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A Hybrid Web Caching Design Model for Internet-Content Delivery

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Abstract - The need for online contents (or resources) to be shared and distributed in a large and sophisticated networks of users, geographical dispersed location of servers and their clients, time taken to fulfil clients requests pose major challenge. Therefore the choice of suitable architecture for Internet-based content delivery (ICD) technologies readily comes to mind. To achieve this, Akamai and Gnutella Web technologies are extensively reviewed to identify their strengths and weakness because of their popularity across the world for delivering contents. This new design for Internet-based content distribution is called AkaGnu because of the extra layer (Gnutella network) inserted into Akamai architecture, which provides greater Internet edge over each technology deployed independently. The paper presents a new ICD technology that performs better than Akamai system as a result of new features and behaviours introduced that reduce network traffic, more clients Internet connectivity, increase file sharing, improved speed of contents deliveries, and enhanced network security.

Keywords/Index Terms- ICD, Akamai, Gnutella, peer-to-peer, AkaGnu, network traffic, security, architecture, technology

1. Introduction

The Internet supports different kinds of services, such as content delivery (David, 1998). The Internet is world-wide network (or collection) of thousands of computers and computer networks. This idea was first conceived by an American Scientist Vinton Cerf as a collaborative enterprise with the United State Department of Defence Advanced Research Projects Agency (ARPA) in 1973 supervised by Robert Kahn (Ion *et al,* 2003).

Traditionally, systems for delivering content have been designed to support the client-server architecture; a case is the World Wide Web (WWW). But, recent development on the Internet content delivery field has changed due to greater awareness of a new application such as peer-to-peer (P2P) file allocation/sharing. Systems with

P2P are fully distributed, utility for proprietary naming, encoding mechanism and protocols (Ion *et al, 2003;* Antony and Peter, 2001; Sylvia *et al,* 2001; Ben *et al,* 2004).

Internets are made up of local networks connection with the help of special computers in each local network (referred to as gateways) (Vinton, 1973). Gateways interconnections are established through various communication channels such as telephone lines, optical fibres, radio and satellite links for the purpose of information exchange and delivery to remote machine using computerized address of that specific machine. The Internet protocol (IP) is the underlying software that is used to control the Internet that is, it determines how information are routed using the gateway machines from the computer sending information to the computer receiving, while Transmission Control Protocol (TCP) ensures the information sent has reached the destination computer and, otherwise, it causes the retransmission of the information (Vinton, 1973).

Content delivery (sometimes referred to as content sharing or caching) is a service of reproducing website page(s) to servers that are physically isolated. Also, Internet content is composed of bits and data packets that are shared or distributed in the Internet. It includes a piece of news or a hypertext make-up language (HTML) page, video or sound files (Zhang, 2010). This is mostly deployed by high-traffic web site manager owners and Internet Service Providers (ISPs) to improve content delivery especially when request for a page is made, it identifies dynamically and serves the page content available on the server closest to the requester (or user) (Vinton, 1973; Zhang, 2010).

The techniques for efficient content delivery include: deployment of cache servers with considerable size access points to Internet located throughout the world; and the use of specially designated routing code that sends request for a web page to the nearby server. Others include redirection of HTTP, Internet Protocol (IP) and domain name system (DNS) forwarding (Zhang, 2010).

The use of content delivery has been effective for specialized events with high-traffic such as Live Web broadcast that involves content to be continually shared or dispensed from the originating server through satellite links (or connectivity) to the receiver server (Vinton, 1973; Zhang, 2010). To that end, there has been an increased attention for enhancing mechanisms used to transport Internet content from servers-to-clients. One of the basic mechanisms currently deployed to improve the distribution of static Internet content is called proxy caching. Multimedia content streaming involves proxy caching and multicast delivery. These operations to a larger extent reduce network load (Zhang, 2010).

Several models exist for a provider seeking to distribute content. The client server is the most deployed in basic Internet. Others are Cloud and Content Delivery Network (CDN) that offer comprehensive packages of services to content providers apart from content distribution. More so, P2P model and other several architectures of information networking are instances of

Internet-based content delivery (Zhang, 2010).

Content delivery is now made easy with the use of the Internet because it is fast, convenient and reliable. The technologies of content delivery using the Internet, its benefits and challenges as well as ways of improving content delivery were discussed in this research work. A portion of Afribank's Content delivery network was used to study the behaviour of workloads and traffic.

