Design of Time Aware Traffic Control Cache Algorithm for Efficient Performance of Web Caching

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ABSTRACT

Web caching plays a vital role to provide better web services and solve the problem of network access delays and network traffic congestion. This paper designed Time Aware Traffic Control Cache replacement algorithm (TATCCA) that saves the network access time by holding those object inside the cache whose access time is more. This considers the access time, object size, frequency, and timespan for choosing the object to be replaced to avoid the cache pollution. Access time is the most prominent factor. The example shows that compared with the traditional cache replacement schemes, the proposed TATCCA strategy has a higher hit rate and provide fastest services to user..

KEY WORDS: WWW, WEB CACHING, TATCCA, PROXY SERVER, CACHE MANAGER BLOCK (CMB).

INTRODUCTION

In recent years, World Wide Web services are highly disseminated among a millions of world population, with heterogeneous interests like marketing, banking, education sector, entertainment, business, personal communication etc. (James Huang and Chao, 2001). Due to this, there has been increase in the network traffic congestion (Kim and Park, 2006) also increase the server load, client latency and bandwidth utilization (Barish and Obraczka, 2000). As every client aspires to get fast network service, the internet must be able to handle an aggressively increasing amount of traffic (N, 2015). Some mechanism should be provide to overcome the network traffic problem. The effective solution is web caching. Web caching is the technique of prefetching and

buffered repository of the web objects closer to clients so that if client request frequently and in the near future is satisfied from the repository located at the client side without interrupting the server (Teng, Chang and Chen, 2005; Ali, Shamsuddin and Ismail, 2011).

The typical structure of the WWW is shown in Fig 1. It includes three elements: cache on the client side, cache on the server side and cache on the proxy server. Proxy server acts as an intermediary between the client and server (Ali, Shamsuddin and Ismail, 2011). Whenever client sends request for the web object, it first arrives at the proxy server instead of the origin server. Proxy server serves these requirements by using either previously stored responses or gain the required document by requesting the original server on behalf of the client. This will reduce network access latency for a web object also reduces network traffic (Arlitt et al., 2000; Barish and Obraczka, 2000).

The overall performance of the system depends on the web cache eviction policies (Bilal and Kang, 2017). Several web cache replacement algorithms have been designed for improving the performance of the system. This paper presents a new approach for Web cache eviction policy by

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preferentially caching the objects whose cost of retrieval is the largest to improve the network performance as well as provide better service to user.

Figure 1: Architecture of World Wide Web

Related Work: Several web cache replacement policies have been proposed for upgrading the network performance. In this, we give an overview of conventional Web Proxy Cache replacement techniques that analyse their performance based on different key parameters used for the eviction and in addition to specify its limitations.

The Original Greedy Dual Algorithm: The original Greedy dual algorithm developed by Young. In this algorithm, every object of equal size corresponds with cost needed to fetch the objects from secondary storage which is defined by H value. When cache needs to be replace, then objects with the minimum standard cost H_{min} is considered for eviction and decrease the cost values H of all other objects in the cache by H_{min} (Cherkasova, 1998). So object having largest cost value may be next object for the replacement. But it does not consider the non-uniform object size.

1. Greedy Dual Size Algorithm: The Greedy Dual Size algorithm (GDS) (Curcio, Leonardi and Vitaletti, 2002) was introduced by Rizzo and Vicisano. which is the modified version of the Greedy Dual algorithm. This algorithm considers the parameter object size $S(i)$, object cost $C(i)$ and inflation value L (offset value) to calculate the standard key value H of object(i) and use the priority queue to store $H(i)$ value. The standard key value for object (i) is calculated in the following way:

$$H(i) = L + C(i) / S(i)$$

In this algorithm, the object having minimum standard key value H_{min} is consider for eviction. The limitation of this algorithm is that it does not consider the frequency value of the object.

2. Greedy Dual Size Frequency Algorithm: To overcome the limitation of GDS algorithm, the Greedy Dual Size Frequency algorithm (GDSF) (Li and Shen, 2004) was proposed that considers the frequency of object i for compute standard key value of objects in the priority queue. GDSF adds the frequency of object $F(i)$ with

the GDS algorithm to calculate the value $H(i)$. The performance of GDSF algorithm is better than GD and GDS algorithm. This algorithm also uses the priority queue. The standard key value for object (i) is calculated in the following way (Li and Shen, 2004):

$$H(i) = L + F(i) * C(i) / S(i)$$

3. Greedy Dual Size Frequency Access Interest Algorithm:

The GDSF-AI (Sarhan, Elmogy and Ali, 2014) algorithm is considered user's access choice, document types and access trait of the web for efficient web cache replacement policies. In GDSF-AI algorithm, the access choice model for i th web user is represented in the form of vector $q_i = \{ \langle C_{i1}, w_{i1} \rangle, \langle C_{i2}, w_{i2} \rangle, \dots, \langle C_{in}, w_{in} \rangle \}$. Where the set $\{ C_{i1}, C_{i2}, \dots, C_{in} \}$ represents the web user's access choice and the set $\{ w_{i1}, w_{i2}, \dots, w_{in} \}$ represents the corresponding weights to the user's access choice. The objects in cache can be specified as the array $Obj = \{ obj_1, obj_2, \dots, obj_m \}$. The interest vector q_i of web user i and the vector d_j of the j th document, they obtain the two term approximation degree of the documents by using the cosine formula as follows:

$$SIM(q_i, d_j) = \frac{\sum_{k=1}^n (w_{dk} * w_{qk})}{\sqrt{\sum_{k=1}^n (w_{dk}^2)} * \sqrt{\sum_{k=1}^n (w_{qk}^2)}}$$

