ISSN (Online): 1694-0814
www.IJCSI.org

QoS-based Objects Replica Placement among Peering Content Distribution Networks (CDNs) in a Virtual Organization Model

Adenike.O.Osofisan[1] and Sunday A. Idowu[2]

[1]Department of Computer Science
University of Ibadan, Ibadan, Oyo State Nigeria

[2]Department of Computer Science and Mathematics
Babcock University, Ilishan-Remo, Ogun State, Nigeria

Abstract

The Internet has experienced a phenomenal growth as a result of increasing demands for contents, content distributions and other services. CDNs have evolved as cooperative and collaborative groups of networks over the Internet where contents are replicated over the surrogate servers for efficient delivery performance to the clients and improved service cost to the CDN providers. However, a CDN is limited in terms of Point of Presence (PoP) and scalability. This work is concerned with content object replication among peering CDNs. It provides an analytical model for the replication problem in terms of a constrained optimization problem subject to a mix of QoS requirements (bandwidth and delay). The objective is to minimize the service cost which consists of both the storage and consistency management cost. In order to ensure content objects consistency in replica placement different values of reading and writing rates were considered assuming a flat update delivery. A greedy algorithm is presented to obtain a near-optima solution and using AMPL/CLEX some computational results are obtained.

Keywords: CDN, peering CDN, virtual organization (VO), replica placement, algorithm

1. Introduction and Background

Replica placement is basically concerned with the problem of locating replicas of surrogates and content [8], [9], [13] and [19].The main goal is to guarantee that the client latency and server load requirements are satisfied. The problem of replica placement comes in two forms, namely, surrogate server and content replica placement. Surrogate servers' replica placement is concerned with selecting the best locations for each surrogate to host the replicas while content object replica placement is aimed at selection of the most appropriate surrogates to host replicas of an object such that QoS is guaranteed and the object hosting and management cost is minimized. There are two types of content replications namely full content replication and partial content replication. In full content replication, all of the origin's server content is replicated in the chosen surrogates thereby making the surrogates to be responsible for the supply of the total content to the clients. Consequently, implementing full content replication means that the CDN provider takes control of the DNS mapping of the content provider's server. The setback of this method is that it is possible for the surrogate to be overwhelmed with request if not provided with enough resources needed especially due to the huge financial implications.

In case of the partial content replication, only some parts of the origin's server content are replicated in the surrogates. With partial content objects replication, the content provider modifies it's content so that links to specific objects have host names in a domain for which the CDN provider is authoritative. A partial content replication is better than full replication in the sense that the partial reduces loads on the origin server and on the site's content generation infrastructure [20] and [2]. A setback of this mechanism is that the content provider, has to decide which objects are to be replicated. This means that the system as a whole is slow to react to " hot-spots" which may occur when some content on the origin server suddenly becomes extremely popular.

ISSN (Online): 1694-0814
www.IJCSI.org

2. Virtual Organization (VO)-based CDN Peering

Virtual Organization (VO) as a process can be described by the following two characteristics among others.

i) The development of relationships with a wide range of potential partnering organization each with a type of assets or resources to complement the others.

ii) The use of computer network or Internet and telecommunication to overcome problems associated with physical locations.

The concept of partnering among CDNs in a virtual environment with the aim of sharing resources in order to meet SLAs with Web clients was introduced by Pathan et al in [13]. In this Service Oriented Architecture (SOA), VO is said to consist of both ***explicit*** and ***implicit*** members. The explicit members are the primary and any partnering CDNs that cooperate for resource sharing, while the implicit members consist of the content providers and the Web clients. If a CDN which is called a primary CDN realizes that it cannot meet its agreed SLA, then a VO is initiated in order to cooperate or partner with other CDNs that have resources to meet the defined SLAs with the customers to the primary CDN. A VO-based arrangement of peering CDNs is shown in figure 1 below

