CDN Perspectives for Quality Delivery of Contents

Meenakshi Gupta[1], Atul Garg[2]

[1](*Research Scholar, MMICT&BM (MCA), Maharishi Markandeshwar University, Mullana, Haryana, India)*

[2](*Associate Professor, MMICT&BM (MCA), Maharishi Markandeshwar University, Mullana, Haryana, India)*

ABSTRACT: *Web performance has become critical and essential with the massive growth of web-based applications and services. Popular web service providers find it difficult to cope up with the increasing demand from their users due to network congestion and overloading of web servers. A Content Delivery Network (CDN) facilitates improved performance by serving end-users, from a number of geographically distributed and closer servers and helps to improve the response time of web requests. This paper analyzes the existing approaches and strategies for implementation of CDN. It provides an insight into CDN from the perspectives of its role in quality delivery of web contents.*

Keywords: *Content Delivery Network, Content Provider, End-user, Quality of Service, Net neutrality*

I. INTRODUCTION

The expansion of Internet and subsequently the web is greatly influencing business and daily life of people. The amount of time they spend online has increased to a large extent. They use Internet to bring the world's information to their fingertips, to stay in touch with people and events, to have access to the global market and to carry out their routine and business activities. This trend is resulting in overloading of web servers. The overload may cause unusually high response time or unresponsiveness for a web request to the overloaded server [1]. This performance problem can be resolved by moving the web contents from centralized server to the edge of the Internet [2]. The techniques such as client-side and proxy server caching have been suggested to serve the contents from locations closer to end-users. The approaches have also been proposed to further enhance web performance by extending cache memory [3, 4]. However, the problem with Client-side caching is that its services are limited to single end-user and proxy server caching serves only the end-users linked to it. Therefore, Content Delivery Network (CDN) has emerged as a scalable solution to improve performance of web content delivery to end-users. It is a network of servers called surrogate servers, which stores and delivers contents on behalf of origin servers. These servers are deployed at various geographically distributed locations closer to end-users [5]. It provides Quality of Service (QoS) to different applications and delivers different types of content [6] such as static, dynamic, secured and streaming contents [7]. The primary benefits of CDN are reduced network cost, no requirement of IT capital expenditure, improved reliability and performance of content delivery, enhanced user-perceived content accessing experience and as a result has more potential to drive business growth [8].

In this paper, various design approaches of CDN are discussed in section 2. Section 3 presents the utility of CDN for content provider and end-user, describing the relationship between these three. Section 4 gives an outline of the different aspects that affect the performance and pricing of a CDN. Section 5 discusses CDN in context of QoS of web content delivery and net neutrality and finally section 6 finally concludes the paper.

II. CDN DESIGN APPROACHES

CDN is used to deal with the performance problem by serving requests from a location closer to end-users. The performance of a CDN depends upon various factors such as CDN organization, number of surrogate servers and their placement, selection and replication of contents, redirection of requests to suitable surrogate server. Some of these factors are concerned with infrastructure of CDN and others with strategies for proper functioning of CDN. The decision about CDN infrastructure is more important as it is long term and can not be changed easily. Generally two approaches are used to build CDNs [9]:

Overlay Approach: In this approach, application-specific servers or caches are placed at different points in the network that manage the delivery of specific contents to end-users. The routers and switches just provide

the basic connectivity and they have no role in content delivery. The CDN service providers such as Akamai, Digital Island and Limelight Networks are based on overlay approach. They have placed a large number of servers closer to end-users for replication of web contents. The requests from end-users for contents are redirected to the server closer to them to improve response time. The management in this approach is easier as it does not require controlling the underlying infrastructure.

Network Approach: In this approach, routers and switches actively participate in content delivery. The code is deployed on them for recognition of specific application types and decision making based on predefined policies. The requests for specific content type are redirected to local cache or specific server optimized for the purpose.

Most of the existing CDNs prefer overlay approach over network approach because of simplified management of underlying network infrastructure and new services integration. Some CDNs such as Akamai, Globix and Mirror Image are based on the combination of both overlay and network approaches [10].

Another decision about CDN design is the number of surrogate servers and locations to deploy them. The approaches used for the purpose can be broadly categorized as – centralized and distributed. In centralized approach, CDNs (like Level3 and Limelight) have large servers only at a few key locations. In distributed approach, CDNs (like Akamai) deploy their servers at thousand of locations across the world [11].

III. CDN UTILITY FOR CONTENT DELIVERY

Content provider, CDN service provider and end-user, each of them has its own role and interest in the implementation of a CDN. The relationship between these is shown in fig. 1 elucidating the utility of CDN for improving goodwill of content provider and user-perceived performance of web content delivery.

