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A Research Perspective on Data Management Techniques for Federated Cloud Environment

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Abstract— Cloud computing has given a large scope of improvement in processing, storage and retrieval of data that is generated in huge amount from devices and users. Heterogenous devices and users generates the multidisciplinary data that needs to take care for easy and efficient storage and fast retrieval by maintaining quality and service level agreements. By just storing the data in cloud will not full fill the user requirements, the data management techniques has to be applied so that data adaptiveness and proactiveness characteristics are upheld. To manage the effectiveness of entire eco system a middleware must be there in between users and cloud service providers. Middleware has set of events and trigger based policies that will act on generated data to intermediate users and cloud service providers. For cloud service providers to deliver an efficient utilization of resources is one of the major issues and has scope of improvement in the federation of cloud service providers to fulfill user's dynamic demands. Along with providing adaptiveness of data management in the middleware layer is challenging. In this paper, the policies of middleware for adaptive data management have been reviewed extensively. The main objectives of middleware are also discussed to accomplish high throughput of cloud service providers by means of federation and qualitative data management by means of adaptiveness and proactiveness. The cloud federation techniques have been studied thoroughly along with the pros and cons of it. Also, the strategies to do management of data has been exponentially explored.

Keywords- Data Management, Cloud Computing, Middleware layer, Cloud service providers, Data centric parameters.

I. INTRODUCTION

Nowadays huge amount of heterogenous data is getting generated on daily-basis and that it is from heterogenous sources. Heterogenous sources can be smart home, smart hospital or smart city. Each source can generate multidisciplinary data which can have different storage and retrieval significant parameters like cost, scalability and easy access. It is a challenging scenario for data to gather and classify while store and retrieve within stipulated time frame to meet the service level agreements and trust of user. Management of such heterogenous data is must along with maintain the integrity and availability of data.

Cloud computing is the key empowering technology and playing significant role in application domain. The current need for dynamic data on demand is also known as anything as a service using refined instinctive queries are increases significantly. Cloud computing demand is increasing as time is passing as large number of user applications are shifting from traditional model of data storage and service to on demand dynamic data storage and retrieval. Private cloud was the solution to manage high on demand requests within organization but having limitations such as managing the resources, over and underutilization of resources. Public cloud is best suited for small and medium scaled organizations where users were charged based on service consumption i.e. pay-per-use.

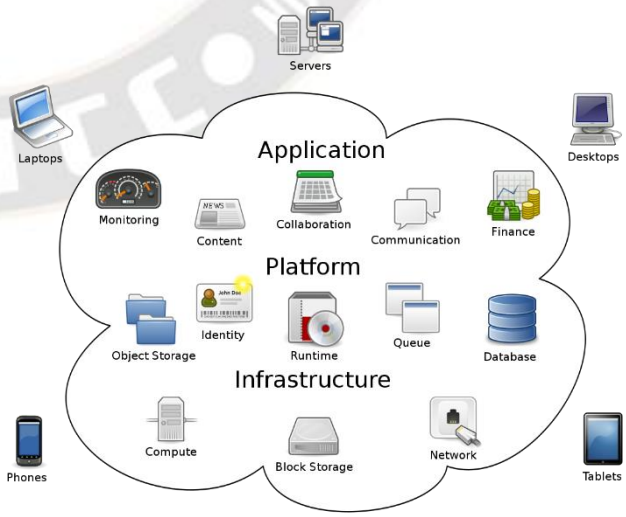

Figure 1. General view of cloud computing [20]

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In figure 1, the general overview of the cloud computing scenario is shown which have multiple private or public users who individually accesses and consumes the application as services, platform as services and infrastructure as services on pay-per-use basis. Each service works independently having independent service providers in cloud computing environment.

Hybrid or interconnected cloud is also based on pay-per-use having the mixture of services from private and public cloud. Federated cloud is the term coined to use two or more than two clouds interact or collaborate to serve common goal. In federated cloud, the resources and services are shared among two or more clouds themselves whenever required and released after goal gets fulfilled. The integration of cloud service provider abilities is done by facilitating distinct interface for each service provider and solitary common interface to the user. With this method cloud interoperability is provided with high capabilities feature set by integrating whenever required [1].

