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Inter-Cloud Computing Architecture
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Abstract

Cloud computing is rapidly gaining importance, not only because of being ubiquitous, but also, due to ease of management of hugely increasing data, specially, multimedia contents. The next era is going to be of cloud federation, in which services would be brought up to the user through multiple clouds, creating an Inter-Cloud computing environment. On the other hand, increase in multimedia content requires much better service provisioning, responsiveness, and efficient transcoding. Thoroughly designing the architecture of Media Cloud Inter-Cloud Computing is today’s requirement. This document focuses on this important issue and presents architectural fundamentals and key concerns in Media Cloud Inter-Cloud Computing.

Conventions used in this document

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC-2119.

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1. Introduction

Digital media has convincingly surpassed traditional media, as a result of which this trend makes big and possibly long-term changes to the contents being exchanged over the Internet [1]. The global Internet video traffic had surpassed global peer-to-peer (P2P) traffic in 2010 [2]. Excluding the amount of video exchanged through P2P file sharing, at the time being, Internet video is 40 percent of consumer Internet traffic. By 2012, it will be over 50 percent and will reach 62 percent by the end of 2015. If all forms of video are counted, the number will be approximately 90 percent by 2015 [2]. To meet the great opportunities and challenges coming along with media revolution, sophisticated technology and better facilities with more powerful capabilities have become the most urgent demands.

Cloud computing recently has emerged and advanced rapidly as a promising as well as inevitable technology. Generally it can be seen as the integration of Software as a Service (SaaS), Platform as a Service (PaaS), Infrastructure as a Service (IaaS), and Network as a Service (NaaS) [3], [4], [5]. Cloud computing platform provides highly scalable, manageable and schedulable virtual servers, storage, computing power, virtual networks, and network bandwidth, according to user’s requirement and affordability. So, it can provide solution package for the media revolution, if wisely designed for media cloud and deployed & integrated with the advanced technologies on media processing, transmission, and storage, keeping in view the industrial and commercial trends and models as well. An average user generates content very quickly, until runs out of storage space. Most of the content may be used frequently by the user, which requires to be accessed easily. Media management is among the key aspects of cloud computing, since cloud makes it possible to store, manage, and share large amounts of digital media. Cloud computing is a handy solution for processing content in distributed environments. Cloud computing provides ubiquitous access to the content, without the hassle of keeping large storage and computing devices. Sharing large amount of media content is another feature that cloud computing provides. Other than social media, traditional cloud computing provides additional features of collaboration and editing of content. Also, if content is to be shared, downloading individual files one by one is not easy. Cloud computing caters this issue, since all the content can be accessed at once by other parties, with whom the content is being shared.

To meet user’s requirements, there comes situations when two or more clouds have to interoperate through an intermediary cloud or gateway.

This scenario is known as Inter-cloud computing or cloud federation. Inter-cloud Computing involves transcoding and interoperability related issues, which also affect the overall process of multimedia content delivery. In this paper, we have tried to dig out deep not only on Media Cloud, but also on Inter-cloud computing. We have presented a detailed architecture, communication pattern and protocols, according to different scenarios and also highlighted some key issues in this regard.

2. Related Work

Media cloud and inter-cloud computing is still in its start, so there is no standard architecture available for data communication, media storage, compression, and media delivery. Already done studies mainly focus on presenting architectural blueprints for this purpose. [6] presents an industrial overview of the media cloud. The authors state that media cloud is the solution to suffice the dramatically increasing trends of media content and media consumption. For media content delivery, QoS is going to be the main concern. We present details in this regard in [7]. To reduce delay and jitter of media streaming, better QoS is required, for which [8] proposes media-edge cloud (MEC) architecture.

It proposes usage of P2P for inter and intra MEC communications, for the purpose of scalability. The authors present in this article that an MEC is a cloudlet which locates at the edge of the cloud. MEC is composed of storage space, central processing unit (CPU), and graphics processing unit (GPU) clusters. The MEC stores, processes, and transmits media content at the edge, thus incurring a shorter delay. In turn the media cloud is composed of MECs, which can be managed in a centralized or peer-to-peer (P2P) manner.

This architecture presents three major features: (i) MECs at the edge of media cloud for the purpose of reducing delay; (ii) P2P technology is used in both intra and inter MEC domains, for scalability; (iii) proxy, which is located at the edge of an MEC or in the gateway, for the purpose of multimedia content caching to compensate for mobile devices, since they have limited computational power and battery life. Proxy can be adopted to seamlessly integrate media cloud, hence addresses heterogeneity problems.