2. Related Works

Previous Research works on Internet and Content delivery focus on Web caching performance. There are three main features that make workload characteristics interconnected to Web caching, which is the most widely researched aspect of workloads. First, algorithms design for both Web proxy caching and cooperative Web. Proxy caching has been an enormously vigorous area of research in recent years (Chankhuntod *et al* , 1996*;* Zhang *et al*, 1997; Touch, 1998; Fan *et al,* 1998; Karger *et al*, 1999; Tewari *et al,* 1999). Second reason that makes it a topic of interest may be because of usefulness of caching as a technique for performance improvement in other parts of computer systems such as file system and architecture of central processing unit (CPU). Third, Content Distribution systems and Web caching are two most commonly deployed applications presently to improve performance of the Web (Tewari *et al,* 1999).

Operationally for proxy caching to be successful, Alastair (2002) proposes that the workload must have the following attributes: the caches allow storage for documents with repeated access requests, those documents that do not alter in between the repeated accesses and many of the requested document have been previously requested at some point in the past (Alastair, 2002). However, we have found that three workload attributes are not available for any kind of CDNs (such as Akamai and Gnutella), and most essential to the overall success of Web caching that is the cachability of Web documents, the rate of changes to Web document, and the amount of reuse of Web document (Alastair, 2002).

The basic Internet largely supports one computing model, the client-server model (Lewandowski, 1998). In the client-server model a server (or a pool of servers) stores information and services and waits inactively for the clients to make request for them. The client-server model needs components of network to function effectively. These network components are placed between the clients and the server for structured communication (that is, structure of the basic Internet interconnectivity). The servers and clients connect to the Internet access providers, who in turn connect to the Internet backbone provider for connection to the whole network. These together with the software employed in the network make up the infrastructure of basic Internet, which can be exploited for Content delivery (Alastair, 2002).

Another widely used Internet Content delivery model is the cloud computing. Cloud computing is a service for management of hardware and software in a better and easier manner. Clouds are made up of pools of virtualized resources such as hardware, software and services that can be accessed with ease (Vaquero *et al,* 2009). The motive behind the cloud is to relocate the network infrastructure, which reduces the cost of resources management for better scalability and flexibility of network. The three major services rendered by cloud are: Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS) (Zhang, 2010).

Content Delivery Network (CDN) provides generally all-inclusive Services, when it is compared to cloud computing. The CDN was intended as overlays, which are virtual topologies that are positioned on top of the basic Internet. It enhances the value to the Internet for instance, guaranteeing the retrieval of data as well as balancing of load (Doval and O'Mahony, 2003). Some of the values introduced by a CDN are reliable network, minimized latencies for consumers, improved throughput and balancing of origin server load (Vakali and Pallis, 2003). This means that, the end-to-end connection is abolished, but, two distinct end-to-end connections exist though, one between the client and the CDN, and the other between the CDN and the Content server. The services offered by CDNs are full storage and distribution as well as management of software and hardware for simplifying Content delivery (Zhang, 2010).

Schollmeier (2002) provides another kind of basic Internet known as peer-to-peer network, which consist of dispersed resources linked by network. The major advancement over the client-server model is that clients connected to the network can perform the role of servers, which is not the case in the client-server because, the role of clients and servers are discrete.

Few things can be said to match with the growth of Internet over the years, especially its phenomenal growth perhaps in the past ten years. The main problem faced by Internet has been infrastructure for distributing progressively more intricate data to a larger and increasing users' population. The idea to further scale down is the motivation for the design of thousands of clusters of node, global-scale CDNs and lately, independent P2P structures. These techniques of Content Delivery have swiftly altered the composition of Internet Content Delivery (ICD) and traffic; hence appreciating the present-day Internet requires for a thorough appreciation of these latest mechanisms as well as the kind of data they serve (Sefan *et al*, 2002).

3. Content Delivery Technologies

There are three main ways of categorizing Internet content/workload distribution namely; the World Wide Web, a content delivery network (Akamai), and peer-to-peer systems (Gnutella).

