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A Novel Approach Where Cloud Computing Meets Content Delivery Network

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Abstract: ***Content delivery networks play a crucial role in today's Internet. They serve a large portion of the multimedia on the Internet and solve problems of scalability and indirectly network congestion (at a price). Content Delivery Networks (CDN) aim at overcoming the inherent limitations of the Internet. The main concept at the basis of this technology is the delivery at edge points of the network, in proximity to the request areas, to improve the user's perceived performance while limiting the costs. Content distribution networks (CDNs) using cloud resources such as storage and compute have started to emerge. Unlike traditional CDNs hosted on private data centres, cloud-based CDNs take advantage of the geographical availability and the pay-as-you-go model of cloud platforms. The key problem is of reliability and durability for content specific applications maintaining cost effectiveness and time efficiency. The objective of this paper is to present a comprehensive study about the Cloud Computing and CDN Networks which in turn will help to improve any of Performance, Durability, Reliability or Security.***

Keywords: Cloud Computing, Content Delivery Networks, traditional CDNs, network congestion, cloud-based CDNs

1. Introduction

Hosting a website with its content on a single server leads to problems like unresponsive website when high number of requests are received. To reduce server processing, static contents are served by some other content server. CDN is used to serve contents geographically to reduce access-response time to clients. This does not completely solve issue of unavailability of contents when a particular CDN service is down. To provide backup service, improved speed, durability and reliability, multiple types of CDNs need to be used called as Hybrid CDN which uses Cloud extensively.

Reliability and Durability is the most important problem for Content Specific Applications. Cost Effectiveness and Time Efficiency cannot be maintained for multiple Content Delivery options. Current CDN, servers and backup options available are either too costly, difficult to migrate or without collaboration with each other.

2. Cloud Computing

Cloud computing is in its infant form and numerous definitions have been proposed by many scientists. Some of the definitions are, Buyya et al. defines, "A Cloud is a type of parallel and distributed system consisting of a collection of inter-connected and virtualized computers that are dynamically provisioned and presented as one or more unified computing resource(s) based on service-level agreements established through negotiation between the service provider and consumers" [1].

The National Institute of Standards and Technology (NIST) defines, "A model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. This cloud model promotes availability and is composed of five essential characteristics, three service models, and four deployment models" [2].

Figure 1: Cloud Computing [2]

In brief cloud is essentially a bunch of commodity computers networked together in same or different geographical locations, operating together to serve a number of customers with different need and workload on demand basis with the help of virtualization. Cloud services are provided to the cloud users as utility services like water, electricity, telephone using pay-as-you-use business model. These utility services are generally described as XaaS (X as a Service) where X can be Software or Platform or Infrastructure etc. Cloud users use these services provided by the cloud providers and build their applications in the internet and thus deliver them to their end users. So the cloud users don't have to worry about installing, maintaining hardware and software needed. And they also can afford these services as they have to pay as much they use. So the cloud users can reduce their expenditure and effort in the field of IT using cloud services instead of establishing IT infrastructure themselves [3].

A. Characteristics of Cloud

- **On Demand Self Service:** On demand self-service refers to services requested by the customers to manage their own computing resources. These services are provided over the internet by a cloud provider to a customer who

has requested for services and can manage their own computing resources.

- **Resource Pooling:** Cloud computing provides shared pool of resources that can be rapidly provisioned and can be released with minimal effort. Customers draw resources from remote data centers.
- **Broad Network Access:** To avail cloud computing services, internet works as a backbone of cloud computing. All services are available over the network and are also accessible through standard protocols using web enabled devices viz. computers, laptops, mobile phones etc.
- **Rapid Elasticity:** As cloud computing provides services over the internet. These services can be managed or can be requested from cloud providers as per customer's requirement. Rapid elasticity refers to services which can be smaller or larger as per user requirement.
- **Measured Service:** These are services which are billed according to customer demand for definite services. As customers can request for services as per their own requirement, services are billed according to customer's demand.

B. Deployment Models

Cloud systems can be deployed in four forms viz. private, public, community and hybrid cloud as per the access allowed to the users and are classified as follows:

Private Cloud

This deployment model is implemented solely for an organization and is exclusively used by their employees at organizational level and is managed and controlled by the organization or third party. The cloud infrastructure in this model is installed on premise or off premise. In this deployment model, management and maintenance are easier, security is very high and organization has more control over the infrastructure and accessibility.

Examples of Private Cloud:

- Eucalyptus
- Ubuntu Enterprise Cloud - UEC (powered by Eucalyptus)
- Amazon VPC (Virtual Private Cloud)
- VMware Cloud Infrastructure Suite
- Microsoft ECI data center.

Figure 2: Private Cloud

Public Cloud

This deployment model is implemented for general users. It is managed and controlled by an organization selling cloud services. The users can be charged for the time duration they use the services. Public clouds are more vulnerable to security threats than other cloud models because all the application and data remains publicly available to all users making it more prone to malicious attacks. The services on public cloud are provided by proper authentication.