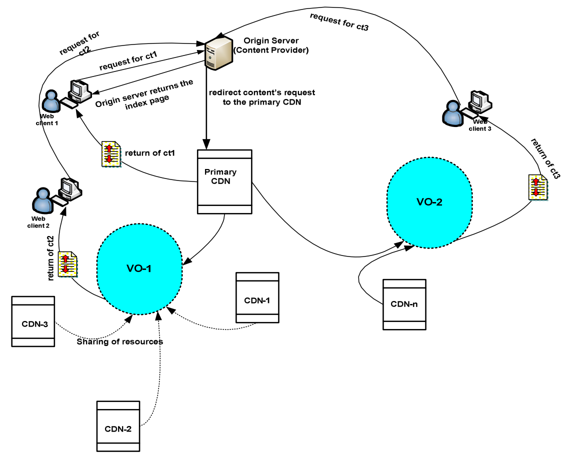

Fig. 1 An Example of VO-based peering of CDNs(Source: Pathan, et.al [13]

3. Related Previous Works

Content object replication problem investigated at the early stage of the Internet services has been concerned with file allocation problem (FAP) in storage systems, [4]and[6]and database allocation problem(DAP) or (DBL) in computer networking [7]and [1]. Both FAP and DAP are modeled as 0-1 constraint optimization problems and solved using various heuristics such as branch-and–bound [7] and network flow algorithms [3]. The algorithms proposed in the above works aimed at reducing the volume of data transferred over the network in processing a given set of queries.

In general, the problem of what and where to replicate has led to solving a constraint optimization problem which is NP-hard [17] and [9]. However, the problem is simplified by ***replica placement algorithm*** (RPA) with the system-level goals of optimal replica placement which include improving content delivery quality of service to the clients, minimizing the total infrastructure and service cost(service cost includes the consistency management costs expressed in terms of update transfers) for the CDN provider, and network bandwidth usage.

Due to progressive advances in Web services that involves demand for dynamic content such as in e-commerce, stock markets, etc. Methods used to reduce access latency of web contents especially dynamic contents include replicating the applications that generate the content along with the programs and the related data needed [18] over distributed locations.

In[21],Tenzakhti et al addressed the issue of number and placement of replicas and the distribution of request among replicas in their work, they further introduced a central algorithm for replicating objects that can keep a balanced load on sites. Mahmood in [10] considered the problem of placing copies of objects in a distributed web server system to minimize the cost of serving read and write requests when the web servers have limited storage capacity. The problem was formulated as 0-1 optimization problem and a polynomial time greedy algorithm was presented to dynamically replicate objects at the appropriate sites to minimize a cost function. More recently in[12] Pathan and Buyya discussed resource discovery and request-redirection on the Internet where they developed load distribution strategy by adopting distributed resource discovery and dynamic request-redirection mechanisms taking into consideration traffic load and network proximity. More works on QoS based content distribution are found in[12 and [16].

In this work, we are presenting an analytical model of objects replication among peering CDNs in terms of constraint optimization subject to QoS requirements under a flat update delivery in a VO-based model. That is, the primary CDN in which the origin copy of the object(s) is housed sends updates directly to the acceptable peering CDNs considering the constraints. The main objective is to minimize the total service cost which consists of the storage cost, consistency management cost or combination and maintain an acceptable QoS level for the Web clients.

4. System Model and Definitions

In this section of the work we present a model for placing replicas of objects in the web servers of peering CDNs subject to QoS requirements prescribed in the SLA as they concern the clients, contents provider and CDN provider with the objective of minimizing the total service cost. The QoS requirement in this case is specified in terms of a mix of bandwidth and delay. The total service cost is determined by the storage cost and consistency management cost.

