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Cloud Computing Standardization Initiatives: State of Play

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ABSTRACT

Cloud computing is an evolutionary paradigm for service delivery in IT industry. Technological evolution and adoption of cloud by reputed companies diverge into development of too many standards. With the wide spread of the technology, these standards cause problems like vendor lock-in, portability, interoperability, preventing the future adoption of cloud computing. Many standardized bodies have developed their own standards but still their adoption is difficult and complex. In this paper, a systematic and comprehensive survey is conducted for finding current standard initiatives by different Standard Development Organizations (SDO), Technical Forums and Government Organizations. Survey is conducted by searching current cloud standards by defining keywords and categorizing result in three categories viz.Arhitecture and Framework, Cloud Management and Cloud Communication. Total 31 standards are studied in the survey. Aim of the survey is to understand standards, their standardization area, and gaps. Recommendations are suggested for development of standards in cloud based on the result of the survey. These recommendations encourage communities to adopt and build common standard by taking consideration from industries and standard development agencies.

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1. INTRODUCTION

Cloud computing inherits the future of service delivery in IT industry with a pay-as-you use and abstracted infrastructure [14]. In recent times cloud computing became popular and it holds a place in Gartner top strategic technologies list for third successive year [1]. Cloud computing is adopted by many organizations and government bodies. A report submitted by International Data Corporation (IDC) in 2010 stated investment in Public cloud services adoption will grow at over five times the rate of the traditional IT industry. Cloud service providers will account for 12% of IT infrastructure spending, growing to 20% by 2014 [2]. Gartner in March 2009 forecasted that the cloud computing worldwide market will reach $150 billion in 2013. A survey conducted by F5 Network and Applied Research West stated that, 66% of 250 IT companies have dedicated budget funds for the cloud, further 71% expect cloud computing budgets to grow over the next two years [3]. Along with the opportunities and promises of cloud computing there are many elements of risk and management complexities. Many cloud adopters raised questions before adopting cloud which are as follows [4]:

- How do I *integrate* computer, network and storage service from one or more cloud service providers to my business and IT process ?
- How do I *manage security and business continuity risk* across many cloud service providers ?

- How do I *manage the lifecycle of a service* in a distributed multi-provider environment in order to satisfy Service Level Agreement (SLA) with my customers ?
- How do I *maintain effective governance and audit processes* across integrated datacentres and cloud providers ?
- How do I *adopt or switch* to new cloud providers ?

As stated by the above questions, there are many incompatibilities in the smooth transition and adoption of cloud computing. These incompatibilities can be classified as follows:

- Technical (Security, Reliability, etc)
- Business (Pricing, Expense, etc)
- Semantic (Portability, Interoperability, etc)

Figure 1. Cloud computing adoption challenges

Figure 1 shows main challenges in management of cloud computing. These challenges neither allow industries nor users to make optimum use of potential of cloud computing. The primary reason for these incompatibilities is the lack of an industry standard for defining cloud computing applications and their management. Without an appropriate standardized framework, architecture, API's and security policies cloud's wider adoption is challenging. Dealing with these challenges in industry and research has the potential to bring cloud computing to the next level [5] [9]. Many industry experts speak about the importance of standards in cloud computing. Dan Kusnetzky, IT analyst of The Kusnetzky Group[1], discuss the crucial importance of standardization in early stages of cloud computing and raised the question of incompatibilities arises due to lack of standardization in cloud computing. Lynda Stadtmueller, program director for cloud computing at Frost & Sullivan's Stratecast, mentions that the lack of standardization is causing difficulties for buyers to compare and evaluate cloud offerings [6]. Nirlay Kundu, Senior manager at Wipro Consulting Services, talk about security standards by addressing issues such as data privacy and encryption which is hurting wider cloud-computing adoption in recent times [6]. Winston Bumpus, Director of Standards Architecture at VMware, acknowledges the development of next set of standards which will revolutionize compute and data sharing in cloud computing [7].