Proposed Algorithm: While providing fastest CPU request, cache prefetching the requested object from the remote memory. As the cache memory is fastest and limited in capacity, its space must be utilized efficiently so that it will satisfy maximum CPU request. In this paper, we designed a new algorithm called as Time Aware Traffic Control Cache Algorithm (TATCCA). This algorithm selects the object for eviction by considering three parameters i. e. size of object, object fetch time, frequency of object. It maintain a database called Cache Manager Block (CMB) as illustrated with the help of dummy dataset shown in Table 1. Our proposed algorithm computes the Least Effective Object (LEO) (whose size is largest and cost of retrieval is less) large size can be consider either one or summation of size of two object that is largest among the cache database and having less fetch time for eviction based on the Cache Manager Block information.

Table 1. Cache Manager Block (CMB)

Object Size(Largest to smallest)	
Obj_id	OBJ_Size (in KB)
OBJA4	32
OBJB2	28
OBJB3	22
OBJA1	16
OBJB1	12
OBJA2	10
OBJA3	8

Descriptions of all the fields of CMB is as Follows:

- **Obj_id:** Obj_id is the object identification number which is used to identify object referred in the cache.
- **Size:** Size is the size of object.
- **Fetch_time:** It is the time required to bring the object into the cache from the remote memory.
- **Frequency:** Frequency of object is the number of times the object is requested by the user.

Table1.2. Database_2(DB_2)

Fetching Time (minimum to maximum)		Freque-ncy of object in cache Freq	Time_Gain TG=(Fetch_Time* Freq) -Fetch_Time
Obj_id	Fetch_Time (in ms)		
OBJA1	25	4	75
OBJA2	41	3	82
OBJB1	52	2	52
OBJA3	71	5	284
OBJB3	95	6	475
OBJA4	101	3	202
OBJB2	122	6	610

Table1.3. Database_3 (DB_3)

Most recently Evicted Objects and
its address in next level memory

Evicted Obj_id	OBJ_ADDR
OBJD1	0xED12A367
OBJC2	0xABFF1256
OBJB4	0x78237698
OBJA5	0xDFE98706
OBJC3	0x3456AC8B
OBJD4	0x7865FABC
OBJC1	0xCCAD7865

I. Design of TATCCA Algorithm**Algorithm1: BROWSER PROCESS NEW REQUEST**

```

// DB_1 is the Database_1 which stores the information about object and its size in a sorted manner (From Largest to Smallest) as shown in table 1.1
// Fetch Time is the time required to fetch the object from the remote location into cache.
CHECK IF (NEW_OBJ ∈ DB_1)
    SEND to CPU for EXECUTE
    CACHE_HIT++
    Call UPDATE Cache Control Block (Obj_id, OBJ_ADDR, OBJ_SIZE, Fetch_Time)
Otherwise CHECK IF (IS CACHE EMPTY OR NEW_OBJ_SIZE ≤ CACHE_FREESPACE)
    CACHE_FREESPACE = CACHE_FREESPACE - NEW_OBJ_SIZE
    Call INSERT INTO LOCAL CACHE (NEW_OBJ)
    Call UPDATE Cache Control Block (Obj_id, OBJ_ADDR, OBJ_SIZE, Fetch_Time)
Otherwise Call TATCCA //select objects for evict
End if
End if

```

Algorithm2: TATCCA // select objects for evict

```

// DB_4 is the database used to store Time_Gain for the objects which satisfy the given condition
// DB_3 is used to keep track of evicted objects
// k is the number of objects in the cache
// OBJ_SIZE (Obj_id[k]) is the sorted array of object size from largest to smallest
// Cache Object identification Vector is Obj_id[] ← {OBJ_A1, OBJ_A2, OBJ_A3, OBJ_A4, OBJ_B1, OBJ_B2, OBJ_B3, ...}
1. i ← 1, j ← 1
2. REPEAT while i ≤ k
    a. CHECK IF (OBJ_SIZE [Obj_id[i]] ≥ NEW_OBJ_SIZE)
        i. DB_4[i] ← TG[Obj_id[i]]
        ii. j ← j+1
    b. Otherwise CHECK IF (SUM(OBJ_SIZE [Obj_id[i]], OBJ_SIZE [Obj_id[i+1]]) ≥ NEW_OBJ_SIZE)
        DB_4[i] ← SUM(TG[Obj_id[i]], TG[Obj_id[i+1]])
        j ← j+1
        Otherwise BREAK LOOP
    End if
    i ← i+1
3. End while
4. SELECT and REPLACE (Obj_id(s) (MIN(TG(DB_4)))
5. INSERT INTO DB_3 (Evicted Obj_id, Address at next level)
6. INSERT INTO DB_1 (NEW_OBJ)
7. UPDATE Cache Control Block Database