In a federated cloud computing scenario, there are three significant elements like Cloud User, Middleware and Cloud Service Provider. In federated cloud environment the cloud provider will be infrastructure provider as well as consumer. Consumers here can be either regular cloud users or member from the federation. In this situation the equal and same quality of service guarantee is maintained. A user can get benefit of multiple capabilities under single umbrella of federation cloud instead of approaching multiple cloud service providers as each cloud service provider has its own capability [2]. The cloud users are the customers of services and can present their service requests from anyplace on the globe. A cloud service provider has a data center that will be of actual physical machines. Utilizing virtualization innovation, virtual machines are made on the top of actual physical machines. Middleware is situated as an intermediary between cloud users and cloud service provider [3].

Middleware is a tool having set of rules and standards through it centralized access will be given to all the dynamic service requests from cloud customers and all services provided by federated cloud environment. Middleware will act as a single interface to various cloud providers features and functionality to evade the complications in transaction by heterogeneity. With middleware a uniform interface to diverse cloud user and cloud providers is provided and maintained [3]. Middleware collects metadata information from customers (type of service, cost, duration, size etc) and providers (instance availability, scalability, cost, etc.) so that user's requested services should get matched with cloud provider's services. Also, middleware plays an important role to provide adaptiveness and proactiveness of data management to user [4].

The remaining paper is ordered as following: Section 2 of the paper reviewed in depth the research done in direction of adaptive middleware for data aggregation techniques and practices available for cloud federation. For this review we reviewed and examined the thirty-two relevant research papers and articles from year 2008 to 2020. Section 3 illustrates the collective findings, the rationale and significance of the survey. An industry use case of the proposed middleware scenario is also discussed. Section 4 continues by providing the research gaps and issues in adaptiveness of data management techniques for federated cloud environment. Section 5 concludes the paper and outlines the future direction of work.

II. LITERATURE REVIEW

This section of the paper presents related work done in the area of adaptive data management in federated cloud environment.

Craig A. Lee et al [1] has proposed a reference cloud federation architecture. Authors started proposing from the most basic clarification of what federation means along with to identify the fundamental capabilities that must be considered while proposing the federated cloud model. The existing NIST Cloud Computing Reference Architecture were augmented with integration of the proposed fundamental capabilities. A proposed framework can be used by industry and government to accurately communicate the mentioned eleven components and cloud computing offerings. Eleven components were described individually and their functionality as a single unit. Authors described the basics of cloud federation by interactions of the actors in layered manner considering trust, security, and resource sharing and usage. Few presented concepts by authors need in depth examination along with scope to cover all areas of standardization like trust and audits.

Misbah Liaqat et al [2] presented resource management schemes overviews in federated cloud computing environments which are based on functional characteristics organization of like resource discovery, resource monitoring, resource pricing, resource allocation, resource selection, and disaster management. Authors briefly defined each resource management function and insights were offered from the advanced research. The resource management functions were also related based on the respective function performance metrics. Authors focuses on resource management functions with respect to the infrastructure as a service that individual cloud service provider consumes and provides to and from the federated members. Many issues of federated cloud resource management that needs to addressed in further research with respect to factors like as adaptiveness, flexibility, and standardization. Whereas designing a resource management framework for federated cloud scenarios a strict performance

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metrics like bandwidth utilization, security and improved service quality experience has to be considered. Another performance enhancing features like intelligent computational, cognitive bots and human reasoning can be added to provide adaptability, flexibility and user demanded customized services.

Sameer Singh Chauhan et al [3] has done an extensive brokering techniques survey in cloud computing environment. As per authors, cloud brokering techniques classification are done with respect to different categories like multi-criteria, optimization, pricing, Quality of Service (QoS) and trust based on the attributes. The strength and weaknesses/limitations of all surveyed techniques have been investigated by authors. To get continuous access and sharing of services and resources the cloud service provider has to address two major aspects interoperability and portability. A cloud user should be able to select the similar cloud service offering with same access pattern as per applications requirement. To coordinate the resource sharing and provide interoperability and portability with available cloud providers an entity has been proposed called cloud broker. Cloud brokering has two major actors cloud service users/consumers and cloud service providers. Proposed model by author consists of user feedback, cloud service provider manager, cloud service user interface, monitoring and service management components, trust management system. Service management component is taking care of discovery, ranking, selection, and allocation of the services. Cloud service provider manager accomplishes the cloud services that are manageable via cloud broker.