3.1 The World Wide Web

Tim Berners-Lee in 1989 put forward that, World Wide Web is a content delivery network with client-server architecture, in which a centralized server contains all the content and accessed through the client's browser (Sefan *et al*, 2002). All the clients in the network are identified using Internet Protocol (IP) addresses. All the contents are saved on Web Server using unique Web addresses as content identifiers. Web workloads include objects with a variety of different types such as text, images, archives, executable code, audio, and video data. Though, the makeup of content types are largely objects (such as text and images), while the remaining content types are relatively small portion of resources. There are two implications of the predominance of text and image data in Web workloads. Firstly, text is amenable to compression. Secondly, text and image data are highly cacheable types of content. A large fraction of Web traffic is therefore likely to be cacheable. The Hypertext Markup Language (HTML) is the standard representation for hypertext documents in American Standard Code for Information Interchange (ASCII) format. HTML allows publishers of content to format their content, reference images or other objects, and embed hypertext links to other content (Sefan *et al*, 2002).

Generally, most of these transmitted objects are small in size, while some other objects are very large. Many workloads exhibit a common variance because, most of the objects are small in size accounting for a relatively small portion of the bandwidth consumed. But, a small quantity of usually very large objects is the justification for a considerable size of the bandwidth consumption. Recently, with emergence of new applications which have a sudden and profound influence on the distribution of content types. There is increasing availability of multimedia content in Web workloads. A higher portion of Web workloads is dedicated to transporting multimedia data. By implication, the size of Web objects could change over time. A different trend that can affect Web workloads is the penetration of high-speed Internet connections (or broadband). Users with high-bandwidth Internet connections are likely to download larger resources (Sefan *et al*, 2002).

The Web, Akamai, and Gnutella are being currently deployed systems architecture for content distribution on the Internet. The main goal of our system when compared to these systems is very similar, that is to deliver content on the Internet. Of course, these systems have well-elicited notions of clients, servers, and objects. These systems follow the same basic principle: clients fetch objects from servers, but with varying architectures. Figure 1 shows the conventional architecture of a content delivery network in which a single server is responsible for delivering content to many users across the Internet. Each arrow indicates a client’s query for an object located on the server (Sefan *et al*, 2002; Geoff, 1999; John *et al*, 2002; Jem, 2003).

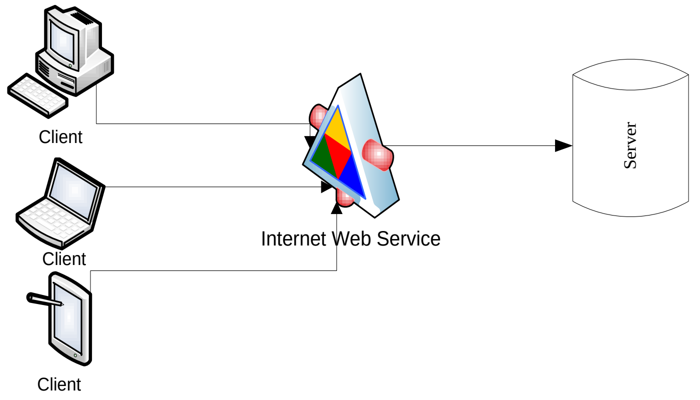

Figure 1: **The conventional layout of client-server architecture of Internet content delivery.** *Source*- (Zhang, 2010)

AkaGnu network consists of a naming infrastructure, a document representation language and an RPC protocol. It uses Uniform Resource Locators (URLs) for naming content. For instance, if a URL is http://postgraduate.futminna.edu/download.htm. This can be broken down in to three parts as shown in Table 1.

Table 1: A URL Parts Resolution

URLs PARTS	MEANING
http	The protocol for communicating with server
Postgraduate.futminna.edu	Server's name
Download.htm	The name of a file on that server

3.2 Content Delivery Network

Content delivery network is made up of a group of non-originating servers that make effort to download work from origin servers by distributing content in place of origin server (Sefan et al, 2002). The servers belonging to a CDN are typically placed at diverse locations throughout the network, whereas some or all of the origin server's content are cached (or replicated) among the CDN servers. For each request, the CDN makes effort to trace a CDN server nearest by proxy to the client to fulfil (or carryout) the request, where the impression of close could be described as latency, geographical or topological.

Comparing CDN to systems based on the client-server or the P2P architecture, a limited number of content delivery networks exist on the Internet, high traffic due to direct inter-communication between its clients and the server. These networks are suitable to be run and managed by private companies. Akamai infrastructure is a typical example of CDN (Sefan et al, 2002; Geoff, 1999; John et al, 2002; Jem, 2003).

