A CONTRASTIVE STUDY OF CONTENT DISTRIBUTION NETWORKS (CDNs) MODELS

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ABSTRACT

Due to overwhelming web-based applications and services, the Internet has been experiencing network congestion and bottlenecks which have led to performance degradation of some websites and loss in revenue. Content Distribution Networks (CDNs) has evolved to address the aforementioned problems by storing and serving content from many distributed locations (surrogate servers) rather than from a few centralized origin points. In this paper, we discuss the different architectural models of CDNs and do some contrasts of features vis-à-vis efficiency of performance of the models which essentially are research response to the problems facing the Internet today. Finally, this study highlighted in general terms some benefits of CDNs.

Keywords: CDN, peering CDN, Brokering –based CDN, QoS-driven CDN

1.0 INTRODUCTION

In recent times, user's requests for web-based applications and various content – html files and other files, streaming media (audio and video) have grown so much to the extent of overwhelming websites infrastructure such as the front-end web server, network equipment or bandwidth. Efforts to provide an acceptable level of performance at the Internet edge include:

- Increasing the bandwidth of the accessing links or the number of servers at the content source.
- Design and Implementation of caching techniques for traditional content.

Content Distribution Network is a network infrastructure or solutions with higher-layer network intelligence used to support and improve the performance of content (static, dynamic and streaming media) delivery over the Internet.

The primitive model of CDN which is referred to as ***conventional*** CDN, (Rabinovich and Spatscheck, 2002), (Buyya, et al 2008) can be described as consisting of the following building components

- The **Origin Server,** this delegates its URI name space for content to be distributed and delivered by the CDN.
- The **Client,** this request for content from what it perceives to be the origin.
- The **Distribution System,** it is responsible for moving content to one or more surrogate servers. It also propagate content signals which specify information such as validation and expiration of content.
- The **Surrogate Servers,** these are responsible for delivery of the requested content to the clients and send accounting information.
- The **Request Routing System** (RRS), this is responsible for routing client's request to the most suitable surrogate in the CDN.

The major interrelated challenges in the implementation of a CDN are Replica placement which is concerned with replicating of both content and the surrogates server at the edge of the Internet and request routing which is concerned with the selection of the most suitable surrogate by the request routing system to respond to the client's request. The choice of surrogate server could be based on network proximity, bandwidth availability, surrogate load and availability of content.

The trend of developments of CDNs models can be described as follows:

2.0 TYPICAL CDN MODELS

These include the following CDNs

(a) Conventional CDNs: This is more of client-server model with limited scalable load balancing mechanisms for content delivery among its surrogate servers, and in which clients requests are served from the servers close to the clients. The distinguishing features of this model are that its infrastructure is shared among multiple content provider servers and effective content delivery is the responsibility of the CDN providers who have to place their servers within PoP or backbones nodes of ISPs. Also in this model, there is no cooperation with external CDNs, among servers and between clients. Service Level Agreement (SLA) always involves the CDN provider and content provider which may include guaranteed uptime, average delay, and other parameters. Associated with this model are the huge maintenance and infrastructure costs. This eventually means no additional and expensive infrastructure is needed by the content providers since both content distribution and delivery will be taken care of by CDN providers. Examples of conventional CDNs include Akamai, Limelight Networks, and Mirror Image (Buyya, et. al. 2008).

2.1 Peer-to-Peer (P2P)-based CDN

This is an essentially different type of CDN which does not use the client-server architecture, but in which all peers form overlay network and share resources such as storage, processing capacity and bandwidth.

In the P2P CDNs the content is delivered straight from and to the end user nodes that constitute the delivery network, in this case the clients can cooperate to improve the performance perceived by all especially when in the same network where as many users can assist each other to distribute contents, Oh-ishi, et al. (2003). A P2P-based CDN architecture is shown in Figure 1.

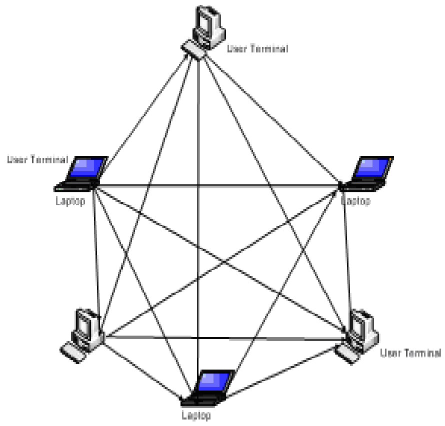

Figure 1: A P2P CDN architecture.