As advocated by numerous industry experts and need shown by cloud market, different work and various initiatives both at low and high level are being done in the field of standardization in cloud computing. NTT technical review consolidated all the standardization activities in a comprehensive manner [8]. National Institute of Standards and Technology (NIST) study different areas for standardization and provide a roadmap for cloud computing standards [10]. Internet Engineering Task Force (IETF) also listed all main Standard Development Organizations (SDO) and provides an introduction to each standard [11]. These studies for depicting current activities in cloud standardization only listed proposed and under development standards. A detailed and extensive insight into standard initiatives in cloud computing emphasizing on comparison between standards, present state of standards and future still needs to be discussed. The rest of this paper is structured as follows. Section 2 describes research method and its result used to conduct the survey. Section 3 reviews all standard initiatives in detail with three broader groups' which are Architecture & Framework, cloud Management and cloud Communication. Section 4 summarizes the current status of cloud computing standard initiatives. Section 5 enlists standardization gaps in three classified areas. Section 6 provides some reccomdenation for standard development process. Before concluding survey in section 8, section 7 provides results of survey with discussion.

2. RESEARCH METHODOLOGY FOR CONDUCTING SURVEY

[1] http://kusnetzky.net/

A systematic approach is used to conduct survey [12]. Below sections explain the research method and its findings. As shown in Figure 2, a systematic set by step process is followed for conducting survey. It started with defining research questions, as stated in Section 2.1. In the next step we define keywords and their synonyms, as listed in Table 1. Using these keywords and their synonyms we conducted a search in selected online databases, as listed in Section 2.2. Relevant cloud standards came in the search were listed, each cloud standard is studied individually from their respective websites and online resources.

Figure 2. Study Selection Process

Document, code or any other resource of standard was studied and review is generated providing its area of standardization, work till date and its adoption by standard agencies or industries. Then, the relationship between standards is studied. Finally, Reference analysis is done to ensure that no known standard is left till date.

Table 1 Keywords and Synonyms for searching cloud Standards

Keywords	Synonyms
cloud computing Standards	cloud Standards, Standarization in cloud computing
cloud Interoperability	Interoperability in cloud, cloud Compuitng Interoperability
cloud Standard Bodies	cloud standard Organization/Institutes/communities

2.1 Research Questions

This survey aims at summarizing the current state of the art standard initiatives in cloud computing by proposing answers to the following questions:

- What standard initiatives exist or are under development for cloud computing?
- Which cloud product or process implements those standards?
- How well these standards have worked for implementation of cloud (Success or Failure of standards)?
- Which cloud standard bodies or industries are collaborating in the development of standards?
- Which standards are accepted world-wide by all bodies and industries?

2.2 Sources of Information

In order to conduct this survey a systematic mythology is used to review the literature [12]. We started surveying by searching major online research databases of computer science, that are listed below:

- IEEE Xplore,
- ACM digital Library,
- Google Scholar,
- Standardization bodies,
- Industries Initiatives,
- Research conducted by institutes,
- Research organizations/communities.