3.2.1 Akamai Technology

Akamai technology is a business-related content delivery network consisting of hundreds of thousands of content distribution servers dispersed throughout the world whose roles are to distribute content to nearby clients. Web servers sign up with Akamai to replicate and serve a portion of their local content from the Akamai's servers. The benefits from using Akamai are two-fold. First, Akamai servers perform as proxy caches. They help to minimize client latencies, network traffic and server load. Second, proxy caching service rendered by Akamai is accessible to all clients on Internet world-wide, as opposed to proxy caches that only serve a limited client population (Sefan et al, 2002).

Akamai exploits DNS-based name redirection to forward (or route) requests of client to Akamai servers. Upon receipt of a DNS request, an Akamai nameserver provides the corresponding address of an Akamai content server located closest to the client issuing the request. Because of the transparent nature of DNS name resolution, Akamai's client redirection mechanism does not require any modifications to client software, server protocols, or Web applications. Akamai's architecture: Web client's requests are routed to nearby Akamai servers instead of the origin Web server as illustrated in Figure 2. Web is similar to Akamai, because it delivers HTML objects, it uses URLs to name objects, and it uses HTTP to transport content (Stefan *et al*, 2002).

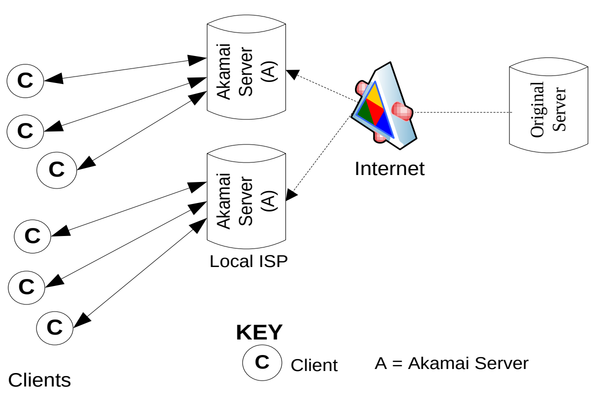

Figure 2: **Akamai network architecture.** *Source*-(Alastair, 2002)

3.2.2 Gnutella Peer-to-Peer Network Technology

Gnutella is a dispersed peer-to-peer system, made up of hosts linked to one another over TCP/IP and running on common software that supports the Gnutella protocols. This connection of individual hosts (or nodes) produce a network of computers exchanging Gnutella traffic such as queries, replies to queries as well as other control messages used to detect nodes. Basically, this network permits the participating hosts to easily share arbitrary resources. For instance, some resources may be associated with other resources, meta-information (or other sorts of pointers). At present, its exploitations are based exclusively on data files; that is a specific host can submit its local files for others to download, and can download files put forward by others on their computers for the purpose of sharing. The control of each node is the responsibility of user running the application software, who partakes in the network by: (a) specifying explicitly a list of local files to share across the network (b) searching for files existing somewhere on the network and (c) downloading files from other nodes (Matei, 2001; Sefan *et al*, 2002; Stephen, 2004).

Gnutella is a network of broadcast-type that pings and queries are duplicated and relayed to several other nodes. To minimize consumption of network resource, nodes cache pongs and supply them as responses to pings when they can. Pongs and Query Hits are routed by each node back along the path needed to reach the destination. Another important attribute is Ultra peer scheme that increases efficiency and scalability of network by classifying nodes into normal clients and super nodes. A super node is a reliably connected host with sufficient network bandwidth that performs as a proxy for a well-built numbers of connecting clients. The super node eliminates the trouble of extensive network message routing from client that may be a low bandwidth modem user. In this case, the modem user (leaf node) makes use of the well-connected super node as network's access point.

Gnutella network imitate the Internet itself; nodes of low bandwidth are connected to well-built super nodes (routers) that help pass on majority of the data over high bandwidth backbones (Matei, 2001; Sefan *et al*, 2002; Stephen, 2004).

Gnutella architecture is shown in figure 3.

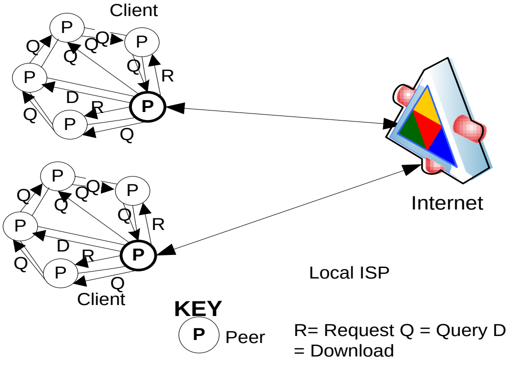

Figure 3: **Gnutella peer-to-peer network architecture.** *Source*- (Zhang, 2010)

4. Methodology

The new model is developed based on limitations observed from Akamai's infrastructures such as latencies, traffic congestions and file sharing. Using Akamai's infrastructure, each client will have to query and get response directly from Akamai server (or local ISP) which leads to lower network performance. AkaGnu network design is composed of Akamai's infrastructure and Gnutella peer-to-peer infrastructure to enhance the network performance for content delivery as shown in Figure 4.