The P2P–based CDN can be classified roughly into two types of architecture, namely Hybrid and Pure P2P architectures. In hybrid P2P architectures the peers may first interact with the specialized/dedicated servers to gain knowledge of other peers and resources in order to directly share data or resources with them. Examples of this kind of server-centric architecture are Napster (2005), SETI@home (2005), and Groove (2005).

In pure P2P architecture there is no dedicated/specialized servers. Instead, all the peers are treated as equal in the P2P system. Gnutella [9] is an example of a pure P2P system. Also in this type of CDN the peers use distributed search mechanisms to search for other peers and resources inside the P2P system and share data or resources directly with other peers.

The P2P technology-based content delivery systems have some advantages which include load balancing, dynamic information repositories, fault tolerance, availability, content based addressing and improved searches (Parameswaran, et.al. 2001). The type of cooperation among the peers can be invoked dynamically when there is heavy traffic like the time of flash crowds. Since no real SLA exist among the cooperating peers(self-interested users) enforcing specific QoS constraints for the content providers become hard, especially when there is compensation for participating in the peering arrangements.

2.2 CDN Peering Models

(i) Content Distribution Internet-working (CDI)—CDN Peering

In the selection of the most suitable surrogate to serve a client's request, a number of metrics may be considered which include content availability and integrity, server availability, network proximity and surrogate server's load. The most commonly used of the metrics are the network proximity and surrogate server's load. Generally, the performance of a CDN can be improved by an increasing number of surrogate servers. However, increasing the number of surrogates amount to increasing the Point-of- Presence (PoP) on the internet by CDN which is capital intensive in terms of infrastructure cost, time and so on. Thus, in order to obtain a better performance at a minimal service cost and provide a guarantee for flash crowds or Distributed Denial of Service (DDoS) attacks the concept of CDN partnering or peering arrangement among CDNs evolved, this may also be referred to as Content Distribution Internetworking (CDI), or CDNs federation (Green, et. al 2002; Day, et al., 2003) and others.

Definition (Buyya et. al. 2008)

A peering arrangement among CDNs is formed by a set of autonomous CDNs {CDN_1, CDN_2...CDN_n}, which cooperate through a mechanism M that provides facilities and infrastructure for cooperation between multiple CDNs for sharing resources in order to ensure efficient service delivery. Each CDN_i is connected to the other peers through a 'conduit' C_i which assists in discovering useful resources that can be harnessed from other CDNs.

By interconnecting CDNs, separately administered CDNs with their own exclusive proprietary policy, hidden internal details and administrative protocols (Green, et. al., 2002) can cooperate to share resources in order to optimize content or service delivery and service cost. However, the challenges involved include the design of a virtualized multiple providers, redirection of users' request from the primary CDN to peers subject to certain constraints such that the main system goal is achieved.

Suppose CDN-1 is the primary CDN and it is peering with CDN-2, then the content or objects for which CDN-1 is authoritative can be delivered to the clients requesting the content by CDN-2 on behalf of CDN-1 within a stipulated service level of agreement (SLA) that can be easily described by certain metrics and measurable parameters. This means there is cooperation with external CDNs and also cooperation between CDNs. Thus, a CDN provider's failure to provide a quality of service to the clients may result in SLA (which may be short-term or long-term) violation which deserves some penalties. Generally, CDN-1 peering or partnering with CDN-2 does not necessarily establish a commutative relationship between the CDNs unless otherwise specified (Barbir et. al. 2002)

The basic architectural components in the design of a CDI consist of Request-Routing Interconnecting System (RRIS), which is responsible for request routing among the cooperating CDNs for efficient content or service delivery as well as routing request within the participating CDNs; the other component is Distribution Internetworking System (DIS) which is responsible for moving content from the primary CDN to the destination CDN(s) and for sending necessary information to the RRIS concerning content locations. The last component is the Accounting Internet-working System (AIS) which is responsible for exchange of information for accounting purposes in order to monitor resources consumption. The participating CDNs in a CDI communicate through the use of CDN Peering Gateways (CPGs), the DIS only recognizes the CPG locations and is not concerned with the distribution of content within a CDN (Buyya et. al. 2006). The conceptual representation of CDN peering consisting of three CDNs is shown below in Figure 2.