Ansar Rafique [4] in his PhD thesis proposed a middleware for data management in multi-cloud environment. Author contributed to identify an appropriate trade-off between the performance impact and the portability of the application code base. Based on the analysis author proposed comprehensible middleware framework for federated cloud data management, PERSIST middleware for managing the data in federated cloud storage setup, for secure data management a scalable and reusable data protection strategy, self-adaptive and autonomic SCOPE middleware for service level agreement aware data management and at end the validation and evaluation of proposed system with SaaS application i.e. log management and document processing service offering. An effective middlewares and frameworks has been designed to cope with challenges to adopt the federated cloud storage setup and get the benefits of reduced effort and management effort by keeping quantifiable the performance overhead. Enhancement of the work can be done with respect to validation against performance critical applications, maintaining centralized policy engine, having the static data modeling, and scalability can be validated against bulky, multidisciplinary and heterogenous applications.

Syed Muhammad Danish et al [5] proposed a system called BlockAM which is an adaptive middleware through which storage technology will be selected based on the user service requirements for a specific IoT applications. The adaptations of the best possible storage solution for specific internet of things application in the anticipated middleware performs by the continuous monitoring of the storage solutions and internet of things application parameters. The two polynomial-time heuristic algorithms based on dynamic programming-based algorithm and greedy style algorithm are modeled to optimization the cost storage selection for better selection of data storage based on internet of things application service requirements. For storage of internet of things data on-chain to maintain the accountability, auditability, and integrity to the middleware architecture the blockchain technologies were employed.

A. M. Sermakani et al [6] focuses on to simplify the authorization and authentication process. Authors proposed an algorithm called ATDSRA which will be used for public and private cloud user's secured data storage and retrieval on cloud database. Authors also proposed dynamic data auditing scheme called CRTDDA for conducting the occasional cloud data auditing over the federated cloud and restricting the data access to protect the stored data from malicious access. Effective cryptographic algorithms can be used to provide high security and efficiency services to cloud data user and cloud data access.

Leonard Heilig et al [7] proposed multi-criteria problem formulation extension to Cloud Service Purchasing Problem in which they considered the network latency between cloud data centers and consumers. Authors has integrated brokering ways to provision a multi-criteria location aware selection of virtual machines in multi-cloud environment with two large neighborhood search metaheuristics and greedy heuristic approaches in CloudSim. The relationship between costs and latency along with region constraints shows that latency improvement can be achieved at high price cost and with regional flexibility the latency improvements are shown while cost reduction. The challenge from cloud user perspective to find the optimization approach for ease the assignment and scheduling of events and applications in cloud environment can be better way handled with location-aware brokering mechanism.

Fereshteh Sheikholeslami et al [8] provided an exhaustive review and survey of the auction-based resource allocation mechanisms in the cloud environments. Authors classified the important cloud resource allocation mechanisms into four categories as combinatorial, double-sided, one-sided, and other types of auction-based mechanisms. The more resource allocation categories can be considered like priority and heuristic based resource allocation. For autonomic systems the policies

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and utility functions can be proposed to limit the hardware resource dependency and heterogeneity for resource allocation in cloud environment. Also, providing adaptive capabilities and self-management of resources according to the situations.

