.

### E. Component Partitioning

Designing a hybrid cloud requires careful attention in determining the best split between public and private cloud components [26]. Determining how to distribute applications across both private and public clouds is a challenge. Our result shows that in order to migrate some of the applications components from private cloud to public cloud in the context of hybrid cloud environment, implementation of migration progress management functions like Pacer which is capable of accurately predicting the migration time and coordinating the migrations of multiple application component. Table 8 presents our identified list of five practices for addressing the hybrid cloud adoption challenge 'component partitioning' and graphically represented by Fig. 5.

### F. Lack of Trust

Establishing trust is recognized as a key problem in the way of adopting the hybrid cloud computing environments [27]. Due to the fact that data owners and cloud storage are no longer in the same trusted domain, and therefore, establishment of trust is one of the most challenging issues [28]. Our result indicates that establishing trustworthy relationships

**Table 6.** Practices for addressing Integration issue.

| CC # 3: Integration Complexity | | | |
|---|---|---|---|
| | | SLR Vs Empirical Study | |
| **S. No.** | **Practices for addressing integration complexity** | **Frequency of Practices via SLR (N=90)** | **% of Practices via Empirical Study (N=30)** |
| **CCP#3.1** | Use of the available infrastructures such as Eucalyptus and Open Nebula, open source software framework, in order to assist integration (front end integration, data integration and process integration) in hybrid cloud | 3 | 54 |
| **CCP#3.2** | Use standard API(Application Programming Interface) to integrate applications and data between the private clouds and the public clouds | 5 | 68 |
| **CCP#3.3** | Adopt technologies such as information integration, enterprise application integration, and enterprise service bus for effective integration | 3 | 52 |
| **CCP#3.4** | Establish integration mechanism to be controlled dynamically in response to changes in business requirements with the passage of time | 1 | 58 |
| **CCP#3.5** | Select form number of vendors offering solutions for data integration including companies such as Dell Boomi, IBM, Informatica, Pervasive Software, Liaison Technologies, and Talend. | 1 | 48 |

**Table 7.** Practices for addressing QoS Issue.

| CC # 4: Achieving QoS | | | |
|---|---|---|---|
| | | SLR Vs Empirical Study | |
| **S. No.** | **Practices for addressing QoS** | **Frequency of Practices via SLR (N=90)** | **% of Practices via Empirical Study (N=30)** |
| **CCP#4.1** | Select a cloud provider that can offer improved services in the following QoS parameters/attributes: such as price, offered load, Job deadline constraint, energy consumption of the integrated infrastructure and security | 1 | 68 |
| **CCP#4.2** | Ensure that access to the internal infrastructure is only possible through secure communications | 3 | 74 |
| **CCP#4.3** | Follow secure communication protocols (such as Transport Layer Security (TLS) and its predecessor, Secure Sockets Layer (SSL) etc) when communicating with endpoint applications and databases. | 1 | 58 |
| **CCP#4.4** | Select a public cloud provider which can offer the capacity needed by internal cloud and execute dynamically | 1 | 48 |
| **CCP#4.5** | Select a cloud provider that can ensure high degree of availability of services at all times | 2 | 55 |

**Table 8.** Practices for addressing components portioning**.**

| CC # 5: Component Partitioning | | | |
|---|---|---|---|
| | | SLR Vs Empirical Study | |
| **S. No.** | **Practices for addressing component partitioning** | **Frequency of Practices via SLR (N=90)** | **% of Practices via Empirical Study (N=30)** |
| **CCP#5.1** | In order to distribute an application's over a hybrid cloud the following parameters should be kept in mind<br>• data disclosure risk<br>• resource allocation cost<br>• private cloud load | 1 | 55 |
| **CCP#5.2** | In order to migrate some of the applications components from private cloud to public cloud in the context of hybrid cloud environment, Implement Migration progress management functions like Pacer which is capable of accurately predicting the migration time and coordinating the migrations of multiple application component. | 2 | 65 |
| **CCP#5.3** | Divide the workload to be executed across local and public clouds so that the workloads can move among resource pools which will result in a well-designed cloud environment. | 1 | 61 |
| **CCP#5.4** | Replicate some part of the data to the public side so as to enable the distribution of the computation | 1 | 61 |
| **CCP#5.5** | Consider a sensitivity aware data partitioning mechanism like Sedic that guarantees that no sensitive data is exposed to public cloud | 1 | 61 |