Paper [9] presents an approach to use a pair of proxy, a client proxy at the user’s side and a server proxy at the cloud side, to integrate the cloud seamlessly to the wireless applications. [10], [11] also present proxy as a bridge, for sharing the contents of home cloud to other home clouds and to the outside, public media clouds. This proxy can do additional task of indexing the multimedia content, allowing public cloud to build search database and content classification. Media cloud can then provide discovery service to the users to search the content of their interest. [12] also presents a proxy scheme for transcoding and delivery of media. On the other hand, [13] and [14] propose usage of P2P for delivering media stream outside the media cloud. In both the cases, it builds a hybrid architecture, which includes P2P as well as media cloud.

Transcoding and compression of media content requires a lot of resources. [15] and [16] presents an architecture, in which Map-Reduce model is applied for this purpose, in private and public clouds.

[17] has proposed the concept of stream oriented cloud and stream-oriented object. The authors introduce stream-oriented cloud with a high-level description. In [18], the authors discuss about mobile multimedia broadcast over cloud computing. [19] discusses about personal rich media information management, searching, and sharing.

3. Media Cloud

Meeting the consumption requirements of future is a challenge now. The extraordinary growth in mobile phone usage, specially with smart phones along with 3G, LTE, and LTE Advanced, Multimedia Broadcast and Multicast Services (MBMS) networks, and then the availability of more convenient access network, like: Wi-Fi, WiMAX, Fiber to the home, and broadband networks, has hugely increased the production as well as communication of multimedia content. It is estimated that by 2015, up to 500 billion hours of content will be available for digital distribution. With social media, IPTV, Video on Demand, Voice over IP, Time Shifted Television (TSTV), Pause Live Television (PLTV), Remote Storage Digital Video Recorder (RSDVR), Network Personal Video Recorder (nPVR), and other such services available more easily, users now demand anytime and on-the-go access to content. As estimated, by 2015, there will be 1 billion mobile video customers and 15 billion devices will be able to receive content over the Internet [6].

3.1. Media Cloud storage

Since media cloud architecture is not standardized and study available is not enough. Some of the existing work uses simple storage schemes for multimedia content, while most of the works rely on Hadoop Distributed File System (HDFS) [20]. But the issue with

HDFS is that it is designed mainly for batch processing, rather than for interactive user activities. Also, HDFS files are write-once and can have only one writer at a time, which makes it very restricted for those applications which require real-time processing, before the actual delivery of data. Other than these issues, dynamic load-balancing cannot be done with HDFS, since it does not support data rebalancing schemes.

Energy consumption is an important issue in media cloud content communication, since it requires lot of processing, quality display, and playback. [21] discusses about this issue. The forecast, based on the power consumption trend, says that by year 2021, the world population would require 1175GW power to support media consumption. Storage also plays an important role in this regard, because efficient storage technique will consumes less energy.

3.2. Media Cloud design considerations

Architecting media cloud is among the main concerns right now. As it has been discussed that content receiving devices are heterogeneous, so a media cloud must have the capability to deliver content according to device’s capabilities and via multiple pathways. A cloud must be able to deliver content via multiple paths, having support for multiple tenants and allowing multiple service providers to share the infrastructure and software components. When there are multiple tenants, their need keeps on changing, which media cloud should be able to meet.

Cloud architecture should be able to add or remove virtual machines and servers quickly and cost-effectively. Same is the case with storage capacity. Low latency transcoding, caching, streaming, and delivery of content are must for media cloud. Disk I/O subsystem speed is going to be crucial in this regard. Using advanced technologies, like solid state drives (SSD), serial attached SCSI (SAS) interfaces, next-generation processors, etc., would become a necessity. Power utilization is another vital thing to be considered. Due to huge amount of processing and communication of large amount of data, which is then received by devices which also include small, power constraint nodes, it is going to be very important to have an affective power saving mechanism.

Since we are talking about media cloud, which involves virtual machines (VM’s), which would be created during run-time to suffice user’s needs and at times, many VM’s will not be in use, whether temporarily or permanently, so they should be monitored and suspended or shutdown, when required. This will save a lot of power of the datacenter. On the receiver's side, data received should be only what is required and should be in the most appropriate format, which suits the receiving node's requirements as well as processing and power utilization attributes. For thin client, the device which has to perform all these activities, like, broker or access network gateway, must ensure presentation conformity of the client node. Security and protection is going to be another issue [22] [23] [25]. Data, receiver, and VM security would become difficult to manage, though very important.

In a virtual networking and multitenant environment, VM isolation and isolation of clients becomes very important. Similarly for data, it is not only required to store the data protectively and securely, but also to be transmitted through secure session. So, both kinds of security, storage security and communication security are required.

