# Cache Replacement Positions in Information-Centric Network

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***Abstract*—Information dissemination as the sole functionality driving the current Internet trend has been of keen interest for its manageability. Information Centric Network (ICN) proposed as a new paradigm shift to mitigate the predicted traffic of the current Internet. However, caching as an advantageous building block of ICN is faced with the challenges of content placement, content replacement and eviction. The current practice of ICN caching has given birth to the problems of content redundancy, path redundancy and excessive wastage of bandwidth. This study analyze the intelligence in cache content management to palliate the gross expenses incurred in the ICN practice. The use of the current factors in previous studies in recency and frequency in content usage plays delicate roles in our study. Replacement strategies are agreed to influence the entire cache-hit, stretch and network diversity.**

***Index Terms*—Cache, Content placement, Information centric network, redundancy.**

## I. INTRODUCTION

Information-centric network (ICN) [1], [2] as a paradigm shift to improve large data handling in the future Internet practice that will bring about Internet of Things (IoT), Internet of Everything (IoE), full ubiquity and pervasive Internet involves neighbor aid intercommunication. Neighbor node intercommunication of ICN nodes is the ability for interest (requested data) to be temporarily saved as cache in specific locations. ICN caching practice has lots of medium, operations, strategies and other form of manageability that enables its functioning. Among the issues of ICN cache handling is the position of caches [3], nature of content storage [4] due to either it popularity, content referral known as the recency and frequency of its usage and demand[3]. This thus categorizes caching into two distinct forms namely on-path and off-path caching.

Off-path caching is the form of caching that benefits the nodes and stations storing of information out of the network. It can be referred to the device caching of contents while on-path caching serves the content placement known as storing and replacement operations on node edges, mid-nodes and leaf nodes in the network cycle. The wide popularity of media-driven data currently shared on the Internet has made the on-path caching form a promising option. However, to successfully benefit from the ICN form of information categorization and handling, several dependent instructions and operation makes on-path caching feasible. Among the dependent operations are content placement, content replacement, cache deployment (positions) strategies and management schemes [3], [5], [6]. ICN caching initiates its operation from the point of requesting data. A chunk record is usually saved in a storage repository known as Content Store (CS). This CS serves as the first point of visitation to fulfill the requested information. In an even that the information is not matched, a requested information is searched in the Pending Interest Table (PIT) which saves the index of the data requested as unfulfilled in its home node. This is seen as a first point of caching. However, data caching is entirely different to the aforementioned description due to the limited size of catalog and cache memory. This thus necessitated the redefinition of caching in terms of the following subsections:

1) Content placement
2) Content replacement
3) Caching strategy
4) and Cache management.

The paper shall discuss the above in the subsequent section. This paper is structured as follows: Section II describes the related work while Section III presents the cache placement strategies and Section IV highlights the properties of cache replacements with an introductory discussion of the ICN cache strategies. Cache management is covered in Section V with empirical simulation comparison of the famous cache strategies against some content replacement policies. Section VI concludes the paper.

## II. RELATED WORK

Caching in ICN is the ability to hold and conserve predictor contents of the named data. The amount of cache has provided the need for its adequate selection due to the huge amount of data network envisioned in the Internet future [7], [8]. Several caching studies have been proposed and submitted with each distinctive from practice, positions, approaches and strategy of deployments. Caching is thus categorized into two major classes namely, on-path and off-path caching. The off-path as described in[8], [9] proves to require additional functionalities and mechanism. Off-path caching is the knowledge to cache at sites or off the devices (see ubiquitous caching in ICN [8]). However, on-path caching aspire the possibility and lesser mechanism to implement along its benefits. In ICN, once a neighbor node holds an information, it has the flexible ability to transfer to the subscriber on demand. Studies conducted in caching have gained more attention. The initial caching strategy was the Leave Copy Down (LCD) [10], [11]. In LCD caching practice, content data are demanded by a subscriber which cache a copy at the immediate neighbor node. A subscriber broadcast interest into the network to get feedback. On the other hand, a publisher (provider) listens and sends the data content through some routes using the ICN binding and forwarding concepts. Replacing this content has been noticed to affect the overall cache-hit ration in the network. As the data leaves the subscriber point, the cache (chunk) copy of the data object is stored on the next node. This node/routers serves as intermediary between the sender and the receiver. In LCD, copies are dropped immediately at the neighbor node. This practice gained attention by predicting the ICN drive of data independence.