We shall consider a network graph G = (V,E)**,** where V is the set of all nodes and it is assumed that **E = ({p,q}:p,q $\in$ V)** is the set of logical links that connects the primary CDN and the peering CDNs. We consider content population of **I** objects and **J = {j_0 , j_1 ,j_2,…… j_n}** of the peering CDNs such that ith object from CDN j has size of **s_i** units**.** We note that the same objects have the same size in all peering CDNs. The primary CDN-0 denoted by j_p stores the primary copies of all the objects to be replicated and that cannot be allocated in the peering CDNs.

The unit cost of transferring an object i over a link (j_p, j) where j is any peering CDN in a VO k is denoted by c_{ij}^{k} and it is assumed that (j_p, j) = (j, j_p) and also assumed to be known a priori, The prescribed bandwidth in SLA over the link (j_p, j) with CDN j in VO k is denoted by b_j^k while the unit delay experienced over the link is denoted by δ_j^k .The reading rate of an object i by the CDN j in VO k from the primary j_p within a period of time T is denoted by γ_{ij}^k and the writing rate of an object i to the CDN j in VO k by the primary j_p within a period T is denoted by ω_{ij}^k .The aggregate delay threshold within which read/write should be completed is given as

$$\Delta_j^k = \delta_j^k \sum_i (\gamma_{ij}{}^k + \omega_{ij}^k) \quad \text{for all j.}$$

Since the clients are not content or information providers, and as well not directly under the control of the VO management we do not include them in the model and hence cannot be modeled explicitly. We also assume that each object i has a primary (origin) copy in the primary CDN-0, j_p that cannot be allocated or removed.

The primary CDN-0 maintains information about the *replication policy*, R_p, of each object i such as which of the peering CDNs already has an update of object i. The replication policy, R_p is defined as $R_p = \{R_{P_i}\}_{i=1}^{N}$. Each of the peering CDNs has information about the primary CDN. Our main objective is to minimize the total replication cost (TRC) which consist of the storage cost, the update cost or combination as will be described below.

Let $\Re_{ij}^k$ denote total cost of reading object i from j_p by the peering CDN j in VO k under the replication policy R_{p_i}. The total cost of reading object i is defined as

$$\Re_{ij}^k = \gamma_{ij}^k s_i c_{ij}^k \qquad \text{----------------- (1)}$$

Thus, the cumulative total cost of reading all objects from j_p is given as

$$T_r C = \sum_i \sum_j \Re_{ij}^k$$

$$= \sum_i \sum_j \sum_k \gamma_{ij}^k s_i c_{ij}^k \qquad \text{--------------- (2)}$$

The total cost of writing object i by the primary CDN j_p and the cost of broadcasting updates of object i to all the appropriate peering CDNs having a replica of the object i is given as

$$W_{ij}^k = \omega_{ij}^k s_i [c_{ij}^k + \sum_{\forall j \in J} c_{ij}^k]$$

Thus, the cumulative total cost of writing all objects by the primary CDN is given as

$$T_wC = \sum_i \sum_j \sum_k W_{ij}^k$$

$$= \sum_i \sum_j \sum_k \omega_{ij}^k s_i [c_{ij}^k + \sum_{j \in J} c_{ij}^k] \quad \text{---- (3)}$$

Therefore, the total update cost is given

$$T_uC = T_rC + T_wC \qquad \text{------- (4)}$$

The storage cost is assumed to be proportional to the size and duration of storage of the objects in the peering CDN per month. This storage cost per unit per duration is denoted by π_i .

The total storage cost is defined as

$$ST_c = \sum_i \sum_j \sum_k \pi_i s_i x_{ij}^k$$

Using the binary decision variable defined as $x_{ij}^k(\mu) = 1$, if object i is replicated in the peering CDN j in VO k and $x_{ij}^k(\mu) = 0$ otherwise, we formulate the total replication cost (TRC) as a 0-1 decision problem to find the minimum TRC. That is,