Current state-of-the-art devices can produce, store and deliver high quality media content, that can be further shared on social media and other media forums. Since, different types of digital media contents can be produced and disseminated across different networks, so a standard mechanism is required to allow interoperability between clouds and transcoding of media contents [11]. Purpose of media cloud is to address this problem and to allow users constitute a cloud and manage media content transparently, even if it is located outside the user's domain. Different device types, resolutions, and qualities require generating different versions of the same content. This makes transcoding one of the most critical tasks to be conducted, when media traverses networks. This requires a lot of media processing that is computationally expensive.

Media cloud helps fulfilling four major goals: ubiquitous access; content classification; sharing large amount of media; content discovery service. Since media content is produced big time and very rapidly, it also requires efficient access, other than being ubiquitously accessed. Media cloud provides indexing and proper classification of content, which makes access of content easier as well as makes searching efficient. Media cloud also provide content discovery service, with which, content stored on other clouds can be accessed, after searching and negotiating licensing terms and conditions. This creates accessibility of huge amount of multimedia content and creates cloud of clouds (CoC) that can interoperate with each other.

4. Media Cloud Architecture

Architecting media cloud and its standardization is becoming very important now. Media content is increasing big time and with cloud computing, the online resource utilization is becoming ubiquitous. Users do not tend to keep data with them anymore. Other than the conventional things media cloud has to do, as compared to standard cloud computing, media cloud has to handle different types of multimedia content as well. Handling multimedia does not only mean transcoding of different media contents into interoperable form, but also to be able to communicate multimedia according to the quality and type of content the user wants. Storage of multimedia content plays a very vital role in this regard. Storage technology has to be standardized to ensure efficiency of coding-decoding and storage space.

In a study we conducted on media cloud storage, it was observed that different cloud storage services use different storage schemes, which affect the size of data, its presentation, and quality. For bulk data, this heterogeneity of storage technologies matters a lot, since they are going to put more impact, when there is cloud federation taking place.

Media cloud tasks are divided into layers, to make it more comprehensive that what kinds of things media cloud has to do and to what extent. Figure 1 presents an overall layered architecture of media cloud. In figure 1, at virtualization layer, cloud has to deal with computing virtualization, memory virtualization, and network virtualization.

Storage layer deals with storage space virtualization and storage technology to be used for media content storage, like Network Attached Storage (NAS), Direct Attached Storage (DAS), Fiber Channel (FC), Fiber Channel over IP (FCIP), Internet Fiber Channel Protocol (iFCP), Content Addressed Storage (CAS) or Fixed Content Storage (FCS), and Internet Small Computer Systems Interface (iSCSI). It also has to deal with data security, privacy, and integrity. Other than this, data replication, de-duplication, and other added features are also part of this layer. Data replication is for the overall protection of stored contents, to make sure that if one copy of data is lost or corrupted, its replica exists. On the other hand, data de-duplication is for the user, which protects making unnecessary copies of the same content. Its purpose is to increase storage efficiency.

Next is the Access Layer, which has to deal with network access, whether the access network or wide area network. It also has to ensure secure communication of the data.

Middleware layer is to deal with encoding/decoding tasks and interoperability related things. As discussed, heterogeneous clients, having heterogeneous requirements, access heterogeneous types and formats of data, so transcoding and interoperability is perhaps the most important part in media delivery. That is why this layer is very crucial. Section V discusses on it in more detail.

Application layer provides the user interface (UI). UI can be in two forms, a web interface or a client application, running on the user's machine. Media cloud provider, or cloud service provider has a business in all these services that it provides to its customers. Business layer deals with that part of media cloud architecture. The services will have different types for different customers and accessing devices. Quality and quantity of data is also considered when offering services. Different kinds of packages can be made available to the user.

```
+------------------------------------------------------------------+
|Business     |------------------------------------------------|   |
|Layer        |services types, offerings, and packages          |   |
|             |------------------------------------------------|   |
|                                                                  |
|Application  |------------------------------------------------|   |
|Layer        |Services types, offerings, and packages          |   |
|             |------------------------------------------------|   |
|                                                                  |
|Middleware   |------------------------------------------------|   |
|Layer        |Transcoding and interoperability                 |   |
|             |------------------------------------------------|   |
|                                                                  |
|             |------------------------------------------------|   |
|             |Network access, WAN/LAN                          |   |
|Access Layer|------------------------------------------------|   |
|             |Authentication and access control,secure transfer|   |
|             |------------------------------------------------|   |
|                                                                  |
|Storage      |------------------------------------------------|   |
|Layer        |Data security, privacy, and integrity            |   |
|             |------------------------------------------------|   |
|             |data distribution,replication,de-duplication     |   |
|             |storage virtualization, storage techniques       |   |
|             |------------------------------------------------|   |
|                                                                  |
|Virtual-     |------------------------------------------------|   |
|ization      |Virtualiation, virtualization techniques         |   |
|Layer        |------------------------------------------------|   |
|             |Physical hardware                                |   |
|             |------------------------------------------------|   |
|                                                                  |
+------------------------------------------------------------------+
```