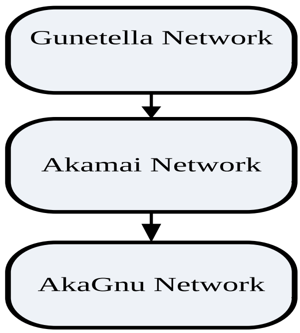

Figure 4: Design steps of AkaGnu Network

All peers exhibit client-server characteristics, to find a file; a controlled flood of a query packet is initiated by a peer across the overlay network to all of its neighbours (or peers). A peer checks upon taking delivery of a query packet, if the query matches any locally stored files. If confirmed, the peer sends back a query response packet towards query originator peer. In a case where a file match is not found, the peer sends continuously a huge number of the query across the overlay. HTTP protocol is used to download content, once content is found.

AkaGnu architecture is made up of two system architectures, that is, peer-to-peer client (Gnutella) to the right hand and the content delivery network (Akamai) as shown in Figure 5.

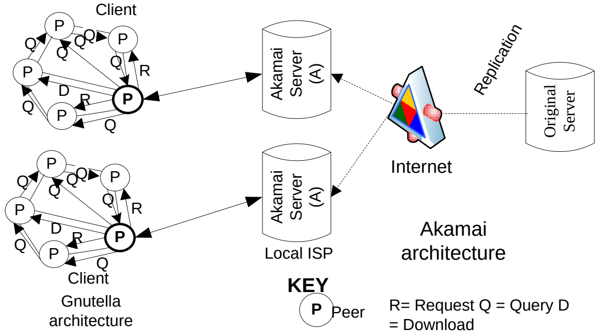

Figure 5: AkaGnu technology architecture.

The original server replicates (or copies) its contents through the Internet platform to Akamai servers (meta-data (a set of data about an entity)/information) located in the Local ISP. On the other hand, the clients are connected to decentralized peer-to-peer network with a host running Gnutella software providing protocols. All the peer-to-peer clients have access privileges to query (Q) and respond (R) to queries and upload/download (D) data files. These processes are controlled by a super node (or client) connected to both clients peer-to-peer and the Akamai servers in the Local ISP. The new system is different from other systems because of improved security, reduced network traffic on the original server and Akamai servers, file sharing among all peer-to-peer clients without internet connections, minimized rate of clients accessing network resources and fast and increased availability of contents.

5. Results and Discussions

5.1 Monitoring Traffic Generation of AkaGnu Vs Akamai and Gnutella Networks

AkaGnu uses Gnutella protocol versions 0.4 (from the legacy peers), the ultra-peer and leaf peers are implemented. The function of the protocol is to provide bootstrapping and simulator runs application as a component of the AkaGnu technology. The legacy server afribank.local provides the Akamai server the contents of the original server for the bank's branches transactions processing and the resources. The two branches of the bank were connected each to a local Akamai network (a sub-server) of the original server located at the head office. Each branch has a leaf node and super node system typical of Gnutella architecture. Every branch uses IP addresses to initiate communication to every other node and super node such as messages passing, query and respond, download and upload, file sharing and resource sharing without having to connect directly to the main Akamai servers. The peer-to-peer nodes communicate with each other directly and Akamai server through the super nodes, as result the traffic congestion experienced by branch staff connected to these branches local network is reduced, support for larger volume of transactions and need for continuous local and Internet connections.