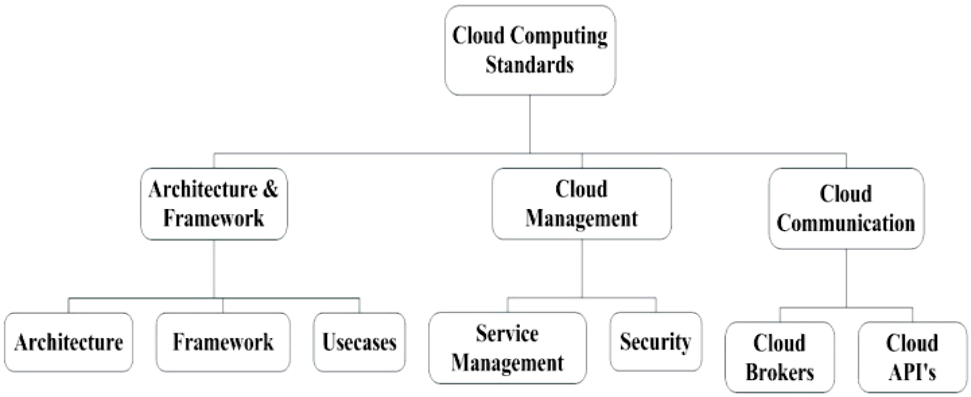

Figure 3. Categorization of Standards

2.3 Result of Selection Process

By following above selection process, 31 Standard initiatives from 20 different organizations were identified. These cloud standard initiatives were categorized in three groups which are, Architecture & Framework, cloud Management and cloud Communication as shown in Figure 3. The three groups shown in Figure 3, 10 standard initiatives are found in Architecture & Framework and cloud Management plus 11 standard initiatives are found in cloud Communication, as shown in Figure 4. Number of standardization initiatives in three fileds is almost same which depicts that industry is working in all the three fields and all three fileds are equally important. Figure 5 shows year wise standard initiatives from 2006 to 2012 in all three groups. As seen in Figure 5, highest numbers of standard initiatives are in 2009 followed by 2010. Standards initiatives started in 2009 and 2010 are maturing and research is going on implementing these standards. In 2011 and 2012 only 3 standard initiatives have started for the similar reasons. Standard initiatives are also classified based on type of standard bodies' namely Forum standard bodies, Information and Communication technology (ICT) oriented standard bodies, de jure (concerning law) standard bodies and Government affiliated bodies. Figure 6, shows share in cloud standard development from these bodies.

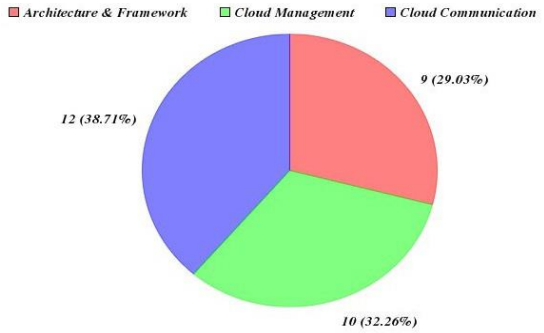

Figure 4. Contribution of Groups in Discovered cloud Standards

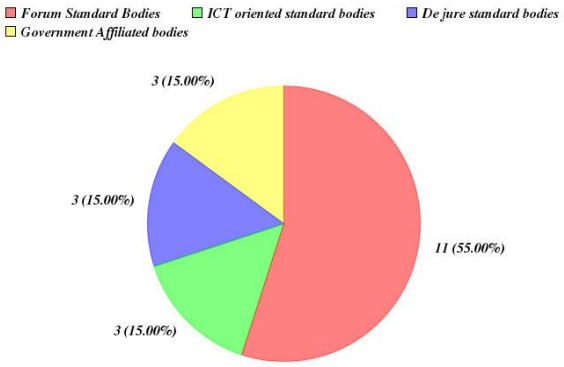

Figure 6. Contribution from Different Standard Bodies in Each Group

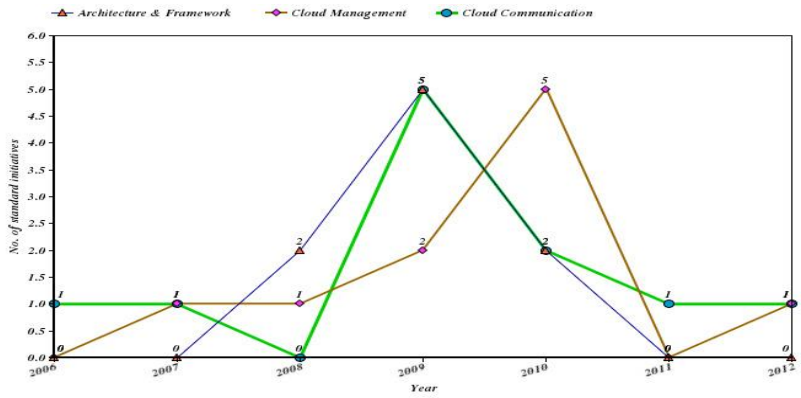

Figure 5. No. of Standard Initiatives per Year in Each Group

3. CLOUD COMPUTING STANDARD INITIATIVES

All discovered standards are divided into 3 groups, as shown in Figure 3. In the following section, we will specify details of each standard in its relevant group and capture their area of standardization in tabular format.