Figure 1 Media Cloud layered architecture

5. Media Cloud Inter-Cloud Computing Architecture

Communication of two or more clouds with each other is known as Inter-cloud computing. When there are many clouds existing with multimedia content, clouds should be able to communicate with each other, creating inter-cloud computing scenario. This is also important to meet the increasing demands, as diverse type of requirements can be made by the user, which may not be offered by one single cloud. To meet the requirement, one cloud has to request another cloud or multiple clouds. Other than this, cloud should be able to discover services available elsewhere.

This inter-cloud computing will create a Cloud of Clouds (CoC), being able to communicate the data that is not stored by its datacenters directly. For this, cloud interoperability must be in a standardized way. Standardized way of service level agreement (SLA) must be made part of it. Inter-cloud Protocol, with the support of 1-to-1, 1-to-many, and many-to-many cloud to cloud communication and messaging must exist. Some of the basics are presented in [24]. To start with, first the entities are to be defined.

5.1. Inter-Cloud Entities

Four entities are involved in Inter-cloud communication, as given below.

5.1.1. Cloud Service Provider

Cloud Service Provider provides network connectivity, cloud services, and network management services to the Cloud Service Customer, Cloud Service Partner, and other Cloud Service Providers. Provider may be operating from within the data center, outside, or both. Cloud Service Provider has the roles of: cloud service administrator, cloud service manager, business manager, and security & risk manager. They are further discussed below.

Cloud service administrator has the responsibility of performing all operational processes and procedures of the cloud service provider, making it sure that services and associated infrastructure meets the operational targets.

Cloud service manger ensures that services are available to the customers for usage. It also ensures that service function correctly and adhere to the service level agreement. It also makes sure that provider’s business support system and operational support system work smoothly.

Business manager is responsible for business related matters of the services being offered. Creating and then keeping track of business plans, making service offering strategies, and maintaining relationship with the customers are also among the jobs business manager performs.

Security & risk manger makes it sure that the provider manages the risks appropriately, which are associated with deployment, delivery, and use of the services being offered. It includes ensuring the adherence of security policies to the service level agreement.

The sub-roles of cloud service provider include: inter-cloud provider, deployment manager, customer support & care representative.

Inter-cloud provider relies on more than one cloud service providers to provide services to the customers. Inter-cloud provider allows customers to access data residing in external cloud service providers by aggregating, federating, and intermediating services of multiple cloud service providers and adding a layer of technical functionality that provides consistent interface and addresses interoperability issues. Inter-cloud provider can be combined with business services or independent of this.

Deployment manager performs deployment of service into production. It defines operational environment for the services, initial steps, and requirements for the deployment and proper working of the services. It also gathers the metrics and ensures that services meet Service Level Agreements (SLAs).

Customer support & care representative is the main interface between customers and provider. Its purpose is to address customer’s queries and issues. Customer support & care representative monitors customer’s requests and performs the required initial problem analysis.

5.1.2. Cloud Service Customer

Cloud Service Customer in that entity which uses cloud services and has a business relationship with the Cloud Service Provider. The roles of Cloud Service Customer are: cloud service user, customer cloud service administrator, customer business manager, and customer cloud service integrator.

Cloud service user only uses cloud service(s), according to the needs. Customer cloud service administrator ensures that the usage of cloud services goes smoothly. It oversees the administrative tasks and operational processes, related to the use of services and communication between the customer and the provider.

Cloud business manager has a role of meeting business goals of customer, by using cloud services in a cost effective way. It takes into account the financial and legal aspects of the use of services, including accountability, approval, and ownership. It creates a business plan and then keeps track of it. It then selects service(s), according to the plan and then purchases it. It also requests audit reports from the Auditor, an independent third party.

Customer cloud service integrator integrates the cloud services with customers internal, non-cloud based services. For smooth operations and efficient working, Integrator has a very vital role to play. Services' interoperability and compatibility are the main concerns in this task.

5.1.3. Cloud Service Partner

Cloud service partner is kind of a third party which provides auxiliary roles, which are beyond the scope of cloud service provider and cloud service customer. Cloud service partner has the roles of Cloud Developer, Auditor, and Cloud Broker.