Ansar Rafique et al [9] proposed an autonomic and policy-based middleware called SCOPE middleware that has capability of self-adaptiveness for data management in federated clouds. The validation of SCOPE middleware is done with extensive thorough experimental evaluation and functional validation in the context of a realistic industry level document processing SaaS application. The evaluation results of proposed system validate the capability of the middleware to accomplish run-time data management choices to meet promised SLAs and provide self-adaptiveness. SCOPE has been designed upon two fundamental principles, One: dynamic data management and placement decisions executions considering dynamic properties into account making compatibility of underlying federated cloud storage. Two: By using external and reusable reconfiguration policies the reconfiguration of underlying cloud storage setup is accomplished. SCOPE middleware comprises of three layers i.e. SaaS application layer, adaptive data management middle layer, and federated cloud storage layer. The adaptiveness capabilities of the middleware layer has to respond towards run time dynamic changes and should satisfy different service level agreements requirements quantified by the respective application. Self-adaptive systems has input of continuous monitoring of federated cloud storage resources and support of process adaptation for auto scaling of cloud resources. This can happen with maintaining appropriate monitoring interval and static configuration policies respectively.

Ansar Rafique et al [10] identified issues to manage a multi-cloud storage architecture for both SaaS providers and tenants. Author presented a data management middleware platform which is policy-driven which styles notion of numerous cloud storage providers, provisions a annoying collection of endlessly altering application-wide and tenant-specific storage policies for the data management, and provisions tenant customization and enhancement. Middleware performance will increase and run-time complexity can be minimized through examining the entities, evaluate and execute the policies at compile time and performing decisions in the memory.

Juliana Oliveira et al [11] investigated the strategies and techniques for multiple cloud resources management in perspective of the user, in which the users and applications demands were identified in multiple clouds to manage the resources. Managing multiple clouds resource management is considered to be NP-hard problem. Cloud resource management integration approach should be from user as well as provider perspective.

Ansar Rafique et al [12] discussed the detailed about complexity and plans of proposed architectural visualization of self-adaptive middleware solutions which monitors and changes the storage architecture semi-autonomously. Authors highlighted two expanses of their enduring and forthcoming research as thoroughly monitoring the storage systems considering the heterogeneousness and uniformity approaches also the methods to change and control the diverse storage resources dynamically. To make multi-cloud data placement decisions efficient the factor of dynamicity and runtime conditions need to be considered.

Rajkumar Buyya et al [13] presented a detailed review about cloud computing from market perspective considering the factors for delivering IT services as computing utilities similar to electricity and telephony. Authors defined Cloud computing and suggests the suitable architecture for creating market-oriented Clouds by influencer technologies such as VMs. Getting cloud user and cloud service provider together for market maker through clearing house and intermediatory broker will be interesting such that the mapping of services to providers can happen and quality of service will be maintained.

Mohammad Aazam et al [14] proposed a broker as a service model (BaaS). BaaS were designed considering user price to be pay for resource consumption and resource consumption estimation. Proposed model will take the characteristics and traits of customers and based on this the required resources are forecasted and price estimation is calculated. Cloud federation and brokering middleware must have standard architecture and more parameters of function and non-fictional type need to include along with the quality of service and types of devices.

Raghavendra Achar et al [15] presented an architecture of broker for infrastructure as a service provider so the cloud user will select the appropriate cloud provider out of available providers based on requirements. According to author the broker fulfills the requests of user by measuring the quality of cloud providers and then prioritizing them for requests. To select the appropriate cloud provider out of multiple cloud provider, each cloud service provider is ranked by TOPSIS method and characterized on service measurement index.

Alba Amato et al [16] proposed a distributed cloud broker who have the major job of choosing dynamic pool of cloud resources from available different vendors so that it will best fits for users requirements. Authors also addressed the issues of elasticity and scalability of resources. Brokering is based on set of constraints (architectural constraints and service level constraints) and objectives (solutions for interoperability and portability problem occurring due to disparity and heterogeneity of service technology) on parameters like best price per unit

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time, maximum number of cores, best known provider, and minimum expected availability.

Gaetano F. Anastasi et al [17] proposed cloud Brokering solution called QBROKAGE over a heuristic based genetic approach which has major focus on discovery of Infrastructure-as-a-Service resources for fulfilling quality of service requirements of applications. Authors claimed with experiment that proposed system can find best possible solutions even though it is when dealing with hundreds of providers and minimizing the vendor lock-in issue. To support non-functional requirements expressed in natural language using ontology matching, throughput and response time must be included in brokering model.