3.1 Standardization Initiatives in Architecture & Frameworks

There is need of a widely adopted cloud computing architectures and frameworks . Architecture should be generic high level conceptual model which should be powerful tool for discussing requirements, use cases, frameworks and operations in cloud computing [10]. This section includes standard bodies which are currently working in development of Architecture, framework, use cases, promotion and coordination of cloud computing. Table 2 shows all standard initiatives for architecture and framework in chronological order and explain their respective standardization area.

1. cloud Security Alliance (CSA): It is a non-profit group started in 2008 to study best practices in cloud security and governess. It also provides training, education and certification in security in cloud computing [13].
2. Korea cloud Service Association (KCSA): KCSA established in June, 2008. The main activities of KCSA are the creation and promotion of cloud services [15].
3. cloud computing Usecase Group (CCUG): CCUG started its initiative in developing cloud computing use cases in 2009 with goal to bring cloud consumer and cloud vendor to define common use cases for cloud implementation [16] [17].
4. International Organization for Standards/ International Electrotechnical Commission Joint Technical Committee (ISO/IEC JTC): In ISO subcommittee 38 (SC38) meeting, it commenced a study group in cloud computing. Since then many standards have been developed and are under development [18].
5. Open cloud Consortium (OCC): OCC is a non-profit organization established in 2009. It primarily focuses on managing and operating cloud infrastructure to support scientific, environmental and healthcare research [19]. The main members include NASA, Yahoo, Cisco and Citrix [8].
6. Open Group cloud- Working Group (OGF-WG): This working group is responsible for creating a common understanding between buyers and suppliers. OGC collaborates with many other standard bodies and groups which are CSA, OCM, CCIF, and CCUG to develop cloud standards [20].
7. Object Management Group (OMG): OMG is responsible for making coordination among various standard bodies and groups. Participants in OMG are DMTF, OGF, SNIA, TM Forum (TeleManagement Forum), OASIS, OCC, CSA, ETSI and NIST [21].
8. International Telecommunication Unit (ITU-T): ITU-T started a focus group on cloud in 2010. This group works in standardization of cloud from the telecommunication perspective [22].
9. National Institute of Standards and Technology (NIST): NIST is a technical department belonging to the U.S. department of commerce. NIST aims to shorten the adoption cycle, which will enable near-term cost savings and increased ability to quickly create and deploy enterprise applications [23] [24] [25].

Table 2. Standard initiatives in Architecture & Frameworks

Standard Initiative	Year	Area of Standardization
CSA [13]	2008	Governess, Architecture
KCSA [15]	2008	Promote cloud computing
CCUG [16]	2009	cloud use cases
ISO/IEC JTC [18]	2009	Definition, Terminology, Framework
OCC [19]	2009	Benchmark, Tested
OGC-WG [20]	2009	Architecture, Security, Use cases, Business Artifacts
OMG [21]	2009	Coordination among bodies
ITU-T [22]	2010	Functional Architecture, Utilization of Network
NIST [23]	2010	Architecture, Definition, Use cases

3.2 Standardization Initiatives in cloud Management

Cloud Management deals with Security & Risk issues, Resource Management & Monitoring, and Assessment of cloud services. Following section discuss all standardization initiatives in cloud Management group. Table 3 shows cloud Management standard initiatives in chronological order with their area of standardization respectively.

1. Distributed Management Task Force- Virtual Management (DMTF-VMAN): DMTF VMAN is a standard which includes a set of specification that addresses the management Lifecycle of virtual environment. They developed a standard format for packaging virtual machines known as Open Virtualization Format(OVF) which helps to make virtual machines portable [26]. This standard is adopted by ISO [18] and ANSI [27].