**Table 9.** Practices for addressing trust issue.

| CC # 6: Lack of Trust | | | |
|---|---|---|---|
| | | SLR Vs Empirical Study | |
| **S. No.** | **Practices for addressing lack of trust issue** | **Frequency of Practices via SLR (N=90)** | **% of Practices via Empirical Study (N=30)** |
| **CCP#6.1** | Establish trustworthy relationships with cloud service providers through service level agreement (SLA) | 3 | 50 |
| **CCP#6.2** | Ensure the provision of security at different levels i.e. how cloud providers implement, deploy, and manage security | 1 | 68 |
| **CCP#6.3** | Keep in mind that client is still ultimately responsible for compliance and protection of their critical data, even if that workload had moved to the cloud | 1 | 61 |
| **CCP#6.4** | Use services of a broker in order to negotiate trust relationships with cloud providers. | 4 | 87 |
| **CCP#6.5** | Ensure that what sort of certifications does the cloud providers have in place which can ensure service quality of the cloud provider. | 3 | 52 |

**Table 10.** Practices for addressing SLA assurance.

| CC # 7: SLA Assurance | | | |
|---|---|---|---|
| | | SLR Vs Empirical Study | |
| **S. No.** | **Practices for addressing SLA assurance** | **Frequency of Practices via SLR (N=90)** | **% of Practices via Empirical Study (N=30)** |
| **CCP#7.1** | Ensure the maximum availability of services, provided by cloud providers, and duration of the contract period to be explicitly defined in the SLA | 1 | 58 |
| **CCP#7.2** | Define explicitly in the SLA terms and conditions regarding security of the client's data | 1 | 58 |
| **CCP#7.3** | Keep the clients aware about where the processes are running or where the data is stored to ensure security of the client's data | 1 | 60 |
| **CCP#7.4** | To mitigate the risk of a cloud provider failure, define revert strategies in the SLA. This is because they put cloud customers in a much stronger position when renegotiating a cloud service contract because cloud customers know that they could readily switch from the provider if needed | 2 | 45 |
| **CCP#7.5** | Perform third party auditing on a regular basis to monitor the cloud service provider's compliance to agreed terms | 4 | 61 |
| **CCP#7.6** | Ensure in service level agreements that what are the contingency plans in case of the breakdown of the system | 4 | 71 |

**Table 11.** Practices for addressing task scheduling and execution.

| CC # 8: Task Scheduling and Execution | | | |
|---|---|---|---|
| | | SLR Vs Empirical Study | |
| **S. No.** | **Practices for addressing task scheduling and execution** | **Frequency of Practices via SLR (N=90)** | **% of Practices via Empirical Study (N=30))** |
| **CCP#8.1** | Use of an efficient scheduling mechanism/ algorithm to enable efficient utilization of the on-premise resources and to minimize the task outsourcing cost, while meeting the task completion time requirements as well. These scheduling algorithms include Hybrid Cloud Optimized Cost (HCOC), Deadline-Markov Decision Process (MDP), Heterogeneous Earliest Finish Time (HEFT) based on resource discovering, filtering, selection, and task submission | **1** | **60** |
| **CCP#8.2** | Execute part of the application on public cloud to achieve output within deadline as public cloud resources has much high processing power as compare to private cloud resources. On the other hand, executing the whole application on the public cloud will be costly. | **4** | **68** |
| **CCP#8.3** | The capacity of the communication channels in hybrid cloud must be considered because it impacts the cost of workflow execution. | **1** | **61** |
| **CCP#8.4** | Implement workflow management system like CWMS (Cloud Workflow Management System) to increase productivity and efficiency | **1** | **58** |