Luciano Barreto et al [18] presented a conceptual federation brokerage model to address the two issues, first is availability and sharing of resources and second is user management and authentication in federated environment. In proposed model a global agent will search for resources by auctioned model and then allocating that to users in a cloud federation along with that model is providing user authentication mechanism via identity provider to allow user recognition in different cloud domains. A cloud framework should be designed in which integration of available algorithms and authentication mechanisms will be carried out.

Table 1 shows the summary of various techniques like pricing, multi-criteria, service optimization, QoS and trust for federated cloud with parameters or services or criteria like resource allocation, response time, scheduling, service selection, user definitions, authorization and authentication along with objectives, strengths and limitations. Out of this major focus has to be on context awareness so that the middleware can be adaptive in environment.

III. RATIONALE AND SIGNIFICANCE OF THE SURVEY

Following are the collective findings that are present in data management for federated cloud environment:

- **Multidisciplinary Data:**

With the introduction of new technologies like Internet of Things and fog computing many users data is generated in the form of multidisciplinary. Storage and Classification of run time heterogenous data generating from varied sources is a big challenge. Also, the analysis and classification of run time data is must to store and retrieve for enhancing the user experience and proactive suggestions/notifications.

- **Vendor Lock-in:**

User consumes the cloud's services like as SaaS, PaaS and IaaS on pay-per-use basis. While consuming the services the applications and data of users were hosted in available anyone of the data centers. Cloud users are unaware about the hosted application's or data's data center and location. Each cloud service provider will have its unique interface and model for interaction with cloud users/customers. Now its challenge in front of user to adjust the multiple interfaces and models every time cloud customers changes the service provider for hosting their applications over cloud. Due to binding to respective service provider the modifications users are expecting in their service while switch and shifting to another provider will be hectic and chaotic. As per changing user requirements the cloud

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Table 1: Summary of techniques for federated cloud environment

Sr. No.	Authors	Techniques	Environment	Parameters/ Services/ Criteria	Objective	Strengths	Limitations
1	R. Mehrotra et al [25]	Pricing	Federated Cloud	Resource Allocation	Increase profit and reducing the cost of operation.	Resources are allocated on dynamic basis.	Focus on homogenous resources.
2	M. Aazam et al [26]	Pricing	Federated Cloud	Resource Allocation	Prediction of essential resource.	Essential resources are predicted based on historic user data.	More parameters need to be considered.
3	E. Pacini et al [27]	Multi-criteria	Federated Cloud	Response Time	Reduce the response time.	In case of increasing cloud machines the response time gets reduce.	Supports to horizontal scalability only.
4	M. Rosa et al [28]	Service Optimization	Federated Cloud	Scheduling	Enhance computational time.	Computational time works better for bioinformatics workflow applications.	Solutions with respect to security and containers based can be offered.
5	M. Hamze et al [29]	Quality of Service	Federated Cloud	User Defined	Cost optimization by maintaining QoS integrity of NaaS & IaaS.	Minimized the cost with optimization algorithms.	More objectives can be taken into consideration.
6	M. Aazam et al [30]	Quality of Service	Federated Cloud	User Defined	Address the major features of QoS and Resource allocation.	Successfully monitored the QoS levels & worked refunding.	More experiments can be performed on heterogenous resources.
7	E. Badidi et al [31]	Quality of Service	Federated Cloud	Service selection	Cloud service selection based on context aware.	Proposed techniques select the best available cloud service provider from federation.	Various attributes need to be added to verify and validate the results.
8	L. Barreto et al [32]	Trust	Federated Cloud	Authorization and Authentication	Allocation of resources with secure search from federated members.	For resource discovery the best model is auction based.	Identity management must be done by external entity.

customer who are interested in another service and wants to change the cloud service provider then it becomes challenge in front of customer to adapt suitable interface and model of the respective cloud service provider. The raised situation will be recognized as vendor lock-in.