2. Open cloud computing Interface (OCCI): Open Grid Forum (OGF) has announced Open cloud computing Interface(OCCI) in 2009 and released API specifications for Infrastructure as a Service (IAAS) [8]. It supplies a general purpose set of specifications for cloud based interaction with resources. These set of specifications are explicitly vendor independent, platform neutral and can be extended easily [28] [29]. The main participants in OCCI are Fujitsu, EMC, and Oracle.
3. TeleManagement Forum (TM Forum): TM forum is not for profit global organization with more than 900 company members around the world [30]. It started Enterprise cloud Leadership Council (ECLC) in 2009 to resolve issues in standardization, security, performance etc. [8]. The main members of TM forum are Microsoft, IBM and AT&T.
4. Cloud Audit (CA): CA provides a common interface and namespace that allow cloud providers to automate the audit and assessment process of their environment and allow authorized consumers to do likewise via an open, extensible and secure API's. It is also known as the A6, Automated Audit, Assertion, Assessment, and Assurance API's [31].

Table 3. Standard initiatives in cloud Management

Standard Name	Year	Area of standardization
DMTF-VMAN [26]	2007	Virtualization, Resource Management
CSA [13]	2008	Security and Risk Management
OGF [20]	2009	Scaling, Monitoring, Deployment
TM Forum [30]	2009	Security, Performance
CA [31]	2009	Audit, Asses
IETF	2010	Resource Management and Mointoring
ITU-T [22]	2010	Security
NIST [23]	2010	Security,Monitoring
OASIS IDcloud	2010	Identity deployment, provisioning, monitoring
Fed RAMP	2012	Assessment, Authorization, Monitoring

3.3 Standardization Initiatives in cloud Communication

The cloud communication group considers standards that are used for communication between different cloud Services and cloud providers. It covers domains such as creation of common API's, interoperability and portability. Below section discusses all standardization initiatives for cloud Communication. Table 4 shows all standard initiatives for cloud communication in chronological order with their area of standardization respectively.

1. European Telecommunication Standard Institute - Specialist Task Force (ETSI-STF): This group works in grid computing, IT to telecom convergence and in particular, the lack of interoperable grid solutions. Now a technical committee on cloud computing has also been established [32].
2. Cloud computing Interoperability Forum (CCIF): CCIF is a open forum for interoperability in cloud computing. It works for development of an ontology framework in which one or more organization can work together [33].
3. Distributed Management Task Force- cloud Management Working Group (DMTF-CMWG): DMTF open cloud standard incubator developed in 2009, provides usecases and reference architecture to built an interface between cloud service provider and consumer [4]. This group then merges into CMWG in 2010. CMWG also released a set of specifications called cloud Infrastructure Management Interface

(CIMI) as a work-in-progress to enable interoperability in cloud management [34]. Its board members includes VMware, Microsoft, IBM, Citrix, Cisco, and Hitachi [8].

4. Global Inter-cloud Technology Forum (GICTF): GICTF deals with creation of usecases, requirements and specifications for inter-cloud communication. It has a total of 78 members which includes NTT, KDDI, NEC, Hitachi, Toshiba Solutions, IBM, and Oracle [8]. GICTF recently partners with DMTF for cloud resource management [35].
5. OASIS Symptoms Automation Framework (SAF): OASIS started this Technical committee (TC) in 2009 to automate appropriate response to changing business conditions and integrate it to all domains. SAF facilitates knowledge sharing across different domains allowing consumer and provider to work cooperatively [36].
6. Storage Network Industry Association (SNIA): SNIA has formulated the specifications of cloud Data Management Interface(CDMI) which is an API for controlling storage units. It provides storage for cloud applications in elastic, on-demand and bill as you use basis [37]. SNIA submit CDMI to ISO/IEC JTC for approval [38].
7. IEEE- P2301/P2302: IEEE launched its two standards dedicated to cloud interoperability in 2011. P2301 is for cloud Portability and Interoperability Profiles (CPIP). P2302 is Standard for Inter-cloud Interoperability and federation (SIIF) [39].
8. OASIS Topology and orchestration Specification for cloud Applications (TOSCA): OASIS starts TOSCA Technical Committee in 2012 with the support of many leading cloud industries. TOSCA is used to standardize the language to describe the structure of IT services i.e. topology model and how to orchestrate operational behavior i.e. plans such as build, deploy, patch, shutdown etc. [5].