Moreover, with the LCD, contents are later observed to be cached in the routers that may not necessarily need the contents. This therefore arose the problem of content redundancy and a need to multiplex interest [12] could bail the network out from this hook. Furthermore, Leave Copy Everywhere (LCE) [13] was also proposed. The idea of LCE was to enhance the cache-hit by availing every router on-path the chunk copy of the data with the designated replacement policy in the strategy. However, the practice proved great in terms of data availability with redundancy as a slight disadvantage. Collaborative cache[14], AssignCache and Popcache[15] are some extension of the aforementioned practices with each incurring computational cost of careful node selection. Psaras et al.[13], [16], study the probabilistic nature of the network and proposed the ProbCache. ProbCache proposal used the probabilistic form of node-caching the contents in the network. Its practice recorded good cache-hit and mitigated some of the problems faced by LCD and LCE. Like the previously mentioned work, Cacheless strategy in ICN was also proposed and analyzed. In Cacheless, the total number of caches are minimized to eliminate over flooding dating but to maintain high network and data efficiency.

## III. Cache Placements and Strategies

The position and nature of data manageability is referred to as the strategy. This involves the overall placement forms, the replacement and eviction of contents. In this section, the study shall present some of the popular strategies in relation to how content replacement affects the entire network in ICN.

### A. Leave Copy Everywhere

Cache management in LCE[11] is defined by it operation of caching chunks or data in every node crossed. Part of the practice of the ICN is the ability to make information readily and easily accessible as describe in ICN initial proposal [1]. As a user sends out a request using LCE, the nature of the network serves the interest using hierarchical search and ordering of nodes to acquire a cache-hit. Given a network with a hierarchy ordered nodes $n_1$, $n_2$, ..., $n_m$, once a request for a data is sent in the order 1,..., m (from the subscriber to Publisher R5-R1) and the data gets a hit (cache-hit) at a node $n_i$, the copy of the data (cache) is cached at all immediate nodes on the route of content delivery in the order: $\{n_{i-1}, n_{(i+1)-1}, ..., n_{(1-m)}\}$. This as a result of having to save a copy of the content in all single leveled node causing the high *content redundancy*. Its replacement algorithm could take the First In First Out (FIFO), Least Recently Used (LRU), Most Frequently Used (MFU), Random etc. Figure 1 presents a LCE caching operation.

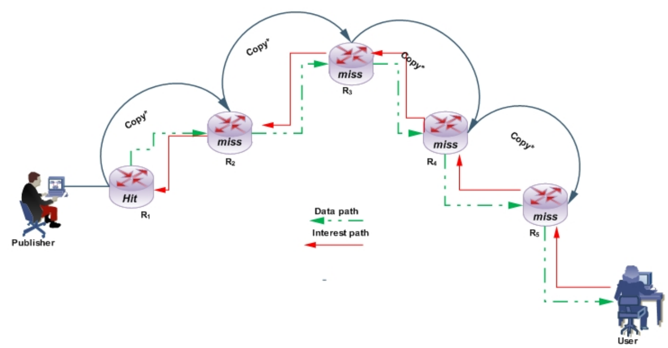
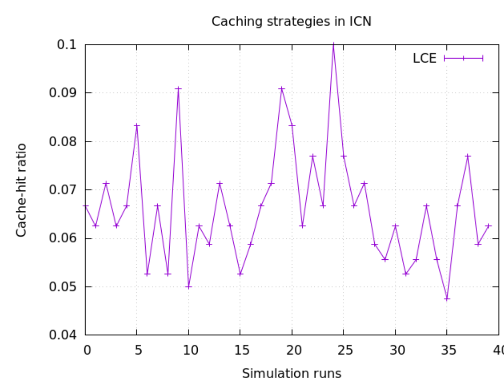



Figure 1: Leave copy everywhere




(a) LCE with Abilene

Figure 1(a) presents the analyzed scenario in Abilene network topology using LRU.