- **Interoperability Issue:**

Another major issue which can be addressed as service inaccessibility during the situation of service provider unavailability. This can be significant obstacles for the implementation of cloud computing. It becomes highly challenging to provide satisfactory usability and responsiveness for the users that are located all over the globe. For single cloud service provider to offer services globally and fulfill the requirements in satisfactory manner by considering numerous and differing regulations is very challenging and difficult. So, changing the cloud service provider is obvious and, in such situations, maintain the service level agreements without facing any violations is difficult. Also, the digital data management policies and rules varies from country to country. To provide and consume service in the global environment becomes problematic to perceive all the directions. Making cloud computing a state-of-the-art efficacy like as telephony and electricity its essential to provide and access numerous cloud computing services with location independent, platform independent, technology independent and provider independent. Interconnecting cloud environment having common area of interest and work known as cloud federation is the solutions of mentioned problems.

- **Disparity of Services:**

In current era the data that is generating is either multidisciplinary or multi-sensing. Generated dynamic data is

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usually stored on clouds to get easy access whenever required and cloud computing services are used to get proactive notifications. For such dynamic storage and computing services to get a suitable cloud service provider is very challenging from user perspective as user is unaware about the best available options in terms of cost, scalability, trust, adaptability etc. [3][4][5]

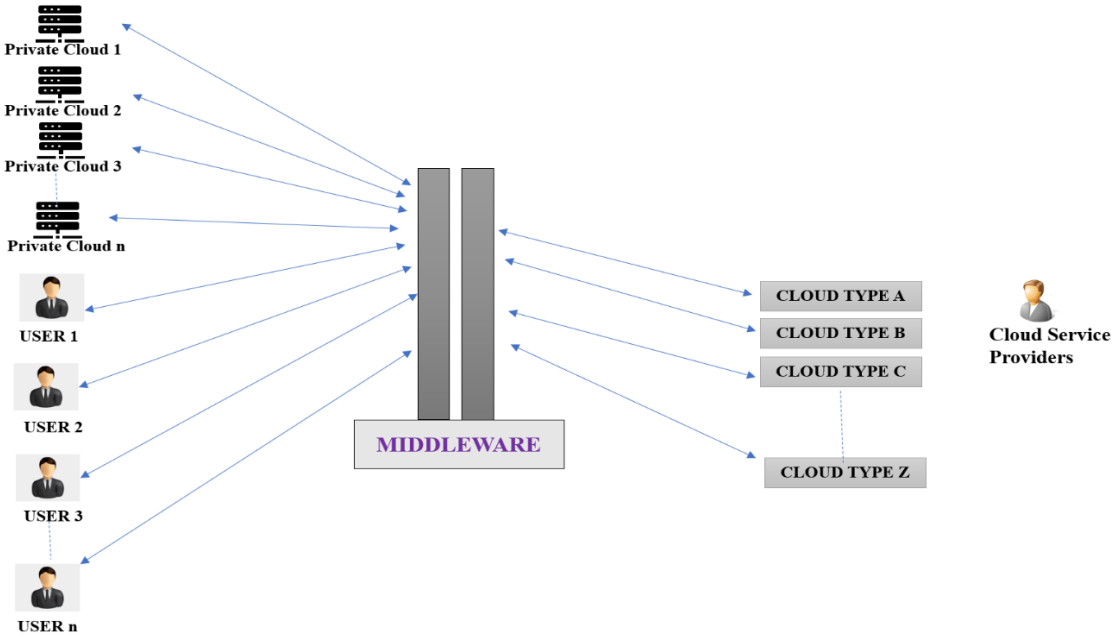

Figure 2: Proposed overview of cloud users, middleware, and federated cloud service providers.

To overcome the above findings a middleware-based framework can be a solution. A middleware layer which will be acted as centralized point of contact to access of all the dynamic service requests from users and all services that is provided by federated cloud environments. Middleware will be used to deploy dynamic services along with efficient storage handling of multidisciplinary dynamic data. In general, a middleware helps user in choosing a precise cloud service provider based on requirements. Middleware could be used to serve dynamic service requests and do frequent data auditing for integrity and authentication in federated cloud environment. Adaptive and proactive middleware can have a set of events and trigger-based policies to full fill the requests of cloud user and handle efficient resources utilization of cloud service providers.