In a broad sense, Cloud Developer develops services for other entities, like Cloud Service Customer and Cloud Service Provider. Among the roles, Cloud Developer performs the tasks of designing, developing, testing, and maintaining the cloud service. Among the sub-roles, Cloud Developer performs as Service Integrator and Service Component Developer. As Service Integrator, Cloud Developer deals with composition of service from other services. While as a Service Component Developer, it deals with design, development, testing, and maintenance of individual components of service. Cloud Developer ensures meeting the standard of development, based on certain user or general users, according to the needs of the project. Since, Inter-cloud computing is going to be standardized, it should be mentioned in case of Cloud Service Developer, that the services being developed, must meet the standard. Since heterogeneous clients (devices) are going to use the services and on the other hand, various diverse types of development environments are available to the developer, so it must be tightly coupled with some specific standard of development.

Since service provider and service customer are separate entities, so the service quality, usage behavior, and conformance to service level agreement, all this has to be audited by the third party, having the role of Auditor. Cloud Auditor performs the audit of the provision and use of cloud services. Audit covers operations, performance, security, and examines whether a specific criteria of service level agreement and the audit is met or not. Auditor can be a software system or an organization.

Cloud Broker offers business and relationship services to Cloud Service Customers to evaluate and select Cloud Service Providers, according to their needs. Negotiating between provider and customer is among the main roles of Cloud Broker. With Inter-cloud or Cloud of Clouds communication, it will be very important for Cloud Broker to perform inter-cloud interoperability, instead of having another node for this purpose. The basic activities a Cloud Broker performs are that it acquires and assesses customers, assesses marketplace, performs negotiation and setting up service level agreements, getting information from cloud service providers on services and resources, receive and response to requests from cloud service customers, evaluate the service requests and select appropriate service(s) for customer and complete the requests. Assessment of marketplace can also be done prior to customer acquisition, when Cloud Broker provisions the customers to select a service or provider, from a given set of catalogue. In any case, Cloud Broker plays its role only during the contracting phase between customer and provider, not during the consumption of services. For negotiation between customer and provider, while assessing both of them, it is important to assess interoperability issues, because they directly impact the transcoding process and eventually affect the overall processing delay. SLA negotiation has to be done in prior, because the services are provided on the basis of agreed SLA’s. Explicit negotiation makes it easy for customer to decide whether to avail a particular service or not.

5.1.4. Cloud Service Carrier

Cloud carrier is an intermediary that provides connectivity and transport of cloud services, from cloud providers to cloud customers. With the role of Cloud network provider it provides network connectivity and related services. It may operate within the date center, outside of it, or both. It provides network connectivity, provides other network related services, and manages the services.

Figure 2 presents the entities and their roles in Inter-cloud computing/CoC.

```
+------------------+ +-----------------------------------------------+
|  Cloud Service   | |           Cloud Service Customer              |
|     Partner      | |                                               |
|                  | | |---------||---------||---------| |--------|  |
|  |-------------| | | |   CSU   ||  CCSA   ||   CBM   | |  CCSI  |  |
|  |Cloud Service| | | |---------||---------||---------| |--------|  |
|  |  Developer  | | +-----------------------------------------------+
|  |-------------| | +-----------------------------------------------+
|                  | |           Cloud Service Provider              |
|  |-------------| | |                                               |
|  |  Auditor    | | | |-------------| |--------------||----------|  |
|  |-------------| | | |Cloud Service| |Cloud Service || Business |  |
|                  | | |   Manager   | |    Service   ||  Manager |  |
|  |-------------| | | |-------------| |--------------||----------|  |
|  |  Broker     | | |                                               |
|  |-------------| | | |-------------| |--------------| |---------|  |
|                  | | | Development | |Support & Care| |Security |  |
+------------------+ | |   Manager   | |Representative| |&Risk Mgr|  |
+------------------+ | |-------------| |--------------| |---------|  |
|   Cloud Service  | |                                               |
|     Carrier      | | |-------------|                               |
|  |-------------| | | |Inter-Cloud  |                               |
|  |Cloud Network| | | |  Provider   |                               |
|  |  Provider   | | | |-------------|                               |
|  |-------------| | |                                               |
+------------------+ +-----------------------------------------------+
```

Figure 2 Entities and their roles in Inter-Cloud computing

5.2. Inter-Cloud Topology Elements

Inter-cloud computing involves three basic entities, which are explained in this part of the article.

5.2.1. Inter-Cloud Exchanges

Inter-cloud Exchanges (ICXs) are those entities which are capable of introducing attributes of cloud environment for inter-cloud computing. It is a complex and variable system of service providers and the users of services. It involves applications, platform, and services needed to be accessible through uniform interfaces. Brokering tools play an important part in actively balancing the demands and offerings, to guarantee the required SLA at higher levels of service. Cloud Service Providers exchange resources among each other effectively pooling together part of their infrastructure. ICXs perform aggregation of offer and demand of computing resources, creating an opportunity for brokering services. In ICXs, proxy mechanisms are required to handle active sessions, when migration is to be performed. This is done by Redirecting Proxy in Inter-Cloud Exchange. Redirecting Proxy performs public IP to private IP mapping. This public IP to private IP mapping is important to provide transparent addressing.