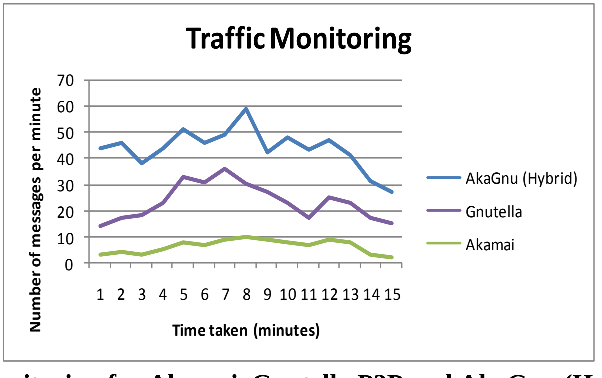

Figure 6: **Traffic monitoring for Akamai, Gnutella P2P and AkaGnu (Hybrid) Networks.**

Figure 6 shows the mean number of messages and time taken for 20 trials for Akamai, Gnutella P2P and Hybrid CDNs monitored over 5 months period, December, 2012 to April, 2013, at Afribank's ICD networks. The mean numbers of messages are plotted against time taken to deliver the messages over the CDNs separately for Akamai, Gnutella P2P and Hybrid networks, to enable us differentiate the effectiveness of the each of the CDNs.

It can be observed that there is a clear difference in the number of messages delivered at a particular time for each of the ICD techniques, with Akamai recording the smallest number of messages and requiring longer time for successful delivery as illustrated in Figure 6. Gnutella P2P is better when compared to Akamai in terms of time required to deliver messages over its network, because peer-to-peer infrastructure provides faster Internet and content delivery. The Hybrid (AkaGnu) is the best ICD technology, because it allows more messages delivery within a relatively short time as shown in Figure 6. The results of hybrid technology for ICD far outweigh the individual technique of Akamai and Gnutella P2P networks, because peer-to-peer architecture, relationships existing among clients, speed of Internet and local ISPs connectivity, reduced traffic congestions and availability of contents on the network.

5.2 Analysis of Node Connectivity and Network Topology

One major attribute of the AkaGnu network over 4 month period compared to Gnutella network (as illustrated in Figure 5) is the scaling down of the network magnitude. The average number of connections for every node is higher and relatively stable for AkaGnu network when compared to Gnutella network connectivity as shown in Figure 7. This behaviour makes it feasible to determine the number of connection a larger network will generate and finding limits of scalability as based on bandwidth available. When evaluating connectivity and reliability patterns globally in AkaGnu network, it is essential to point out the self-organized behaviour of the network. Users decide on only the maximum number of connections a node should maintain, while nodes based on local information only decide to whom to connect or when to drop/add a connection.

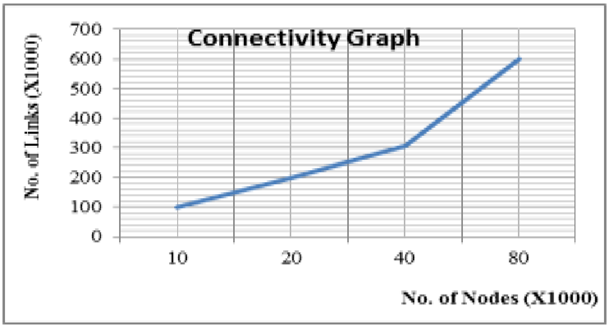

Figure 7: AkaGnu (Hybrid) Node connectivity relationship.

5.3 Benefits of a Hybrid CDN Technology

Some of the benefits of the hybrid CDN include:

a) It uses http as its file-transfer protocol; it implements a micro and standard Web browsers which facilitate easy access to other peers and their files.
b) It provides end-users improved performance such as in data availability, reduction of server load and load balancing.
c) It has further scaled down the workloads associated with the Akamai CDN by decreasing the amount of time taken for requests (or queries) to get responses accomplished by Akamai servers.
d) It allows sharing of files among peers of clients directly, minimizing storages required for floods of queries, contents and responses.

6. Conclusion

AkaGnu is a web caching Internet-based technique for content delivery. AkaGnu technology has further scaled down the workloads associated with the Akamai content delivery network by reducing the amount of time taken for requests (or queries) to get responses accomplished by Akamai servers, allow sharing of files among peers of clients directly, minimizing storages required for floods queries, contents and responses. There is a lower hit rate on the Akamai servers and originating server. Traffic on the Internet and local ISP is significantly minimized as a consequence of shorter path travelled by queries/responses in the networks. The security of the Hybrid design model is better, because it combines best security features of Gnutella and Akamai networks. This design model guarantees better performance, availability of contents and services any time desired without delays. The limitation of AkaGnu network is the cost incurred in building each Gnutella P2P that is attached to the Akamai network in the Hybrid architecture. The security of files and individual system on the Hybrid CDNs is another future research area.

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