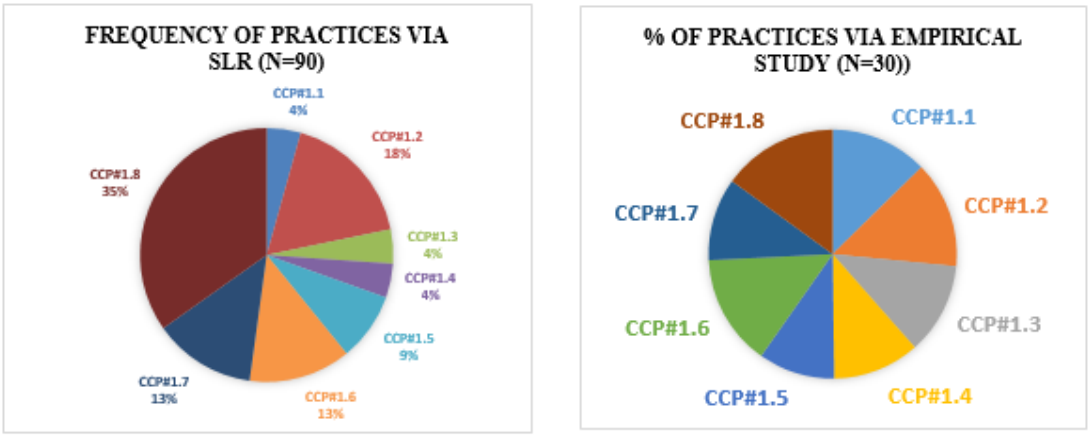


**Fig. 1.** SLR vs empirical**.**

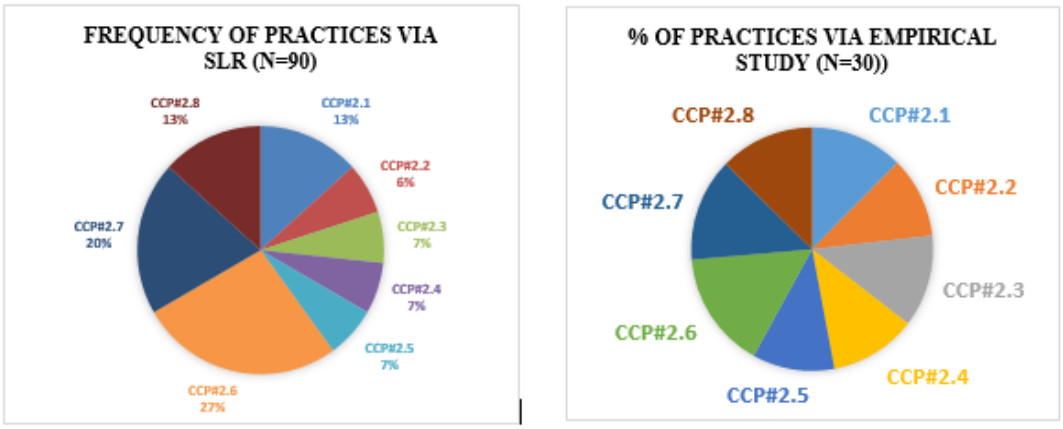


**Fig. 2.** SLR vs empirical.

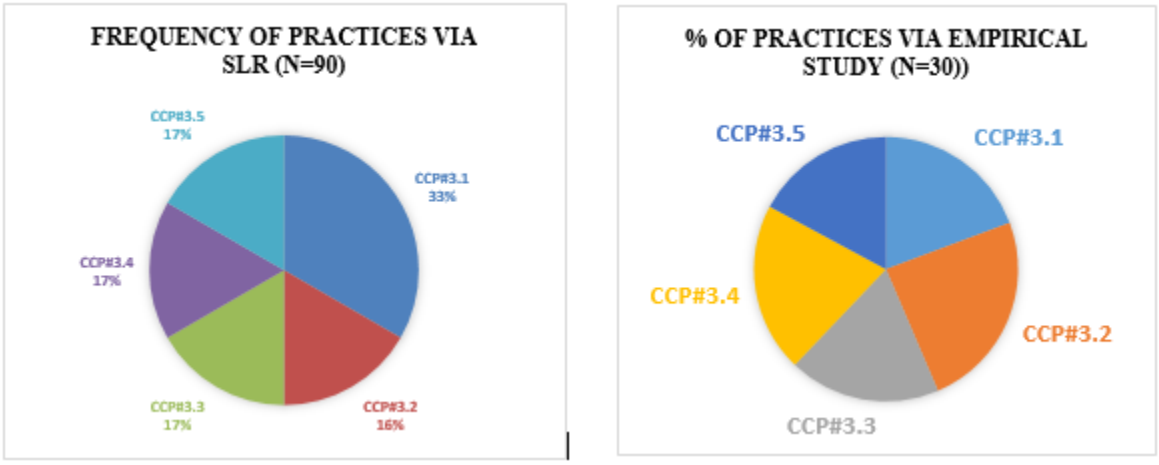


**Fig. 3.** SLR vs empirical.

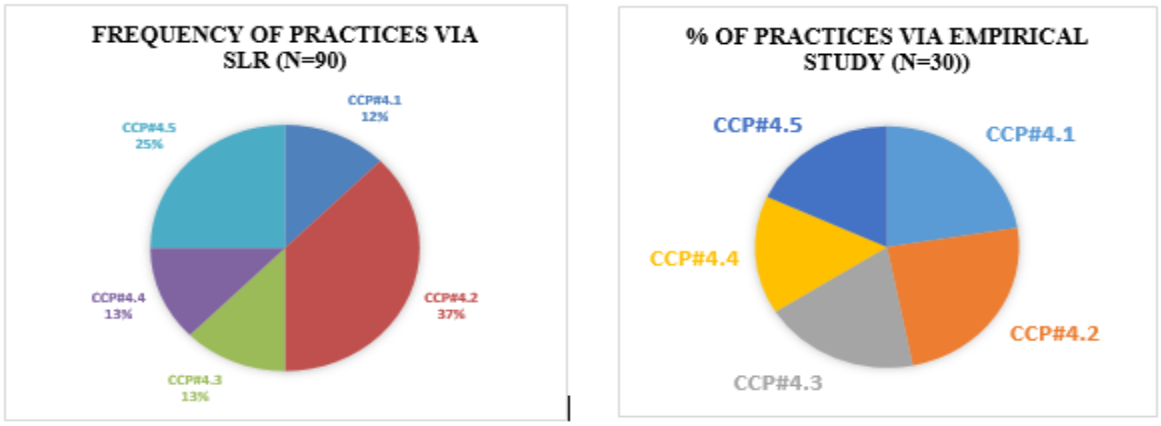


**Fig. 4.** SLR vs empirical.

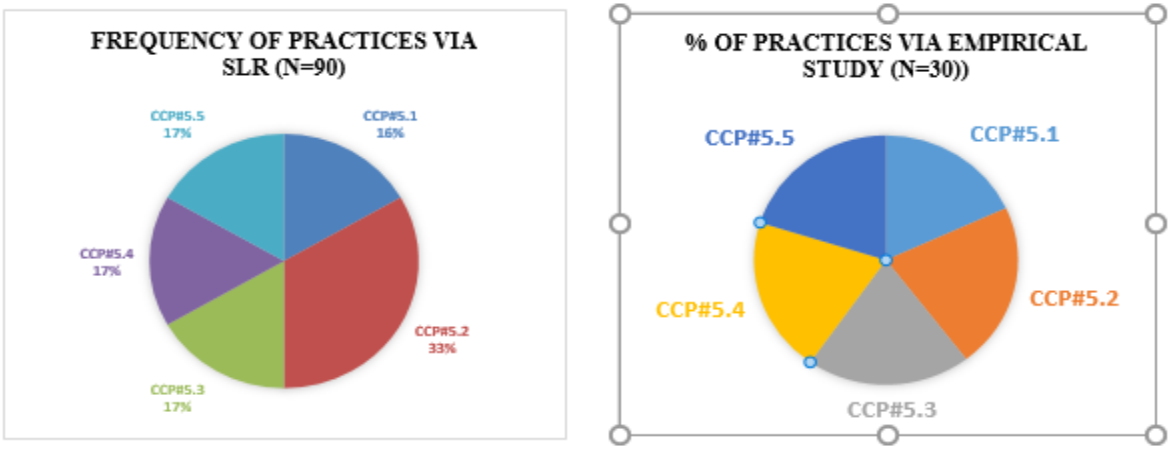


**Fig. 5.** SLR vs empirical.

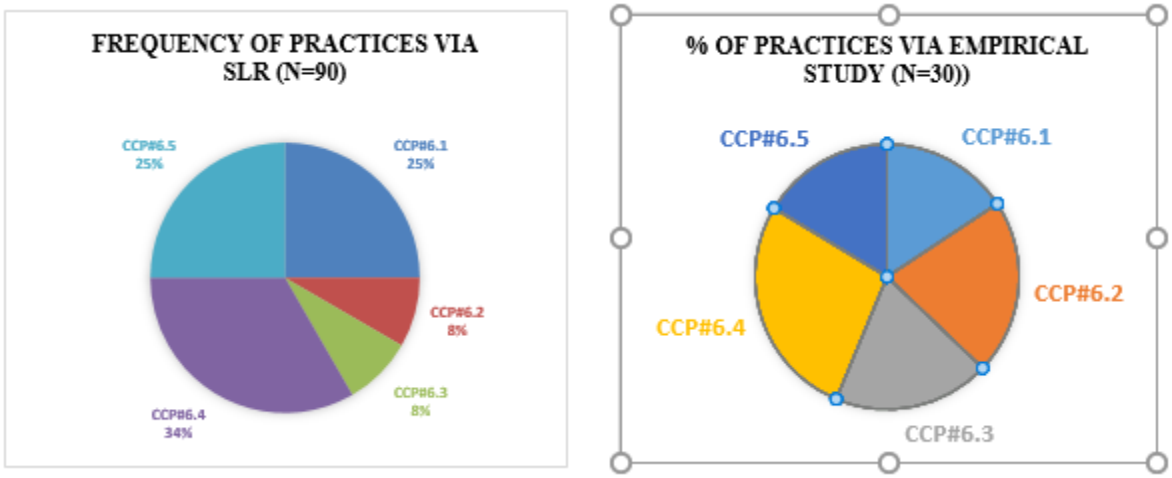


**Fig. 6.** SLR vs empirical.

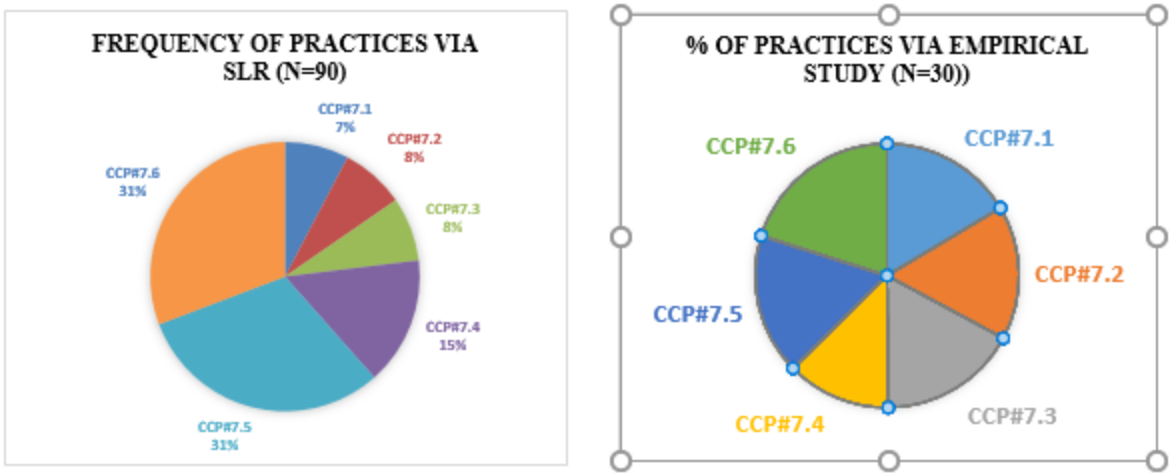


**Fig. 7.** SLR vs empirical.

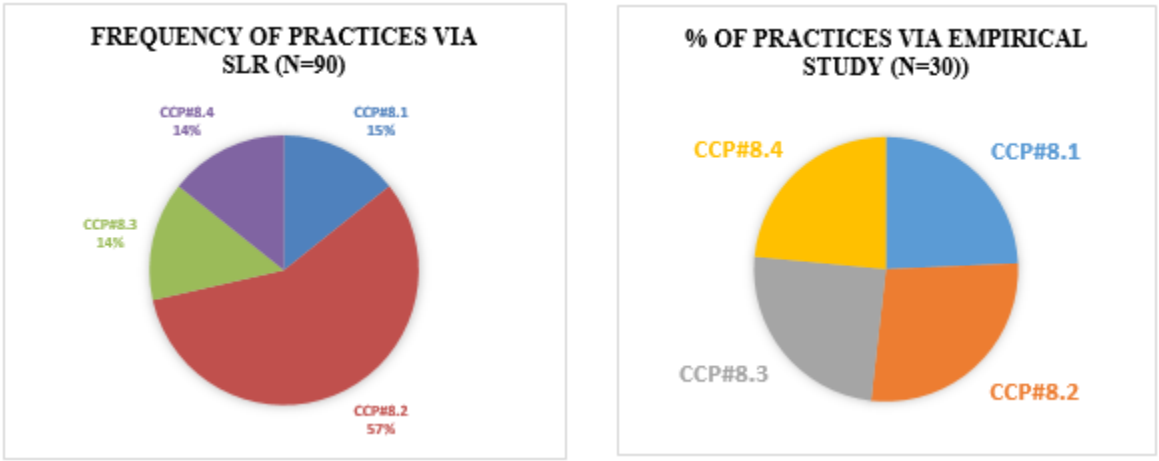