5.2.2. Inter-Cloud Root

Inter-cloud Root contains services like, Naming Authority, Directory Services, Trust Authority, etc. it is physically not a single entity, but a DNS-like global replicating and hierarchical system. It may also act as broker.

5.2.3. Inter-Cloud Gateway

It is a router that implements Inter-cloud protocols and allows Inter-cloud interoperability. It provides mechanism for supporting the entire profile of Inter-cloud protocols and standards. Once the initial negotiation is done, each cloud collaborates with each other directly. The purpose of Inter-Cloud Gateway is providing mechanism for supporting the entire profile of Inter-Cloud standards and protocols. On the other hand, the Inter-Cloud Root and Inter-Cloud Exchanges mediate and facilitate the initial Inter-Cloud negotiation process among Clouds.

5.3. Inter-Cloud Scenarios

Communication between cloud service customer and cloud service provider(s) can take place in two ways: (a). with broker and (b). without broker. The cloud broker is an intermediary that negotiates between the cloud service customer and one or more cloud providers by providing attractive value-added services to users on top of various cloud service providers. A cloud broker provides a single interface through which multiple clouds can be managed and share resources. Cloud broker operates outside of the clouds and controls and monitors those clouds. The main purpose of the broker is assisting the customer to find the best provider and the service, according to customer's needs, with respect to specified SLA and providing him with a uniform interface to manage and observe the deployed services.

A broker earns its profit by fulfilling requirements of both the parties. Cloud broker uses a variety of methods, such as a repository for data sharing and integration across data sharing services [26] to develop a commendable service environment and achieve the best possible deal and service level agreement between two parties (i.e., Cloud Service Provider and Cloud Service Customer). Broker typically makes a profit either by taking remuneration from the completed deal or by varying the broker’s spread, or some combination of both. The spread is the difference between the price at which a broker buys from seller (provider) and the price at which it sells to the buyer (customer). To handle commercial services, Broker has a cost management system.

Shown in figure 3, Cloud Broker includes application programming interfaces (APIs) and a standard abstract API, which is used to manage cloud resources from different cloud providers. Cloud Broker holds another abstract API for the negotiation of cloud service facilities with the customer.

This access of services can be direct, between cloud service customer and cloud service provider(s). In that case, the interoperability and transcoding related things are handled by the customer itself. Figure 3 depicts the architecture of broker and both the communication scenarios in detail.

```
                           Access without broker
      |--------------------------------------------------------------|
      |     +---------------------------------------------------+    |
      |     |                    B R O K E R                    |    |
      |     |  +------------------------------+ |               |    |
      |     |  |Service Registration Manager  | |               |    |
      |     |  +------------------------------+ |               |    |
      |     |  +------------------------------+ |               |    |
      |     |  |Discovery Mgr | Monitoring Mgr| |               |    |
      |     |  +------------------------------+ |            +-+|    |
      |     |  +------------------------------+ |            |C||    |
      |     |  |Deployment Manager            | |            |S|| +----+
      |     |  +------------------------------+ |            |P|| |CSP1|
      |     |  +------------------------------+ |            |1|| +----+
      |     |  |Match Maker                   | |      +-----|&||    |
      |     |  +------------------------------+ |+---+ | |L| |C||  +---+
      |     |  +------------------------------+ | ICR| |C|R|S|S||--|ICG|
      |     |  |Profit Calc | Refund Mgr      | |----|-|D|M|M|P||  +---+
      |     |  +------------------------------+ | ICX| | | | |2||  +---+
      |     |  +------------------------------+ |+---+ +-----|A||--|ICG|
      |     |B |Customer Manager              | |            |P||  +---+
      |     |r +------------------------------+ |            |I||    |
   +----+   |o +------------------------------+ |            +-+| +----+
   |CSC |   |k |Customer Device Manager       | |               | |CSP2|
   |    |   |e +------------------------------+ |               | +----+
   |c|w |<->|r'+------------------------------+ |               |    |
   |l|e |   |s |Identity Manager              | |               |    |
   |i|b |   |A +------------------------------+ |               |    |
   |e|s |   |P +------------------------------+ |               |    |
   |n|i |   |I |Customer Assessment Manager   | |               |    |
   |t|t |   |  +------------------------------+ |               |    |
   |A|e |   |  +------------------------------+ |               |    |
   |p|  |   |  |SLA Manager                   | |               |    |
   |p|  |   |  +------------------------------+ |               |    |
   +----+   |  +------------------------------+ |               |    |
            |  |Customer Resource Manager     | |               |    |
            |  +------------------------------+ |               |    |
            +---------------------------------------------------+    |
                              |                                      |
                  +-----------------------+                          |
                  |Storage    |Software   |                          |
                  |resources  |resources  |                          |
                  |-----------------------|--------------------------|
                  |Computing  |Network    |
                  |resources  |resources  |
                  +-----------------------+
```