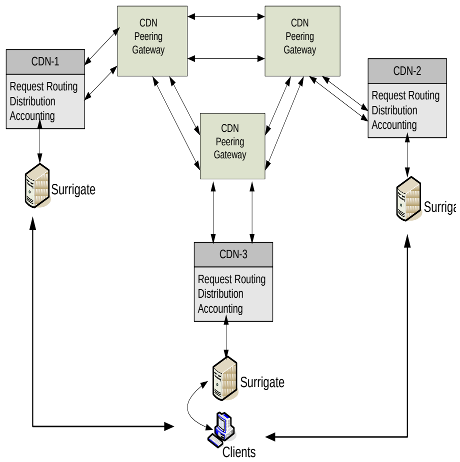

Figure 2. CDN Peering architecture (Brussee *et al*. 2001)

Content Distribution Internetworking (CDI) as a new technology is a new research area with active interest from both academics and industries (Buyya et. al., 2006; Turini, 2004).However, the technology is still being faced with challenging issues some of which include

(a) Request routing for replica-aware and non replica-aware situations so as to ensure balanced load distribution subject to certain QoS metrics in order to optimize resources management.

(b) Developing an effective request routing and replica placement policy and mechanism among the peering CDNs.

(c) Pricing of contents and services to ensure that the CDN providers maximize profit at a minimized service cost within a competitive market.

(d) Types of SLA to be considered among the cooperating CDNs and policies to use to support the SLAs. Some of these issues are considered in this work.

i) Brokering-based CDNs: This model was the first of the two models proposed by Buyya et. al. (2008) to assist the creation of CDNs peering. The delivery interaction flows can be described as follows:

a) The user specifies the URL of the content provider in the Web browser in order to make request for content. Client's request is directed to content provider's origin server.

b) The content provider makes use of a brokering system of its own in to select CDNs for delivering content to the clients. In order to deliver content to the clients, a particular content provider can select multiple CDNs based on QoS metrics/ performance, current load and geographical location. The selected CDNs may not be aware that they are working in parallel with each other because the management of responsibilities is being handled by the content provider.

c) There is an established policy-based agreement between the content provider and the selected CDNs.

d) Once peering has been established, the proprietary algorithm of the selected CDNs chooses optimal Web server to deliver the requested content.

Figure 3 shows the architecture of the brokering –based model of peering CDNs.

(ii) QoS-Driven Brokering-Based Peering CDNs: The brokering-based peering CDN above considers the performance of each of the potential participating CDN in the peering process, but does not specifically define the required QoS by the end users.

Thus, the QoS –driven brokering based peering CDNs is an improvement on the brokering –based model for creating peering CDNs. In this second model, the interaction flows are described as follows:

a) Clients send requests to the origin server of the content providers with some specific QoS requirements.

b) Content providers use a dynamic algorithm based on the clients defined QoS metrics to select CDNs.

c) Content provider establishes dynamic agreement with the CDNs selected to ensure clients QoS constraints are satisfied.