**Fig. 8.** SLR vs empirical.

with cloud service providers through service level agreement (SLA) and using the services of a broker in order to negotiate trust relationships with cloud providers can overcome this challenge. Table 9 presents our identified list of five practices for addressing the hybrid cloud adoption challenge 'lack of trust and graphically represented by Fig. 6.

### G. SLA Assurance

Our finding shows that SLA (service level agreement) is also as a challenge between parties in the hybrid cloud, which lowers consumers' confidence in the reliability and availability of services and makes practical hybrid cloud use very challenging [29]. Our high frequency practice (CCP#7.6) indicates that client organization should ensure in service level agreements that what are the contingency plans in case of the breakdown of the system. Table 10 presents our identified list of six practices for addressing the hybrid cloud adoption challenge 'SLA' assurance and graphically represented by Fig. 7.

### H. Task Scheduling and Execution

In hybrid cloud, task scheduling is a complex process as jobs can be allocated resources either from private cloud or from public cloud [30]. An efficient scheduling mechanism is in need to enable efficient utilization of the on-premise resources and to minimize the task outsourcing cost [31]. Our result shows that executing part of the application on public cloud to achieve output within deadline, as public cloud resources has much high processing power as compare to private cloud resources. On

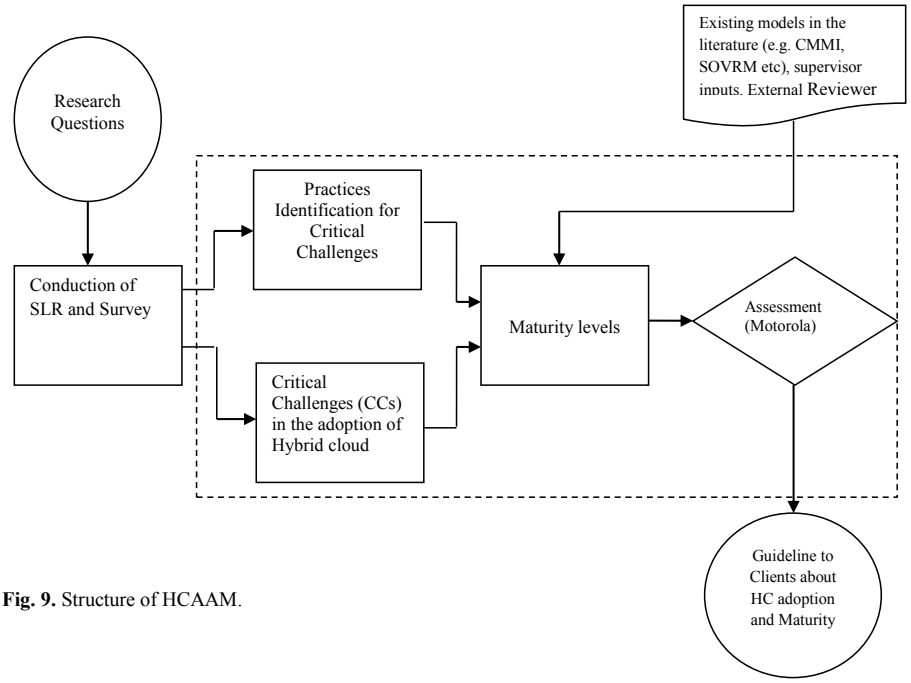


**Fig. 9.** Structure of HCAAM.

the other hand, executing the whole application on the public cloud will be costly. Table 11 presents our identified list of four practices for addressing the hybrid cloud adoption challenge 'task scheduling' assurance and graphically represented by Fig. 8.