Figure 3 The Cloud Broker architecture and representation of communication scenarios

Where, CSC is Cloud Service Customer, ICR is Inter-Cloud Root, ICX is Inter-Cloud Exchanges, CD is for Compatibility Determination, LRM is for Local Resource Manager, SM is for Services Manager, ICG is for Inter-Cloud Gateway, and CSP is for Cloud Service Provider.

5.4. Media Cloud Inter-Cloud Computing Protocols

The generic Inter-cloud computing architecture has a Cloud Service Customer, one or more Cloud Service Provider(s), and an Inter-cloud Provider.

For different types of communications, different Inter-cloud protocols are used [27] [28]. According to their type and extent of use, they are discussed here.

5.4.1. Basic communication

"Extensible Messaging and Presence Protocol (XMPP) [29][30] for basic communication, transport, and using Semantic Web [31] techniques such as Resource Description Framework (RDF) [32] to specify resources." [27]. XMPP is an eXtensible Markup Language (XML) based communications protocol, for message-oriented middleware. XMPP is for near real-time instant messaging (IM), presence information, and contact list maintenance. As it is 'extensible', it has also been used for VoIP signaling, gaming, videos, file transfer, publish-subscribe systems, and Internet of Things applications, such as the smart grid, and social networking services. Resource Description Format (RDF) is a metadata data model, which is used as a general method for conceptual description or modeling of information, implemented in web resources, using various syntax notations and data serialization formats.

5.4.2. Services framework

On top of the base XMPP, one of its extensions, XEP 0244, provides a services framework for M2M communications, named IO Data. XEP-0244 is designed for sending messages from one computer to another, providing a transport for remote service invocation. It also overcomes the problems with SOAP and REST.

5.4.3. Authentication and encryption

Transport Layer Security (TLS) is used for communication security over the Internet. Simple Authentication and Security Layer (SASL) is used for authentication purpose. Streams are first secured with TLS, before completing the authentication through SASL. SASL authenticates a stream by means of an XMPP-specific profile of the protocol. SASL adds authentication support in a generalized way to connection-based protocols. Security Assertion Markup Language (SAML) provides authentication services for cloud federation scenario, but it is still not fully supported in XMPP-specific profiles.

5.4.4. Identity and access management

SAML is particularly used for authentication and authorization between identity provider and service provider. A significance SAML has in this regard is web browser single sign-on (SSO) mechanism. SSO provides access control of multiple independent, but related software systems. Its counter action is single sign-off, which disallows access to multiple services with one action at once, hence saving time and effort. eXtensible Access Control Markup Language (XACML) is also used for access control. It evaluates access requests according to the rules already defined in policies. XACML is more useful in inter-cloud scenarios, where it provides common terminology and interoperability between access control implementations by multiple service providers or vendors. XACML is an Attribute Based Access Control (ABAC), in which rights are granted to the users on the basis of attributes (user attributes, resource attributes, etc.) associated with the user. For larger enterprises, XACML can also be implemented with Role Based Access Control (RBAC), which restricts systems access to the authorized users.

5.4.5. Exchange services directory

Resource Description Framework (RDF) is used for resource allocation, such as, storage and processing, in inter-cloud environment, while SPARQL Protocol and RDF Query Language (SPARQL) is a query/matching service for RDF. SPARQL can retrieve and manipulate data in RDF format. When a request is made, it invokes a SPARQL query over an XMPP connection to the Inter-cloud Root, to apply the constraints and preferences to the computing semantics catalog, where it is determined whether the service description on another cloud are according to the requirements of the first cloud.

5.4.6. Media related communication

H.264/MPEG4 (Motion Picture Experts Group) or also known as Advanced Video Coding (AVC), is one the most commonly used coding scheme for high quality video recording, compression, and distribution. Because of its Block Motion Compensation (BMC) feature, it is also the most widely used encoding scheme by Internet streaming video services, like, YouTube, Vimeo, iTunes, etc., and also in web-based softwares, like, Adobe Flash Player and Microsoft Silverlight. HDTV broadcasts over terrestrials and satellite also use H.264/MPEG4. With Block Motion Compensation, frames are divided into blocks of pixels and then each block is predicted from the previous blocks, making transmission more efficient. H.264 supports both lossy and loss-less compressions, so it is suited for Internet streaming services, in which, streaming quality can be dynamically decided based on the condition of the network or user’s link. Adobe Flash, a platform for rich Internet applications (RIA), also uses H.264. Flash is most widely used for embedding multimedia contents into webpages. Most of the interactive multimedia content, videos, and advertisements are made in Adobe Flash.