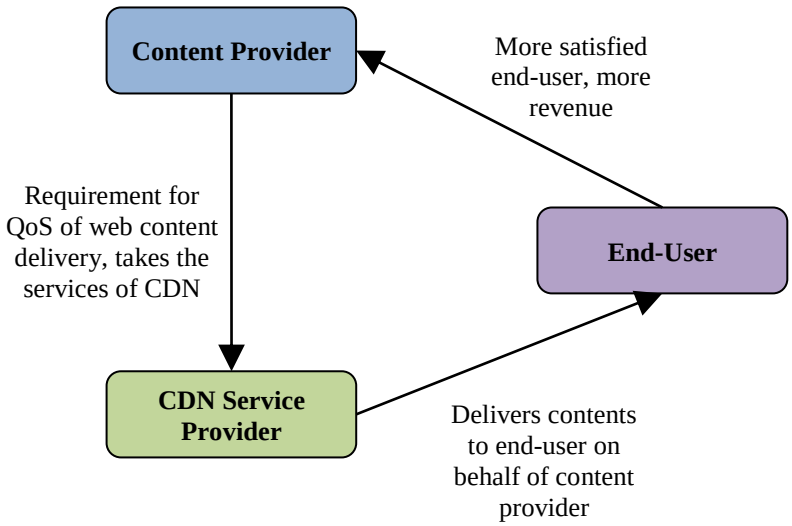

Fig. 1: Content Provider, CDN Service Provider and End-User Triad

Content Provider: A content provider is the owner of web contents that are originally hosted on origin server. It is concerned about response time of web requests from its customers and may find it difficult to meet their expectations for delivery of popular contents. It takes the services of CDN service provider to provide QoS of web content delivery to its customers. This results in enhanced reputation of the content provider among its customers and increase in revenues.

CDN Service Provider: It owns a set of geographically distributed surrogate servers to store and deliver the contents to end-users on behalf of the content provider. The contents from origin server are replicated on the surrogate servers closer to end-users. The request from end-user is redirected to a surrogate server based on

some criteria such as proximity, server load, network condition etc. This process is transparent to the end-user. The selected surrogate server delivers the content to end-user on behalf of the origin server. This helps to reduce load on the origin server and to improve response time for end-users.

End-user: It is a consumer of contents provided by content provider. It expects faster response time, otherwise may switch to some other website. CDN service provider helps content provider in meeting expectations of their customers related to web performance. This leads to more satisfied end-user and more revenue to content provider.

This illustrates that content provider requires better web experience for its customers and takes the services of CDN service provider. This results in more satisfied customers, more revenue and further more requirements for services of CDN service provider. Hence content provider, CDN service provider and end-user together make a valuable triad.

IV. PERFORMANCE AND PRICING

CDN speeds up content delivery and improves availability of contents especially during flash crowds or Denial of Service attacks [12]. Organizations with a large number of geographically distributed web customers tend to use the services of CDN service provider. In return, they have to pay them for using these services [13].

In traditional CDNs, all types of contents were delivered by the same mechanism. This approach is no longer workable as it may not be efficient from the point view of price and performance for all purposes. Different content providers need different solutions based on the content type and business model [14]. Further the effective implementation of a CDN is based on various decisions such as location of surrogate servers, selection of contents for outsourcing and procedure to use for outsourcing. Each of these decisions results in different cost and constraints for CDN service providers [13]. CDNs initially emerged for optimizing latency-oriented applications, are now increasingly serving throughput-oriented applications such as games, software, audio and video downloading and streaming [11]. Video will be accounting for 81% of total revenue in 2017 being the largest contributor to commercial CDNs [15]. For throughput-oriented applications, highly distributed CDNs achieve more throughput as compared to more centralized CDNs. On the other hand they incur more operating cost. Further, more centralized CDNs have a higher price variation with respect to throughput. The unit price increases faster with the throughput increase as compared to highly distributed CDNs [11].

The pricing of CDNs mainly depends on operating cost i.e. management cost, content replication cost and bandwidth cost [11]. The other factors that influence pricing are - Guaranteed availability/uptime, Digital rights management and other value-added services such as technical support, indexing, ad insertion etc. depending on the type of contents [16].

CDNs offer economies of scale in terms of infrastructure cost due to aggregation of network traffic across various websites. They face different considerations for pricing strategies of their services than intermediaries in traditional supply chain [5]. According to [17], Content providers may not find it attractive to buy the services from CDN in every market situations. Content providers opt for services of CDN, when both the content provider side and user side market is fragmented, i.e. is no particular content provider and no particular user location or Internet Service Provider (ISP) site dominates in terms of demand. Therefore, CDN service provider has to provide the solution that defeats the content provider's solution.