$$TRC = \min[T_uC + ST_c]$$

$$= \min \sum_i \sum_j \sum_k \gamma_{ij}^k s_i c_{ij}^k x_{ij}^k + \sum_i \sum_j \sum_k \omega_{ij}^k s_i [c_{ij}^k + \sum_{r \in J} c_{ir}^k] x_{ij}^k + \sum_i \sum_j \sum_k \pi_i s_i x_{ij}^k$$

$$= \min \sum_i \sum_j \sum_k [(\gamma_{ij}^k c_{ij}^k + \pi_i) + \omega_{ij}^k c_{ij}^k (1 + \sum_{r \in J} c_{ir}^k)] s_i x_{ij}^k \qquad \text{(B)}$$

subject to

$$\sum_j s_i x_{ij} \le \beta_i \forall i \qquad \text{-- (i)}$$

$$\sum_i \sum_{\mu \in J} \sum_k \sum_j (\gamma_{ij}^k + \omega_{ij}^k) s_i \frac{b_j^k}{\delta_j^k} x_{ij}^k(\mu) \ge \Gamma \forall j \qquad \text{-------------------------- (ii)}$$

$$\sum_j x_{ij} \le \alpha_i \forall j \qquad \text{--- (iii)}$$

$$x_{ij} = 0 or 1 \qquad \text{-- (iv)}$$

Where $\Gamma = \frac{b}{\Delta_j^k}$ where b is the maximum of the bandwidth agreed on in SLA of the communication link between j_p and j, and $\Delta(j_p, j)$ is as defined before. Thus, all communication links with a large value of Γ can be regarded as a better choice in terms of bandwidth and delay. Constraint (i) specifies the bound on the storage capacity of each of the peering CDN j; constraints (ii) determine the requirement for choice of a peering CDN j to hold a replica of an object in terms of the available bandwidth and delay threshold. Constraints (iii) specifies the bound on the number of replicas in the peering CDNs, while constraints (iv) determine the peering CDN in which an object i is replicated.

5. Proof of NP-Hardness

We shall show that optimization problem defined in (B) is NP-hard. In other words we shall use a reduction argument, that is, showing that problem (B) is NP-hard if we can reduce a known NP-hard problem to (B). We shall consider the classical 0-1 knapsack problem in which exactly one item i is chosen from the set N such that the sum in (KP) is minimized i.e.

$$Z_{kp} = \min \sum_i \sum_j p_{ij} x_{ij} \quad \text{(KP)}$$

subject to

$$\sum_i \sum_j q_{ij} x_{ij} \geq C \quad \text{---------- (1)}$$

$$\sum_i x_{ij} = 1 \quad \text{---------- (2)}$$

$$x_{ij} \in \{0,1\} \quad \text{--------- (3)}$$

Here the decision variable $x_{ij} = 1$ states that the item i was chosen from class J and (2) ensures that exactly one item is chosen from each class. This problem in (KP) has been proved to be NP-hard in the literature [5], [11] and others. Thus, we shall attempt to reduce the problem in (KP) to our model in (B) stated below

$$TRC = \min \sum_i \sum_j \sum_k [(\gamma_{ij}^k c_{ij}^k + \pi_i) + \omega_{ij}^k c_{ij}^k (1 + \sum_{r \in J} c_{ir}^k)] s_i x_{ij}^k \quad \text{(B)}$$

subject to

$$\sum_j s_i x_{ij} \leq \beta_i \forall i \quad \text{-------- (i)}$$

$$\sum_i \sum_{\mu \in J} \sum_k \sum_j (\gamma_{ij}^k + \omega_{ij}^k) s_i \frac{b_j^k}{\delta_j^k} x_{ij}^k(\mu) \geq \Gamma \forall j \quad \text{------- (ii)}$$

$$\sum_j x_{ij} \leq \alpha_i \forall j \quad \text{------- (iii)}$$

$$x_{ij} = 0 or 1 \quad \text{------- (iv)}$$

In this process we shall take delay between the primary CDN and the peering CDN to be $\delta_{ij} \to \in > 0$ and b_j to be a fixed value as agreed in SLA such that Γ is large enough for a very good performance.