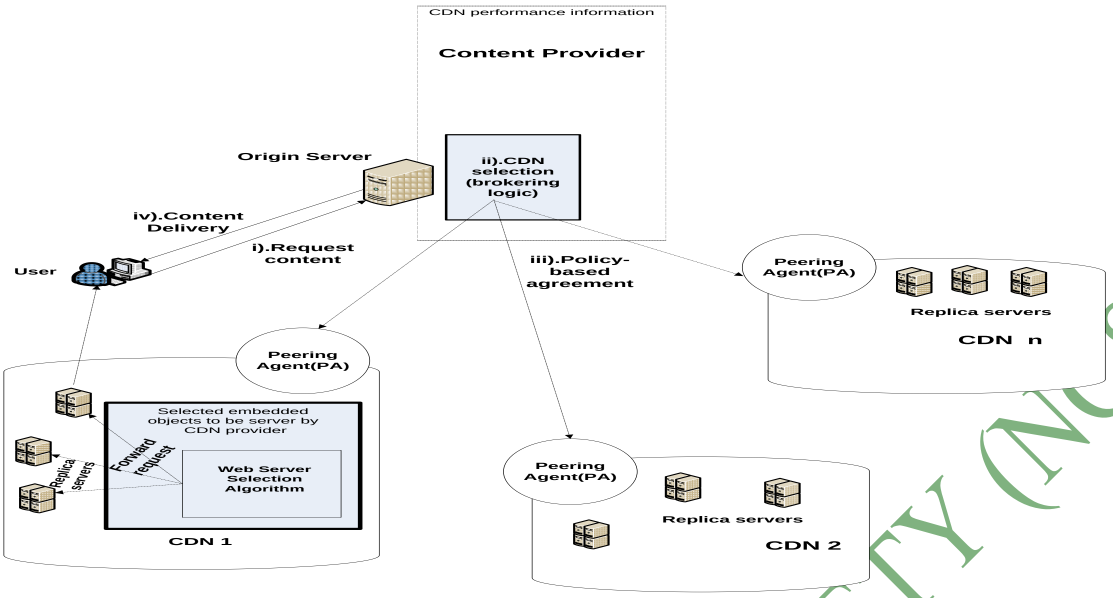

Figure 3. **Brokering-based architecture for peering CDNs (Buyya *et al.*, 2008)**

d) Once peering is established with the selected CDN(s), the requested content is delivered from the optimal Web server of the selected peers.Peering arrangements in this model are clients-based and they depend on the QoS requirements, scope, size and capability.

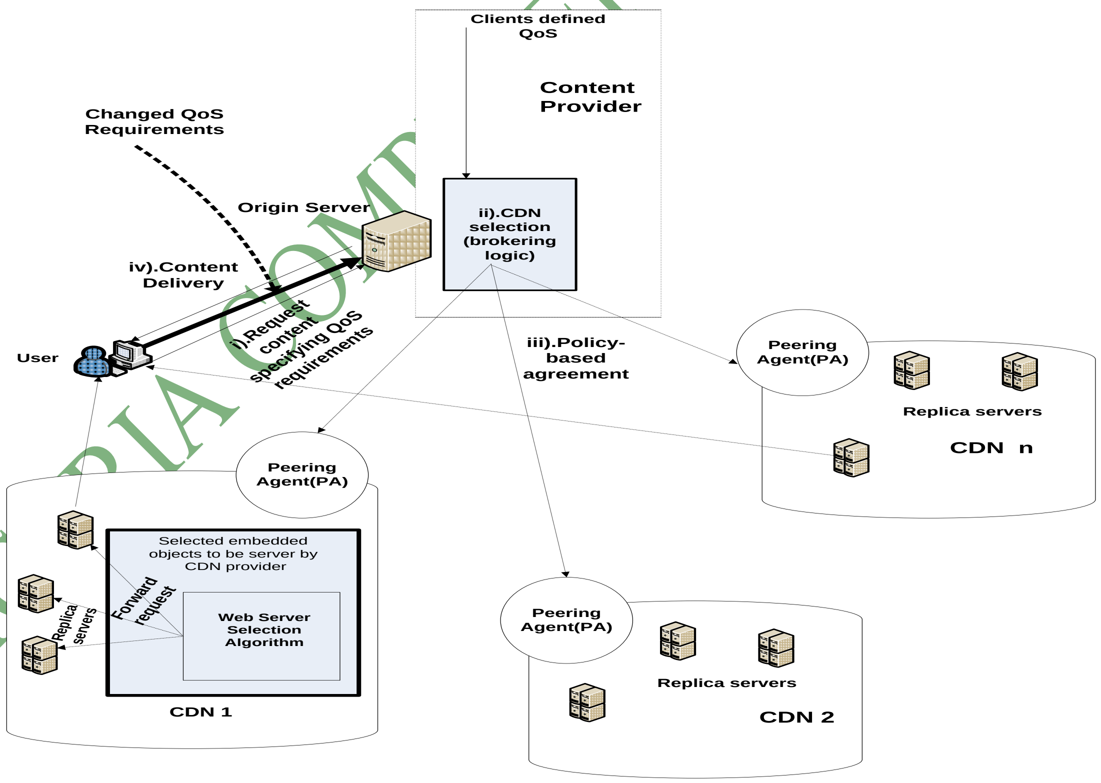

*Figure 4.*QoS-driven brokering based architecture model (Buyya et. al 2008)

3.0 CONCLUSION

Content Distribution Networks (CDNs) technology allow business organizations and service providers to optimize the management, distribution, and delivery of static Web content and streaming audio/video content. While CDN models and services can take many forms, the overall goal of these solutions is to increase revenue opportunities, improve end-user performance, and drive cost savings. Research interest is on the increase in both industries and academics with the sole goal of improving access latency and optimizing total service cost. This paper has looked into different models aimed at achieving the whole system goals.

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