Examples of Public Cloud:

- Google App Engine
- Microsoft Windows Azure
- IBM Smart Cloud
- Amazon EC2

Figure 3: Public Cloud

Community Cloud

This cloud model is implemented jointly by many organizations with shared concerns viz. security requirements, mission, and policy considerations. This cloud is managed by one or more involved organizations and can be managed by third party. The infrastructure may exist on premise to one of the involved organization or it may exist off premise to all organizations.

Examples of Community Cloud:

- Google Apps for Government
- Microsoft Government Community Cloud

Figure 4: Community Cloud

Hybrid Cloud

This deployment model is an amalgamation of two or more clouds (private, community, public or hybrid). The participating clouds are bound together by some standard protocols. It enables the involved organization to serve its needs in their own private cloud and if some critical needs (cloud bursting for load-balancing) occur they can avail public cloud services.

Examples of Hybrid Cloud:

- Windows Azure (capable of Hybrid Cloud)
- VMware vCloud (Hybrid Cloud Services)

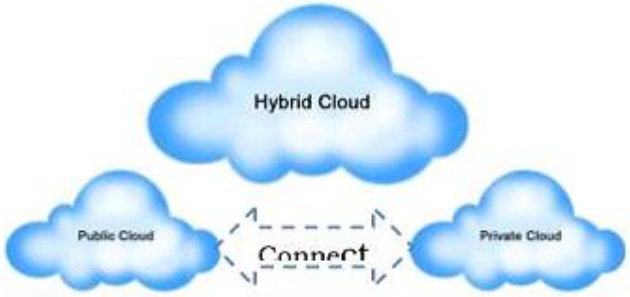

Figure 5: Hybrid Cloud

C. Advantages of Cloud Computing

Cloud computing offers many benefits and flexibility to its users. User can operate from anywhere at any time in a secure way. With the increasing number of web-enabled devices used now-a-days (e.g. tablets, smart phones etc.), access to one's information and data must be quick and easier. Some of these relevant benefits in respect to the usage of a cloud can be as follows:

- Reduces up-front investment, Total Cost of Ownership (TCO), Total Operational Cost (TOC) and minimizes business risks.
- Provides a dynamic infrastructure that provides reduced cost and improved services with less development and maintenance cost.
- Provides on-demand, flexible, scalable, improved and adaptable services on pay-as-you go model.
- Provides consistent availability and performance with automatically provisioned peak loads.
- Can recover rapidly and has improved restore capabilities for improved business resiliency.
- Provides unlimited processing, storage, networking etc. in an elastic way.
- Offers automatic software updates, Improved Document Format Compatibility and improved compatibility between different operating systems.
- Offers easy group collaboration i.e. flexibility to its users on global scale to work on the same project.
- Offers increased return on investment of existing assets, freeing capital to deploy strategically.
- Provides environment friendly computing as it only uses the server space required by the application which in turn reduces the carbon footprints.

D. Disadvantages of Cloud Computing

Every coin has two faces. That's not to say, of course, cloud computing is without disadvantages. Some of the disadvantages while using a cloud can be summarized as:

- Requires high speed network and connectivity constantly.
- Privacy and security is not good. The data and application on a public cloud might not be very secure.
- Disastrous situation are unavoidable and recovery is not possible always. If the cloud loses one's data, the user and the service provider both gets into serious problems.
- Users have external dependency for mission critical applications.
- Requires constantly monitoring and enforcement of service level agreements (SLAs).

3. Content Delivery Network

CDN(s) are globally distributed network of proxy servers. proxy servers are the servers that acts as an intermediary for requests of clients seeking resources from other servers. The goal of CDN is to serve the content to end-users with high availability and high performance. It is the system of distributed servers that deliver web pages & web content to end-user based on:

- The geographic locations of user
- The origin of web page
- Content delivery server [9]

Figure 6: Content Delivery Network [8]

CDN services are effective in speeding up the delivery of content of websites with high traffic & having global reach. Geographically, Closer the CDN Server, Faster is the delivery of content to the user. CDN provides protection from large surges of traffic.

CDN Servers nearest to website visitors (users) responds to the request. CDN copies the website pages which are dispersed at different geographical locations to its network of servers by caching (process of storing data in temporary storage area i.e. cache) the contents of the page. When a user request a web page that is part of CDN, CDN redirects the request from originating site's server to CDN server that is closest to user and deliver the cached content. CDN also communicates with originating server (content provider) to deliver the content which is not previously cashed. The process of bouncing through CDN is transparent to the user. User knows that CDN has been accessed as the delivered URL is different from that of requested URL

CDN serves content to users faster. Organizations use CDN to accelerate :

- Static content
- Dynamic content
- Mobile content
- E-commerce transactions
- Audio/video
- Games and so on…