Rewriting (B) while we drop k for ease of use of notations, we obtain

$$TRC_r = \min \sum_i \sum_j \hat{p}_1 x_{ij}$$

subject to

$$\sum_i \sum_j \hat{p}_2 x_{ij} \geq \Gamma$$

$$\sum_j x_{ij} = 1 \forall j$$

(i.e. the number of replicas is taken to be 1 for simplicity)

$$x_{ij} = 0 or 1$$

where

$$\hat{p}_1 = [(\gamma_{ij} c_{ij} + \pi_i) + \omega_{ij} c_{ij} (1 + \sum_{r \in J} c_j)] s_i \text{ and } \hat{p}_2 = (\gamma_{ij} + \omega_{ij}) s_i \frac{b_j}{\delta_j}$$

Now setting

$$\phi_{ij} = \sum_k [(\gamma_{ij}^k c_{ij}^k + \pi_i) + \omega_{ij}^k c_{ij}^k (1 + \sum_{r \in J} c_{ir}^k)] s_i \text{ and}$$

$$\psi_{ij} = \sum_k (\gamma_{ij}^k + \omega_{ij}^k) s_i \frac{b_j^k}{\delta_j^k} \text{ in (B) we have that}$$

$$TRC = \min \sum_i \sum_j \phi_{ij} x_{ij}$$

subject to

$$\sum_i \sum_j \psi_{ij} x_{ij} \geq \Gamma \text{ where (2) and (3) hold as in (KP) above}$$

Hence we can conclude that (B) is NP-hard.

6. Replica Placement Algorithm

We present a greedy algorithm as follows.

ReplicaPlacementAlgorithm

Given Input: $c_j, \gamma_{ij}, \omega_{ij}, \pi_i, \delta_j, b_j, \rho, s_i$

Initialization: Let $trc \leftarrow 0;$ //assumes the initial total replication cost is zero

for(all j)

$\Delta_j \leftarrow \delta_j \sum_i (\gamma_{ij} + \omega_{ij});$

$\Gamma \leftarrow \frac{b_j}{\Delta_j};$

while $(\Gamma > 0)$

if($x_{ij} = 0)$ and $(\rho > 0)$

$\Re_{ij} \leftarrow \gamma_{ij} s_i c_{ij};$

$W_{ij} \leftarrow \omega_{ij} s_i [c_{ij} + \sum_{\forall j \in J} c_{ij}];$

for(all objects i) and (peering CDN j)

$T_r C \leftarrow \sum_i \sum_j \Re_{ij};$

$T_w C \leftarrow \sum_i \sum_j W_{ij};$

$ST_c \leftarrow \sum_i \sum_j \pi_i s_i x_{ij};$

$T_u C \leftarrow T_r C + T_w C;$

if $(x_{ij} = 1)$

$trc \leftarrow ST_c + T_u;$

return $x_{ij}, trc;$

7. Computational results using AMPL/CPLEX

No.of Objt		TRC	TRC		TRC	TRC		TRC	TRC

Table 1: Content objects replication cost.