Table 4. Standard initiatives in cloud Communication

Standard Name	**Year**	**Area of standardization**
ETSI-STF [32]	2006	Interoperability Testing
DMTF-VMAN [26]	2007	Portability
CCIF [33]	2009	Interoperability
DMTF-CMWG [34]	2009	API‘s for IaaS
GICTF [35]	2009	Usecases for Inter-cloud
OASIS-SAF [36]	2009	Knowledge sharing among provider and consumer
SNIA [37]	2009	API’s for Storage
ITU-T [22]	2010	Portability and Interoperability
NIST [23]	2010	API’s for IaaS
IEEE [39]	2011	Interoperability and Portability
TOSCA [5]	2012	Interoperability and Portability

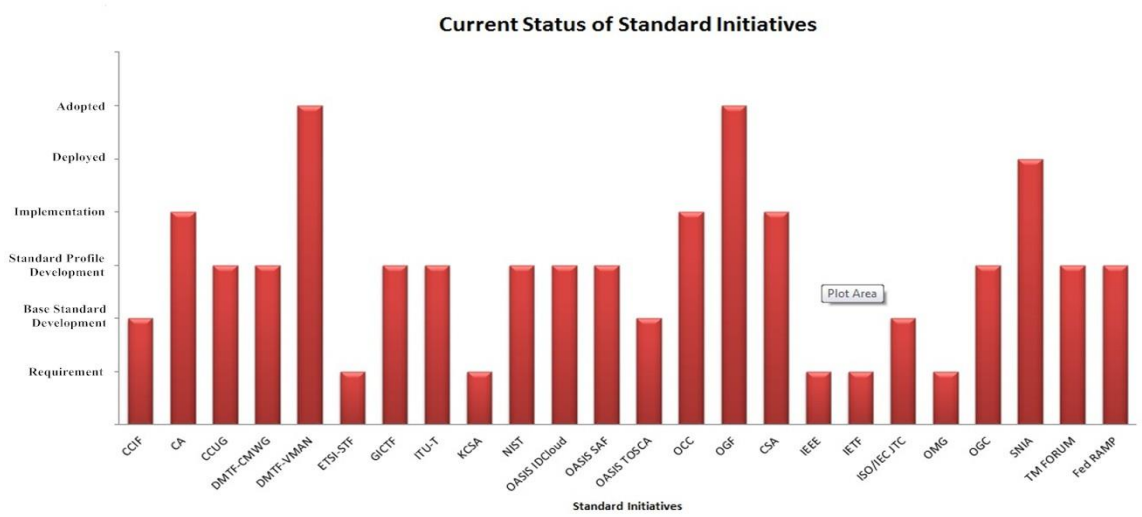

Figure 6. Current Status of each standard initiative

4. CURRENT STATUS IN CLOUD STANDARD INITIATIVES

There is much progress in cloud standardization fields from last 5 years. Major milestone was adoption of OVF by ISO and ANSI as standard for packaging of virtual machines. Other significant standard initiatives by OCCI, CSA, and SNIA are getting world-wide acceptance. Figure 7 shows the status of all standards on the basis of the 6 stages described by NIST [40]. It depicts two standards were adopted by Standard Agencies, four standards are in the implementation phase and rest are developing profiles for their respective standards.Figure 8 discloses the current state of standards from the perspective of different areas of cloud computing. Security standards are farthest from other standards followed by workload portability which is achieved by Open Virtualization Format (OVF). On the other hand, influence should be on standardization in Software License Management which is in its early stages.