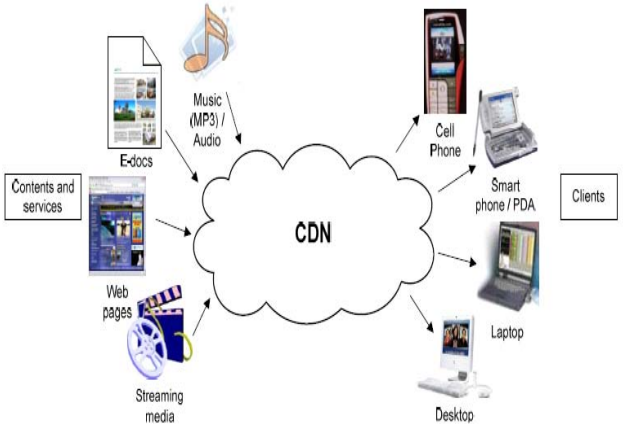

Figure 7: Content/ Services provided by a CDN [10]

The Originating Server (media companies, e-commerce vendors) pay CDN operators to deliver their content to end users. CDN pays to ISPs (Internet Service Providers), carriers, network operators for hosting its servers in their Data Centres. CDN also results in cost saving for content providers as CDN offloads the traffic served directly from content provider's origin infrastructure. CDN also prevents content provider from DoS (Denial of Service) attack. Most early CDNs use dedicated servers owned and operated by CDN. Recent trend is Hybrid Model which uses P2P(peer to peer) technology. Here content is served as an ASP (tool for making dynamic pages) on internet. Microsoft CDN(S) are Microsoft Azure, Amazon CloudFront, Google Cloud CDN.

4. Architecture

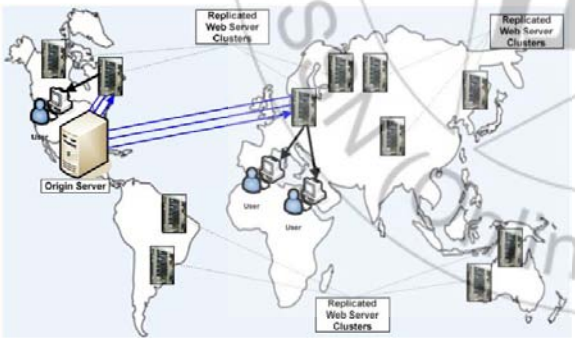

Figure 8: Abstract architecture of a Content Delivery Network (CDN) [9]

Content may exist on several servers, among these DNS resolves to an Optimized Server (based on location, availability, cost and other metrics) when user makes request to CDN, and then the particular server handles the request. CDN nodes are deployed in multiple locations resulting in reduced bandwidth costs, improved page load times, increased global availability of content. No. of nodes and servers in CDN varies depending on the architecture. Some CDN(s) have 1000s of nodes with 10,000s of servers on many remote PoP (points of presence) while others have small number of geographical PoPs (interface point between communicating entities).

Requests for content are directed to nodes in a typical optimized Algorithmic way based on 2 factors: Performance Optimization and Cost Optimization.

- Performance Optimization: Content is served to user by choosing the best location that have fewest hops, geographically close (network seconds away from requesting client), highest availability in terms of server performance.
- Cost Optimization: those locations are chosen which are least expensive.
- In an optimal scenario, both the above goals have to be accomplished. Edge Servers are preferred as they are close to end users at the edge of network which may have an advantage in both performance and cost.

Content Networking Techniques

CDN provides end-to-end transport network by distributing on it a variety of intelligent application employing techniques, which are designed to optimize content delivery. Techniques can be :

- Web Cashing
- Server Load Balancing
- Request Routing
- Content Services

Web Cashing

It stores popular content on servers that have the greatest demand for the content requested. It reduces bandwidth requirements, server loads and improves client response time.

Server Load Balancing

This uses web switch /content switch or multilayer switch, to share traffic among a number of servers or web caches. Switch is assigned single virtual IP address. Traffic arriving at switch is directed to one of the real web servers attached to the switch. Following are the advantages of using this approach:

- Load Balancing
- Increasing Total Capacity
- Improving Scalability
- Providing Increased Reliability
- Providing Server Health Checks

Request Routing

Request Routing directs client request to content source best able to serve the request. This involves directing client request to service node that is closest to the client and having the most capacity. Variety of algorithms are used to route the requests. Few of them are as follows:

- Global Server Load Balancing
- DNS based Request Routing
- Dynamic Metafile Generation
- HTML Rewriting
- Any Casting

Content Services

CDN uses variety of content delivery methods. Few of them are as follows:

- Manual Asset Copying
- Active web Cashes
- Global Network Load Balancers

5. Conclusion

Cloud-based CDNs have gained significant importance due to the wide-spread availability and adoption of cloud computing platforms. The integration of Cloud and CDN has mutual benefits allowing content to be efficiently and effectively distributed in the Internet using a pay-as-you-go model promoting the content-as-a-service model. We identified the key challenges and research dimensions that need to be addressed in the cloud-based CDN space. Finally, we provided a comprehensive analysis of the technical attributes of CDNs, server selection & request redirection; an insight to technology, services, strategies & practices currently followed in this field and a survey of existing CDNs & identifications of future directions that are expected to drive innovation in this domain!

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