Generally, one of the following two pricing policies is used by CDNs. Both of these policies are based on volume of bits delivered over the CDN network [12, 16]:

Aggregate usage-based pricing*:* This pricing model is based on the aggregate usage of content provider for a specific period. Different prices are charged for different amount of network traffic delivered through CDN. Usually, volume discount is offered for considerably high traffic volume.

Percentile based-pricing*:* In this model, subscribers commit to a specific throughput level for a given percent of time period. Prices are charged on the basis of a percentile of the total usage. Industry standard is to use 95^{th} percentile as the measurement. The additional charges are incurred for excessive usage of bandwidth.

Several CDNs offer both billing options. The simultaneous use of both pricing strategies can give rise to adverse selection. The content providers with high bursty traffic will prefer usage-based pricing over the percentile-based pricing. While CDN service providers will not want them to choose in this manner [12]. According to [5], CDN service providers should provide volume discount to content providers as requirement of most of the subscribers of CDN services are high volume of traffic and low security.

Therefore, a market mechanism is needed to make sure that CDN service providers have incentives to deploy and manage CDN infrastructure and content providers can continue to derive value [12].

V. QoS, NET NEUTRALITY AND CDN

QoS is a measurement of performance in a communication network. It refers to the ability of network to handle the traffic such that it meets the service requirements of certain applications. QoS is concerned with non-functional requirements of web services composition such as response time, availability and cost [18]. Not only network QoS, but also end host support for QoS including server QoS and application adaptation is important to deliver end-to-end QoS [19]. Two major approaches used for QoS are:

Integrated Services Approach: This approach is based on resource reservation to provide QoS for real-time applications such as remote video, distributed simulation, multimedia conferencing, and virtual reality. It provides some control over end-to-end packet delays. ReSerVation Protocol (RSVP) is used to reserve resources for sending the data over Internet [20]. This approach provides QoS but lacks scalability [6].

Differentiated Services Approach: This approach implements scalable service differentiation in the Internet by implementing classification and conditioning functions at network boundary nodes. The packets receive per-hop behavior on nodes along the path, on the basis of aggregates of traffic. This approach is desired to accommodate different application requirements and user expectations [21]. This approach achieves scalability but lacks end-to-end QoS due to per-hop behavior mismatch across multiple domains [6].

The architectural design of Internet is based on best-effort principle and data packets in the network are routed autonomously. The packets are not differentiated on the basis of their content or source. However different types of web based applications and services have different requirements for network quality. For example, network quality requirement for video conferencing is different from email service. Therefore, current best-effort Internet cannot be considered as 'neutral' and leads to net neutrality debate. This also raises a question on existence and use of QoS mechanisms in the network. This debate on network neutrality may be the beginning of a larger debate on neutrality in the Internet ecosystem. In addition to content and services, the concept of neutrality may be applied to devices neutrality and other players in the network, specifically CDNs [22].

The US regulator reinforced the notion of net neutrality in 2015 and classified broadband Internet service as a public utility. A key principle of net neutrality is to provide access to contents and applications without differentiation of packets in the network. The purpose is to support new entrants without heavily investing in the infrastructure [23].

In the context of net neutrality, the relationship between content providers and CDNs is noticeable. The content providers pay to CDN service providers to provide QoS of content delivery to their customers. Not all content providers can afford to take the services of a CDN. This puts a question on fair competition among content providers for QoS of content delivery. Further, CDN market is dominated by big players such as Akamai. Large CDN service providers may be seen as gatekeepers in the Internet economy. However, the debate on net neutrality seems to have bypassed CDNs. The reason is that the market for CDNs is competitive and can not be seen as harmful for delivering quality in the public Internet. Moreover, from technical perspective, CDNs deliver data packets with best effort, although not over the same paths as other traffic [22].

VI. CONCLUSION

Content Delivery Network is gaining more attention to deal with the performance problem of overloading web servers. Its role in improving web experience of end-users is indispensable. Though the main goal of CDN is to provide QoS of web content delivery, yet it does not adversely affect net neutrality. Different architectures and strategies have been suggested for implementation of CDN. These have focused on efficient implementation of CDN while considering the cost and performance constraints. However, some of these approaches provide better performance while others are more cost effective. An appropriate balance between these two is required to make the relationship between content provider, CDN service provider and end-user stronger. This paper is a step towards understanding CDN to make better utilization of the resources and enhance user-perceived performance of web content delivery.

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