```

II. Iustration of TATCCA Algorithm: Whenever the web user sends the new request onto the network, browser will first search it into DB_1 of CMB. If it is there, then cache hit occurs and it will directly provide to user but if it is not there then cache miss and search it in the DB_3 of CMB to check if it is either evicted recently or not. If requested object is not found in DB_3 also then TATCCA algorithm works when either the Cache is full or have no sufficient space to store the new object. TATCCA works on the basis of information given in the CMB. In Database_2 contains the information about the time required to bring the object from the source into the cache and number of times the object is referred and also the third most important is calculate the time gain factor by using following formula:

$$\text{Object, TG(Obj_id)} = [(\text{Fetch_Time(Obj_id)} \times \text{Freq(Obj_id)}) - \text{Fetch_Time(Obj_id)}] \dots (1)$$

This time gain factor helps to choose the least effective object, if the object require maximum time to fetch and if it referred more time then it is very beneficial to keep into the cache for a long time until its comparable object comes into the cache. Our algorithm selects the least effective object whose time gain factor is minimum so that the minimum time spend to fetch object if it is requested again. This will also consider the new object is better to fit into the free space of the cache. This algorithm selects the object in a sequence of largest size to smallest size to see the best fit space for the new object size with reference to select minimum corresponding time gain, this algorithm provides two choices for creating space for new object by selecting either one object having largest size and minimum time_gain or summation of two object's time_gain is minimum and the sum of their size is sufficient to fit the new object.

Let us consider example if new request arrives OBJC1 which is of size 24KB, and not found in cache and cache is full, so replacement takes place on the basis of TATCCA algorithm: According to this algorithm and Cache Manager Block information computes least effective object, following Database_4 is created and the object ids OBJA1, OBJB1 is treated as the least effective objects which creates best fit space and their time_gain is also minimum. So if this object is required again then it will take less time to fetch than other objects within the cache.

Table 1.4: Database_4 (DB_4)

SUM(TG(Obj_id(s)))	Obj_id(s)
202	OBJA4
610	OBJB2
550	OBJB3 , OBJA1
127	OBJA1 , OBJB1

Table 1.1: Database_1 (DB_1)

Object Size (Largest to smallest)	
Obj_id	OBJ_Size (in KB)
OBJ _{A4}	32
OBJ _{B2}	28
OBJ _{C1}	24
OBJ _{B3}	22
OBJA2	10
OBJ _{A3}	8

Table 1.3: Database_3(DB_1)

Most recently Evicted Objects and its address in next level memory	
Evicted Obj_id	OBJ_ADDR
OBJ _{A1}	0xEDCEA667
OBJ _{B1}	0xCBFD125B
OBJ _{D1}	0xED12A367
OBJ _{C2}	0xABFF1256
OBJ _{B4}	0x78237698
OBJ _{A5}	0xDFE98706
OBJ _{C3}	0x3456AC8B

According to the table 1.4 the objects OBJA1, OBJB1 have lowest time gain and summation of its size create best space for the newly requested object OBJC1 having size 24KB. If largest size object OBJA4 is replaced then it will take 101 time to fetch if it is requested again. Though OBJA4 has less frequency than OBJA1 still it is better to replace OBJA1, OBJB1 who require only 25

and 52 time to fetch respectively. Due to this process we will save time to access object from remote memory and one or more object can be replaced to create large space in the cache. After replacement new status of CMB database_1 is shown in table 1.1 and reference of replaced object is also save in database_3 shown in table 1.3. This algorithm will save reference of recently replaced object so that after some time if OBJA1 or OBJB1 is requested again then it will be fetched from referenced location directly so that this will save searching time and accessing quickly.

CONCLUSION

Web caching is one of the most promising techniques to reduce network access delay, network traffic congestion, bandwidth utilization. Nonetheless, most of the related work in the literature is about improvements of Web cache replacement algorithm, when the Internet was very different from today's. Starting from this observation, this paper aim to provide new viewpoints on the web cache replacement algorithm i. e. designed Time Aware Traffic Control Cache algorithm (TATCCA) in order to make caching i) efficient in enhancing the metrics that are the most relevant for the fastest network, in particular satisfying users demands quickly, ii) suitable for the type of different file that largely dominates the traffic today, e.g. video, audio and iii) provide quick response to user demands and save access time. In this algorithm, the objects whose has highest frequency and access time, it is affordable to keep those objects inside the cache so that whenever it is requested again then due to this algorithm cache hit occur and save its access time also. This algorithm is better to provide fastest network services.

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