Suppressing Effect of Delayed Caching in ICN Router by Burst Score Aggregation

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1 Introduction

A caching can effectively provide the requested content as close as possible to the requester. Various technology, such as Content Delivery Network (CDN) and Information-Centric Networking (ICN), implement caching to improve the Quality of Experience (QoE) of users. Due to the replacement policy, the popular content can exist longer in the cache, resulting in a high cache hit ratio when a user or consumer requests it. However, the phenomenon of delayed caching can occur in the caching system. A delayed caching can be defined as a cache miss that occurs in the caching because of the updating delay of specific content from the source [2]. As we investigated in [1], the cache hit ratio experiences a significant degradation because of delayed caching. Therefore, this paper proposes a method that implements a specific cache replacement algorithm to suppress the delayed caching effect in the ICN router.

2 Burst score

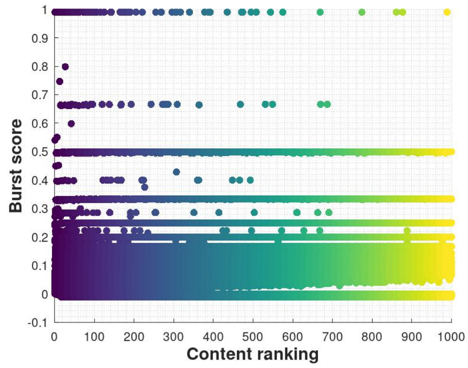
The request distribution of particular contents at the ICN router can be very varied. Under certain conditions, some contents are more dominant compared to others during a short period. This situation is defined as a burst. The burst score of the specific content can be measured by comparing the occurrences of that content between short and long periods. Hoonlor et al. in [3] introduced the burst score of a particular content x in the particular period, ts, which can be defined by

$$Burst(x,ts) = \left(\frac{E_{ts}}{E} - \frac{1}{T}\right), \tag{1}$$

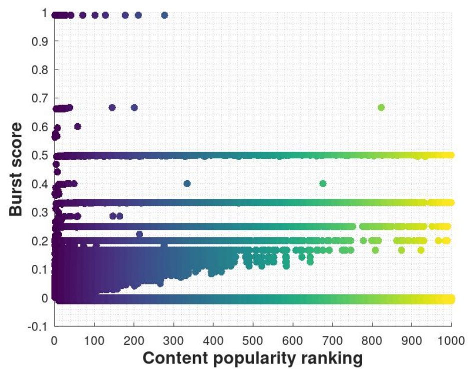
where E_{ts} is the total number of occurrences of event $x \in \{c_1, .., c_N\}$ in short interval of ts and E is the total number of occurrences of $x \in \{c_1, .., c_N\}$ in total elapse time T. The set of $\{c_1, .., c_N\}$ express the number of N total unique contents.

Figure 1 shows the distribution and range of burst scores in content with 1000 unique items that follow Zipf distribution with content skewness parameter (α). Moreover, the data were taken within 10 seconds with a short interval (ts) of about 10 ms to calculate the burst scores. The burst score shows a positive value for bursty content and negative for non-bursty content. However, the burst score depends on the previous appearance of content. Thus, even though content only appears once in the short interval ts for the first time, it has a maximum burst score since the occurrence of the previous content is zero, resulting in $E = E_{ts}$ in equation 1.

Figure 1(a) shows burst scores distribution when $\alpha = 1.0$, and we confirmed that about 70% of the content items showed a high and wide range of burst scores. However, the number of content items with high-wide burst scores decreased in half when $\alpha = 1.5$ as shown in Figure 1(b). Thus, the higher the α, the less the contents have a high-wide of burst scores. This implies that the lower popular content ranks have low-narrow burst scores and dominating by negative burst scores.