		No. of CDN			X>=0	X=0 or 1			X>=0	X=0or1			X>=0	X=0 or 1
		CDN-1	CDN-2	CDN-3			CDN-4	CDN-5			CDN-6	CDN-7		
2	Obj1	0.741	0	0										
	Obj2	0	0.302	0.603										
					16.25	**29.27**								
	Obj1	0.819	0	0			0.273	0						
	Obj2	0	0.333	0.667			0	0.222						
									35.35	**94.11**				
	Obj1	0.969	0	0			0.242	0			0.162	0		
	Obj2	0	0.395	0.789			0	0.263			0	0.056		
													53.02	**193.74**
3	Obj1	1.403	0	0										
	Obj2	0	0.571	0										
	Obj3	0	0	0.281										
					19.99	**55.05**								
	Obj1	0.771	0	0			0.444	0						
	Obj2	0.229	0.543	1.086			0	0.362						
	Obj3	0	0	0			0	0						
									57.88	**119.89**				
	Obj1	0.551	0	0			0.414	0			0.276	0		
	Obj2	0	0.673	0			0	0			0.276	0		
	Obj3	0	0	0.905			0	0.453			0	0.071		
													72.63	**157.44**
4	Obj1	1.900	0	0										
	Obj2	0.099	0.873	0										
	Obj3	0	0	0.430										
	Obj4	0	0	0										
					30.57	**55.05**								
	Obj1	0.160	0	0			0	0						
	Obj2	0.839	0.904	0			0	0.603						
	Obj3	0	0	0			0	0						
	Obj4	0	0	0.241			0.047	0						
									77.00	**128.03**				
	Obj1	0	0	0			0	0			0.429	0		
	Obj2	0.986	1.048	0			0	0			0	0		
	Obj3	0	0	0			0	0.704			0	0.11		
	Obj4	0.014	0	0.279			0.054	0			0	0		
													101.51	**266.85**

Table 2 below gives the summary of the total replication cost with respect to the number of objects and the selected peering CDN.

Table 2: Content object replication cost summary results

No.of Objects	**No.of Peering CDN**	**Total replication cost(trc)**	
		x>=0	x=0 or 1

2	3	16.25	29.27
2	5	35.35	94.11
2	7	53.02	193.74
3	3	19.99	55.05
3	5	57.88	119.89
3	7	72.63	157.44
4	3	30.57	55.05
4	5	77.00	128.03
4	7	101.51	266.35

8. Summary and Conclusion

Present development trends in content networking facilities or resources provisioning has stirred up interest in interconnecting of CDNs. In order to achieve a cost effective content delivery and better overall service, distinct CDN providers seek ways to cooperate and coordinate their services. Customers' interest or preferences are forming a very important part in the provisioning of CDN services while taking into account some specific QoS requirements.

Analytical modeling is a very good and effective tool that can be used to solve the resource sharing and management problems among autonomous CDNs in order to justify the overall system goals. This work has explored the issue of Web content delivery among peering CDNs and considered precisely content objects replication. An analytical model for content objects replication problem among peering CDNs was developed while taking into account combination of some QoS requirements particularly bandwidth and delay. We provided an algorithm for the optimization problems and used AMPL/CPLEX to obtain some computational results.

We believe that further research on modeling in Content Distribution Internetworking (CDI) in particular with respect to clients' requests re-direction and content replications can still be explored. This can be done with two main focuses

i) New model realization to include new situations or parameters to help facilitate the solution of problems being represented.
ii) Algorithm development for more complex situations with more QoS requirements.

Incorporated into the two focuses may include the following

i) The question of how CDN providers maintain optima profit in competitive market which is concerned particularly with the pricing of content and services in CDNs.
ii) Developing a joint model for both request routing and content replica replication among peering CDNs in virtual organization

REFERENCE LIST

[1] P.G.M. Apers, Data allocation in distributed database systems. ACM Trans Database Syst. 13(3), (1988), pp 263-304[DOI]
[2] R.Buyya, A.K.Pathan and A.Vakali (edts). Content Delivery Networks.Springer –Verlag Berlin Heildelberg. 2008.
[3] S. K. Chang, and A. C. Liu, "File allocation in a distributed database," *International Journal of Computer Information Sciences*, Vol. 11, No. 5, (1982) pp. 325-340.
[4]. W.W. Chu. "Multiple file allocation in a multiple computer Systems". IEEE Trans.Comput.Vol.C-18, (1969), pp 885-889
[5]. J. Csirik, J.B.G. Frenk, M. Labbe, and S. Zhang. "Heuristics for the 0-1 Min-Knapsack Problems". Acta Cybernetics, 10(1-2), 1991, pp 15-20.
[6].L.W. Dowdy and D. V. Foster. "Comparative models of the file assignment problem" ACM Computing Surveys, vol.14 no.2, 1982 pp.287-313.
[7]. M.L. Fisher and D.S. Hochbaum. "Database location in computer networks". Journal of the ACM, vol27, no.27 no.4. 1980 pp.718-735
[8].M. Karlson and M. Mahalingam. Do We Need Replica Placement Algorithms in Content Delivery Networks? In *Proceedings of the International Workshop on Web Content Caching and Distribution (WCW)*, 2002, pages 117–128,
[9].M. Karlson and C. Karamanolis. "Choosing Replica Placement Heuristics for Wide–Area