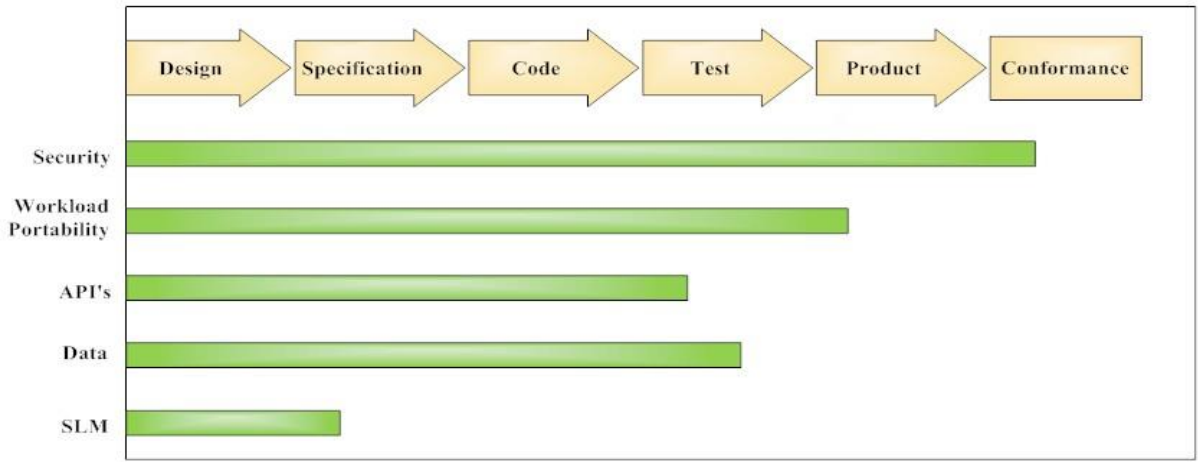

Figure 7. Current Status of standardization in major fields of cloud computing

5. GAPS IN STANDARDIZATION OF CLOUD COMPUTING

Cloud computing is still in its early stages of development. Many challenges have been addressed by technology vendors and service providers separately, which embed many gaps in standardization of cloud computing. Additionally, many gaps from the technology before the cloud computing era are also highlighted [40] e.g. problems due to data formats and identity in a distributed environment. So, gaps in standardization of cloud computing can be divided into two parts, introduced by new service model of cloud computing and pre-cloud computing technology era technology gaps. Below sections explain all gaps in Standardization of cloud computing in three Groups as shown in Figure 3. Table 5 summarizes all Gaps in standardization of cloud computing in all three groups.

5.1 Architecture & Frameworks Standardization Gaps

This section explains all gaps in Architecture & Framework group.

1. **Cloud Service Level Agreement (SLA) and Quality of Service (QoS).** SLA or QoS is a contract that grants cloud consumer information about what he effectively get from this service and provide cloud provider a clear and formal definition of requirement that service should provide. Many requirements (such as response time, security, reliability etc.) can be listed in the SLA or QoS agreement. There is no specific standard in designing SLA or QoS, which causes difficulties for consumers to compare different providers' services and choose most suitable. Standard document or templates should make for SLA and QoS.
2. **Discovering cloud services.** Cloud services are available on demand but there is no use of these services if consumers cannot discover them. Many limitations are found in traditional discovery methods when used in a cloud environment. Standards should develop for proper discovery of cloud resources which include functional and non-functional requirements.
3. **Cloud security and privacy.** Cloud security is one of the major concerns in implementation of cloud computing. Many cloud consumers do not adopt cloud computing because of the risk of their data. Standards should develop for Policies, Processes and technical control for security, privacy and identity in a cloud environment. Regulation and laws should revise for security in cloud computing.
4. **Cloud Reference Architecture.** Reference architecture is an important factor in building standards for different areas. Reference architecture should also determine all usecases and other requirements. NIST develops a reference architecture [41] but it is not adopted as standard reference architecture. Standardized reference architecture for cloud computing should be adopted.

Table 4. Summary of Gaps in Standardization in cloud computing

Standardization Area	Gaps
Architecture & Framework	1. Standard for cloud Service Level Agreement (SLA) and Quality of Service (QoS). 2. Standard for discovering cloud services. 3. Standard for cloud security and privacy. 4. Standard for cloud Reference Architecture.
cloud Management	1. Standard for cloud user account and credential management. 2. Standard for metering and billing for cloud service. 3. Standard for cloud identity management.
cloud Communication	1. Standard for Data and Metadata format. 2. Standard for cloud API Architecture.

5.2 cloud Management Standardization Gaps

This section explains all gaps in cloud Management group.