Consider an industry use case where multiple users are generating a multidisciplinary data that need to be stored and processed at cloud provider side because of less availability of resources like storage and computation at user end. As data is heterogenous that need to be classified based on defined parameters and after that it will be sent to respective cloud provider as per the policy of middleware like after matching the user requirements with available cloud services then allocating the required cloud resources. This is a win-win situation for user and cloud service provider as user got service as per the requirements and for cloud got a customer to consume the services in regard to expand the substantial growth. In this case federation of cloud service providers will done to fulfill the common goal like to satisfy the requests of users and avoid the underutilization of cloud resources. Frequent auditing can be scheduled to maintain the confidentiality, integrity and availability of user data and cloud service.

IV. Research Gaps

Existing research focuses on the resource and service management at cloud service provider side and middleware only. Instead of that the focus should be to provide a middleware-based solution in which user's multidisciplinary data will be analyzed and classified in dynamic way. After doing the reviews and surveys of the data management techniques for federated cloud environment, we identified that data centric parameters need to be identified and focus of the techniques for adaptive data management should be handled in middleware layer. Middleware layer will act an intermediator between the cloud user and cloud service providers. Here, cloud user can be individual person or private clouds.

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Hence, to fill the research gaps and to meet the standards techniques of adaptive data management for federated cloud environment following issues can be addressed:

a) Enhancing adaptive data management techniques to maximize the efficient utilization of cloud resources.

b) Providing proactive services to increase quality and trust value of cloud service provider.

c) Investigating and providing a suitable data management algorithm to middleware layer for maintain adaptiveness of data and trade cloud federation techniques.

d) Designing and developing an adaptive data management middleware framework for federation of cloud service providers.

Figure 2 shows the overview of the proposed federated cloud computing environment which having three major components like cloud users, adaptive middleware, and federation of cloud service providers. The proposed overview can overcome the above mentioned the limitations of traditional cloud computing (as shown in figure 1). The proposed standard adaptive middleware framework will work by considering functional and nonfunctional parameters and act based on events and triggers.

V. CONCLUSION

Effective management of multidisciplinary data is very important to serve the user requests in stipulated timeframe and to get proactive results for decision management. As all data storage and retrieval policy decision will be done at middleware layer side so in this situation service and resource management of federated cloud becomes a critical task. The cloud service providers should be able to trade their un-utilized resources and services by means of the middleware. Also, the cloud service users will be able to purchase or rent cloud resources or services in economical way from federated cloud environment by means of middleware to keep data management active.

In finding the best cloud service provider the middleware plays a major part. Middleware's role for federated cloud environment will to do frequent data auditing for integrity and availability and offer computation capability with utility-services-like way, like online shopping, online entertainment platforms, telephony, water, and electricity. Eventually it will help user as well as cloud service provider.

Different existing data management techniques were examined for the features like adaptiveness and proactiveness. By considering the parameters for middleware layer such as context and performance an outline is presented that is adaptable according to comportment needs of user. A user in this case can be individual user or private cloud. Eventually the framework should be there to address the issues mentioned above like vendor lock-in, interoperability, management of multidisciplinary data. The standard framework needs to be there to manage the dynamic data and service requests of user for federated cloud environment where, two or more clouds will be interconnected for common goal. Frequent data auditing will be scheduled to keep data integrity and availability.

VI. FUTURE SCOPE

As a future work, it will be fascinating to broaden the standard middleware framework by adding more functional and non-functional parameters like performance, context, response time, cost, availability, resource discovery and resource optimization to meet quality and trust value of cloud service provider. Also, by providing a suitable adaptive data management algorithm for a service sector like smart city will increase the interdependent dynamicity working efficiency and maximum competent utilization of federated cloud service provider resources. Another future direction of work can be done on the adaptive framework that can fit to any application scenario to meet the service level agreement and maintain the trust value of cloud service provider. Also, existing algorithms can be enhanced by certain parameters as discussed in earlier section so that unbiased request handling of customer, efficient scheduling of cloud resources and working efficiency of cloud service provider can be increased. Ultimately by reducing the use of redundant resources it will subsidize to green earth.

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