Systems". In International Conference on Distributed Computing Systems (ICDCS), 2004, pp 350-359, Hachioji, Japan

[10].A. Mahmood. Dynamic replication of web contents. Sci China Ser F-Inf. Sci. vol. 50, no. 6, 2007, pp **811-830**

[11]. G.L. Nemhauser, and L. A. Wolsey, Integer and combinatorial optimization. Hoboken, NJ: John Wiley & Sons,1999.

[12]. A – M.K Pathan, and R. Buyya, "Resource discovery and request-redirection for dynamic load sharing in multi-provider peering content delivery networks,"*Journal of Network and Computer Applications,* vol. 32, no. 5, 2009a, pp. 976-990,

[13]. A.M.K. Pathan, K. Broberg, K. Bubendorfer, H. Kim and R. Buyya, "An Architecture for Virtual Organization(VO)-Based Effective Peering of Content Delivery Networks," UPGRADE-CN'07,In Proceedings of 16th IEEE International Symposium on High Performance Distributed Computing, Monterey, CA, USA, 2007 pp 25-29.

[14]. A.M.K. Pathan and R. Buyya "An Approach for QoS-Driven Performance Modelling of Peering Content Delivery Networks". Technical Report, GRIDS-TR-2007-19, The University of Melbourne, Ausralia, 2007

[15]. A.-M. K. Pathan and R. Buyya. "Performance models for peering content delivery Networks". *Proc. 16th IEEE International Conference on Network (ICON'08)*, 2008 pp. 1-7, IEEE Press, NJ, USA.

[16]. A.-M. K. Pathan and R. Buyya. "Architecture and performance models for QoS-driven effective peering of content delivery networks". *Multiagent and Grid Systems*, vol. 5, no. 2, 2009b pp. 165-195.

[17]. L. Qiu, V.N. Padmanabhan, and G.M. Voelker, "On the placement of web server replicas" Proceedings of IEEE INFOCOM, 3, 2001. pp 1587-1596.

[18].M. Rabinovich and O. Spatscheck, Web Caching and Replication Addison Wesley, 2002.

[19]. S. Sirasubramanian, G. Pierre, M. Van Steen and G. Alonso. "Analysis of Caching and Replication Strategies for Web Applications," IEEE Internet Computing, Vol.11, No.1, 2007, pp 60-66.

[20]. X. Tang,and J. Xu, "QoS-aware replica placement for content distribution",IEEE Transaction on Parallel and Distributed Systems, 16, 2005. pp 921-932.

[21]. F. Tenzakhti, K. Day, and M. Ould-Khaoua. Replication algorithms for the World Wide Web. Journal of System Architecture 50, 2004, pp 591-605.

Adenike. O. Osofisan is a professor of Computer Science with PhD in Computer Science. She is presently Head of Department, Department of Computer Science, University of Ibadan, Nigeria. Her areas of research include Computer Networks, Human Computer Interaction, Software Engineering and Database.

Sunday Idowu is a doctoral student with Prof. Osofisan and a Lecurer in Babcock University, Nigeria. He has BSc.Maths, University of Ibadan),MSc Maths,University of Ibadan and MS. Software Engineering,Andrews University, USA) .His research areas include Content distribution Networks, software development, database design and management, and image analysis and compression.