For the delivery of streamed media, Real Time Streaming Protocol (RTSP) is used. RTSP is responsible for establishing and maintaining sessions between two endpoints, while streaming of content is performed by Real-time Transport Protocol (RTP) along with Real Time Control Protocol (RTCP), which is responsible for providing statistics and control information to RTP flows.

6. Major Issues in Interoperability

As an emerging technology, media cloud is competing with the existing media technologies and systems and it has to deal with a lot of challenges, to evolve smoothly and effectively. Interoperability is the key challenge faced by media cloud. Due to various heterogeneities, as discussed below, interoperability becomes the key issue.

6.1. Heterogeneous media contents and media transcoding

Very diverse types of services are available in the media cloud arena, making transcoding and content presentation an area of concern. Services like, Video on Demand (VoD), IPTV, Voice over IP (VoIP), Time Shifted Television (TSTV), Pause Live Television (PLTV), Remote Storage Digital Video Recorder (RSDVR), Network Personal Video

Recorder (nPVR), and the increasing social media content require a lot of effort in this regard.

6.2. Heterogeneous media storage technologies

Storage is an important part. Multimedia content require a lot of space. Also, in case of multimedia contents, it becomes more difficult to search on the basis of actual contents the file contains. Efficiency in storage and searching is an important aspect media cloud should have. Different storage technologies available are Network Attached Storage (NAS), Direct Attached Storage (DAS), Fiber Channel (FC), Fiber Channel over IP (FCIP), Internet Fiber Channel Protocol (iFCP), Content Addressed Storage (CAS) or Fixed Content Storage (FCS), and Internet Small Computer Systems Interface (iSCSI). Communication between clouds creates inefficiency when different storage technologies are provided by the service providers.

6.3. Heterogeneous access networks

Every access network, like, broadband, WiFi, WiBro, GPRS, 2G, 3G, 4G, LTE, LTE Advanced, and other upcoming standards have different attributes, bandwidth, jitter tolerance, and performance.

6.4. Heterogeneous client devices

When contents are available on cloud, or media cloud, to be more specific, then any device that has access to the Internet can request for service. All types of client nodes have different capabilities and constraints. Other than the type of contents it can support, the size of display, buffer memory, power consumption, processing speed, and other such attributes have to be considered before fulfilling the request.

6.5. Heterogeneous applications

Requesting applications are also of different types and require different treatment. Other than the heterogeneity of device, the application type also matters. For example, web browser requesting service will have different requirements, while cloud client application will have different requirements for the same service.

6.6. Heterogeneous QoS requirements and QoS provisioning mechanisms

Depending upon the access network, condition of core network, the requesting device, user’s needs, and type of service, heterogeneous QoS requirements can be made. Dynamic QoS provisioning schemes needs to be implemented in this regard. We have worked on it in detail in our study presented in [7].

6.7. Data/media sanitization

When a client requests for storage space from the cloud, it does not mean that ‘any’ type of data can be now stored. Data has to be filtered. Some of the cloud storage service providers do not allow some specific type of data to be stored, like pornographic material. One of such services is Microsoft SkyDrive.

6.8. Security and trust model

Outsourced data poses new security risks in terms of correctness and privacy of the data in cloud. When we talk about media cloud, not only data service will be request by the user, but also, storage service would also be requested. Storing contents, which may have some sensitive or private information, poses risks to the customers. Some of the details are presented in our work in [5].

6.9. Heterogeneous Internet Protocols

IPv4 address space has exhausted. Migration towards IPv6 has formally been expedited. Both of these versions of IP are not directly interoperable. Since this migration is going to take some time, may be a decade [33], so it creates an overhead by them operate with each other. Tunneling is the viable solution in hand, but has its own overhead. We have worked extensively on this and presented our findings in [33].

Other than the existing heterogeneities and the ones that are to be emerged, media cloud needs to be able to deal with dramatically increasing video contents. Until 2015, in every second, 1 million minutes of video content will cross the network [2]. Therefore, it is very important to carefully design the architecture of media cloud, to be a successful media cloud platform and to be able to adapt to continuously increasing amount of media content, new applications, and services.

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8. References

8.1. Normative References

None

8.2. Informative References

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