## 6. DISCUSSION AND SUMMARY

We initially investigated through SLR the findings from 90 relevant studies that were published since 2009. As a result, we obtained 46 best practices for addressing the hybrid cloud adoption challenges. Our analysis focuses on the occurrences/frequencies of the identified practices. This makes possible to see which practice have been emphasized in past research and thus to identify gaps and possibilities for future research. Similarly an empirical study was conducted in cloud based industry to validate the findings of the SLR and to find any new practice apart from the identified one. A similar approach has been used by other researchers [32-35]. However, we found a strong coherence between the findings of the SLR and the empirical study/ industrial survey.

Related to best practices identified, we have observed that:

- The practice CCP#1.8, 'Categorizing the data into two parts, i.e., sensitive and non-sensitive' and CCP#1.8, 'effective authentications for user' were the most cited practices for 'public cloud security concern' in both SLR (16 studies) and empirical study-77%.
- Four studies in SLR and 74% of the respondent agreed about the practice CCP#2.6, 'Keeping backups of applications and data on on-premises servers and storage devices in order to avoid data loss and time delays in case of failures in the cloud platform' for the challenge 'effective management'.
- About five studies in SLR and 68% respondent agreed about the best practice CCP#3.2, 'Use of standard API (Application Programming Interface) to integrate applications and data between the private clouds and the public clouds' for handling integration complexity challenge.
- The practice CCP#4.2, 'Ensure that access to the internal infrastructure is only possible through secure communications' has three studies in SLR and 74% agreed percentage of the respondent about QoS challenge.
- Two studies in SLR reported the practice CCP#5.2, 'Implementation of migration progress management functions like Pacer' for component partitioning challenge, and 65% respondent highly agreed with this practice.
- It was also observed that 87% of the respondent

and four studies in SLR agreed on the practice CCP#6.4, 'Use services of a broker in order to negotiate trust relationships with cloud providers' for the establishment of trust relationship.

- Four studies in SLR and 71% respondent agreed that best a practice for challenge 'SLA assurance' is CCP#7.6 i.e. 'Ensuring in service level agreements that what are the contingency plans in case of the breakdown of the system'.
- For addressing the 'task scheduling and execution' challenges four studies in SLR and 68% from the respondent agrees that this challenge can be best avoided by the practice CCP#8.2 ,'Execute part of the application on public cloud to achieve output within deadline'.

## 7. STUDY LIMITATIONS

By using systematic literature review, we extracted data about the practices for addressing hybrid cloud adoption challenges. To internal validity one possible threat is that for any specific reporting article in the SLR, which may have not in fact described underlying reasons to report practices for addressing these challenges. In these studies the authors would not be supposed to give the original reason for a particular practice. Similarly, with the increasing number of papers in cloud computing, our SLR process may have missed some relevant papers. However, like other researchers this is not a systematic omission [17]. Our aggregate numbers of respondents in the empirical study/online survey were 30, comprising 8 foreign experts and 22 local experts. For better results, we have to include more participants from abroad. However, because of limited resources and time it was impractical at this stage. Further, we have used all the available resources to approach foreign experts in the field by sending requests for participation through different LinkedIn cloud groups. However, due to the lower response from abroad result generalization was difficult. However, we found a strong coherence between the findings of SLR and empirical study. This extends the reliability in our findings.

## 8. CONCLUSION AND FUTURE WORK

We have identified 45 practices, in total, through SLR and empirical study/industrial survey for addressing hybrid cloud adoption challenges from client's perspective. Our results suggest that client organizations should adopt all of the identified practices in order to mitigate/avoid hybrid cloud adoption challenges and this will also improve hybrid cloud adoption decision process. The objective of our research is to provide client organizations with a body of knowledge that can assist them to successfully embrace hybrid cloud.

Our ultimate aim is to develop Hybrid Cloud Adoption Assessment Model (HCAAM) as shown in Fig. 9, which will measure the organizations maturity for hybrid cloud adoption. HCAAM will maximize the productivity and cost benefits of cloud services and will define a path in the form of maturity levels where organizations will move from one stage to another incrementally.

This paper contributes to the second component of the HCAAM development process, i.e. the identification of practices for addressing hybrid cloud adoption challenges. The final outcome of the research is the development of HCAAM which will provide a more comprehensive theoretical and practical assessment of the organization's maturity in the context of hybrid cloud adoption.

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**Appendix 1: A final list of selected publications for practices during the SLR**


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