1. **Cloud user account and credential management.** Cloud services are accessed from distant location which requires an account for each user to login. Different cloud providers have a different user account which drives problems in attaining portability and interoperability. There is need of standards for Single Sign-On (SSO) interface which provide strong authentication and user management in a cloud environment.
2. **Metering and Billing for cloud service.** On demand scaling and pay-as-you-use are crucial prospect of cloud computing. These help cloud consumers to scale their resources up or down as requires and pay for what they use. So, a sound mechanism is required for billing and metering purpose. Each cloud provider uses its own model for billing and metering. This makes difficult for cloud consumers to compare billing of different providers. The standard should be developed for billing and metering with mutual verifiability among cloud providers.

3. **Cloud identity management.** Single consumer or provider uses/provides cloud services at different location and area. So, a unique identity should be maintained for each consumer or provider. Standards should be developed for secure and efficient replication of identity across systems and services.

5.3 cloud Communication Standardization Gaps

This section explains all gaps in the cloud Communication group.

1. **Data and Metadata.** Portability and interoperability in cloud computing can be achieved if all providers use the same data and metadata format. If all providers use sane data and metadata format, one can easily be converted to another. So, standards should developed for data mad metadata format for cloud computing.
2. **API Architecture.** Communication between different cloud services can easily be done through the common API\lq s. It is very difficult to convince all providers to follow the same architecture. So a standardized API architecture should develop.

6. RECOMMENDATIONS

NIST gave recommendations for accelerating the development and Use of cloud computing Standards [40]. We adapt these recommendations and develop a generic form of recommendations for all cloud Standards. These recommendations are as follows:

1. **Contribute Agency Requirements:** Standard development agencies (ISO, ANSI, IEEE etc.) should provide all requirements clear and unambitious to Standard Development Organizations (SDO's) for development of standards.
2. **Agencies should actively participate in the standard development process:** Agencies contributions can be at many levels viz. Monitor, Influence, Promote, and Lead.
3. **Agencies should encourage compliance testing:** Testing should be done at every phase to have technically sound cloud computing standards and standards-based products, processes, and services.
4. **Agencies should specify cloud computing Standards:** When multiple vendors offer standards-based implementations and there is evidence of successful interoperability testing. In such cases, agencies should ask vendors to show compliance to the specified standards.
5. **Wide Use of cloud computing Standards:** When any standard shows compliance with existing technologies and standards agencies should encourage its use.
6. **Dissemination of Information on cloud computing Standards:** All information on standards should be listed and made available to all users.

7. RESULTS AND DISCUSSION

In this paper, a systematic selection process is defined for conducting the survey. Research questions are disucssed in Section 2.1 and survey is conducted to answer these questions. Related to our research questions following results are found:

1. Total of 31 standard initiatives exist or under development.
2. Products like OVF.CDMI, CIMI, and OCCI are implemented by many industries.
3. Most of standards are under development, OVF, OCCI, and CDMI are successful and only 1 standard initiative CCF is stopped.
4. Industries like VMware, Microsoft, IBM, Cisco, Orange, Citrix and many more are collaborating for standard development.
5. OVF, OCCI are adopted by ISO.

More and more organizations, like OASIS, IEEE, ITU-T and IETF have just begun to get engaged in cloud computing standard development. The sheer number of standardization efforts, led by both vendors and standards bodies, are muddying the waters without coordination among them. These standard development bodies should coordinate with each other to develop cloud standards so that they can be useful to whole community and helps to remove some of cloud adoption barriers.

8. CONCLUSION

Cloud standards deliver interoperability, foster innovation and create competition, which results in lower costs and a wider range of vendors and service providers. Due to lack in standards of cloud architecture, cloud management and cloud communication, cloud adopters are not totally convinced to use cloud. This problem is decreasing the cloud market hence effecting cloud in longer run. This work helps to identify the major areas of cloud which requires universally adopted standards and also enlist current standard initiatives in these areas. Standardization gaps discussed in this paper will help organizations to focus on more critical areas. Lastly, recommendations are provided for creating a process which helps to develop universally adopted standards. Proper coordination is required amoung different organizations and bodies so that work already done does not duplicates and organization focues on standardization gaps. There is still plenty of work to be done such as the interoperability standards, architectures standards and management standards that will enable the broader vision of cloud computing. A standard development process can be developed from provided recommendations in future.

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