(a) When α=1.0

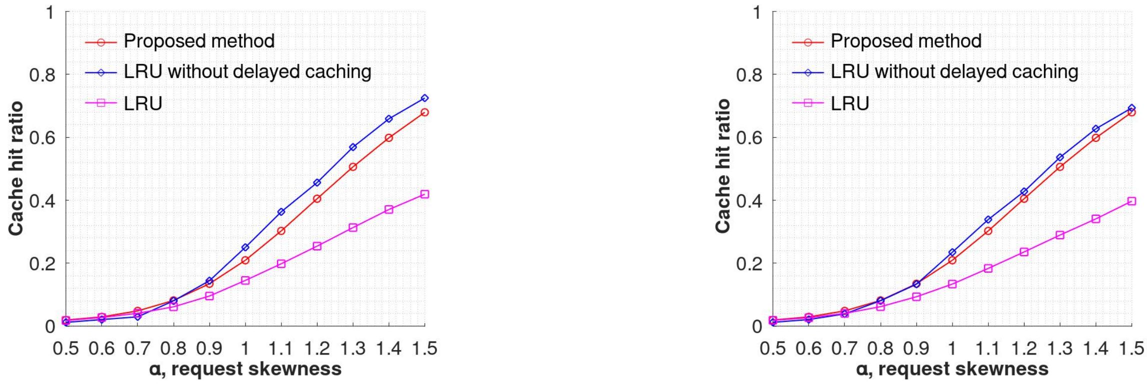


(b) When α=1.5

Figure 1: Comparison of burst score distribution subjected to content skewness (α) in 1000 unique contents (N)

3 Caching method of suppressing effect of delayed caching

The cache miss in delayed caching is caused by the arrival request of the same content before completing the updating process. Therefore, we assume that modification in the cache replacement algorithm to prioritize contents with a high burst score aggregation can effec-



(a) When ts=100 ms　　(b) When ts=10 ms

Figure 2: Comparison of hit ratio between LRU without delayed caching, proposed method, and LRU

tively suppress the effect of delayed caching. Since the burst scores only reveal the condition of burst or non-burst, we collect burst score aggregation that tracks the change of the previous burst score by accumulating with the current burst score so that the aggregation score can imply the occurrences of particular content in short interval. Our strategy to reduce the hit ratio degradation compose of two steps. First, the ICN router must build a database consisting of burst score aggregation of each content. Second, the replacement policy of Content Store (CS) must follow the content's burst score aggregation. As a result, the evicted candidate is the content that has the minimum burst score aggregation, among others.

Algorithm 1: Burst score database.

$ts \leftarrow$ Average producer response time;
$T \leftarrow$ Elapse time;
Burst database $\leftarrow$ Burst(x, ts)=0 $\forall x \in \{c_1, .., c_N\}$;
while $T \mod ts = 0$ **do**
　Count interest Burst(x, ts) $\forall x \in \{c_1, .., c_N\}$;
　Aggregate burst score =
　Burst(x, ts)[previous]+Burst(x, ts)[current]
　$\forall x \in \{c_1, .., c_N\}$ and store in Burst database;
end while

Algorithm 1 shows the pseudo-code in calculating the burst scores for all available contents. Initially, the ICN router set the value of ts with the average producer response time. Afterward, the router calculates all burst scores in every ts interval. The calculation result is aggregated by accumulating the previous burst score with the current value for all content items. Then, it is stored in the database.

Algorithm 2: Content replacement

while CS receives content **do**
　if CS size is full **then**
　　Evict content in CS with lowet burst score aggregation;
　　Store content in CS;
　else
　　Store content in CS;
　end if
end while

Algorithm 2 describes the pseudo-code of content replacement in the ICN router. When the ICN router receives content from a producer or its neighbor router, it stores it in CS. However, if the capacity of CS is oversized, the ICN router executes a content replacement algorithm that removes a particular content with the lowest burst scores.

4 Numerical evaluation

An experiment using a simulator programmed by Python 3.8 was conducted to measure the hit ratio performance using the proposed method and LRU in the ICN router with the varying value of ts. Table 1 shows the metric parameters used in the experiment.

Table 1: Setting values of main parameters

Paramater	Value
Number of unique content items (N)	1000
Cache size	10
Request skewness (α)	0.5 - 1.5
Interval(ts)	10 ms and 100 ms
Interest rate	10000 interests/s

We collected the data from 100000 requests sent by the consumer. The cache hit ratios obtained by the simulator were plotted against the request skewness, α, for each of the three different cases, namely LRU without delayed caching, LRU, and proposed method as seen in Figure 2. In general, the result shows that the proposed method enable to improve the cache hit ratio averagely 40% from LRU in case of ts equal to 100 ms as seen in Figure 2(a), and 30% in case of ts equal to 10 ms as seen in Figure 2(b). Furthermore, the hit ratio of the proposed method was greater than that of the LRU without delayed caching, about 1-5% when $\alpha > 0.9$ for both intervals.

5 Conclusion

The proposed cache replacement method utilizing the burst scores aggregation of content in a specific interval can suppress a hit-ratio degradation. In the future, we will investigate the proposed method's effectiveness in different network traffic models.

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