### B. Leave Copy Down

The Leave Copy Down (LCD)[11], [13] is a cache management strategy that defines the form and manner of content caching on nodes. Its operation works in a similar fashion as the popular "drop at the first neighbor" process. In LCD once a request for an interest is posed, a path link is created in the form of $\{n_1, n_2, ..., n_m\}$ to the Publisher of the data or the content holding node. As the content records a hit on $R_1$, it only stores the copy in its direct neighbor node using the traversing path to the subscriber $R_2$. For LCD to gain the high LCE states of availing contents in almost all nodes, it needs a content-hit at almost all levels of $\{n_1, n_2,...,n_m\}$ (see Figure 2).

Figure 2(a) presents the analyzed scenario in Abilene network topology using LCD.

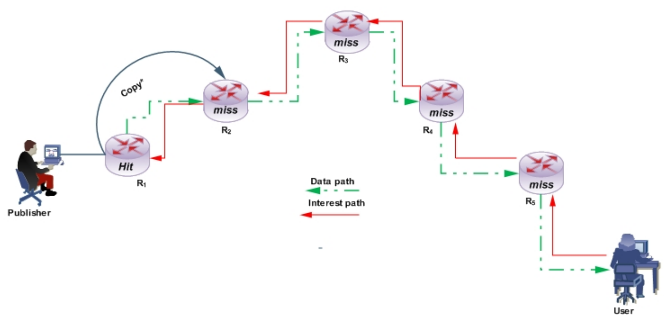



Figure 2: Leave copy down

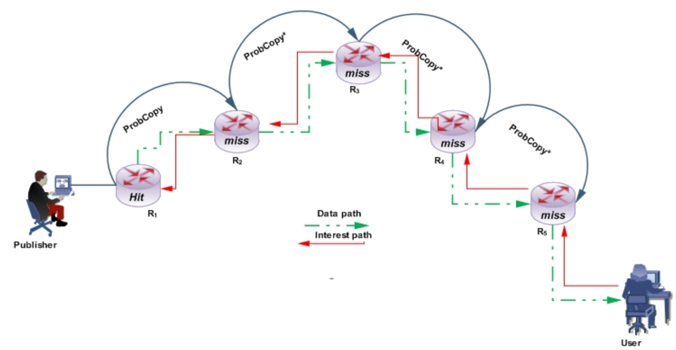
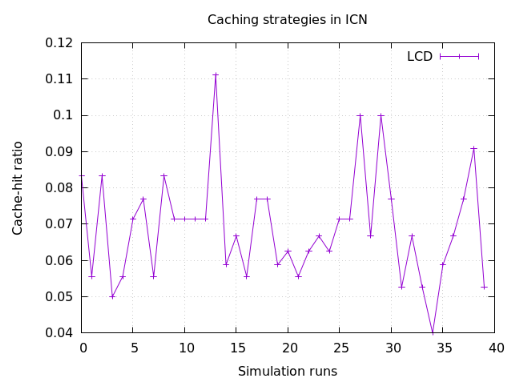
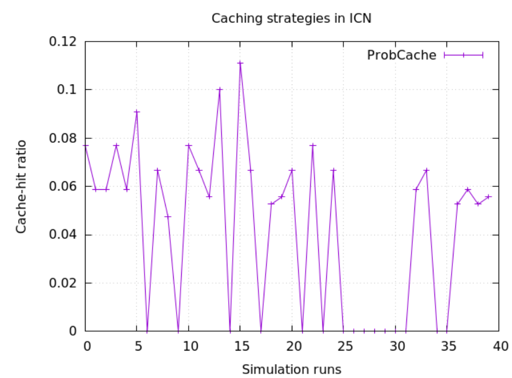



Figure 3: ProbCache




(a) LCD with Abilene




(a) ProbCache with Abilene

### C. Probabilistic Cache

The Probcache[11], [13] is assumed as a probabilistic LCE in a randomized manner. Its main distinction to the LCE is the ability to keep its cache copy in an immediate neighbor node (n) with probability *p*. Probcache therefore does not keep a cached copy in a node with *q (1-p)* probability. Once a cache is hit, a probability computation is acted on depending on the chosen distribution from the subscriber to Publisher $R_5$- $R_1$ (see Figure 3).

Figure 3(a) presents the analyzed scenario in Abilene network topology using ProbCache.

## IV. Cache Replacement Strategies

The size and catalog nature of caches makes it almost impossible to store data and information for long. The major different between caches and secondary, primary storage is the amount of time dished out for a content to reside in a memory. Several replacement policies have been studied and proposed to be inculcated into ICN. A great number of researchers have however argued that the LRU still provides the best results against other types. In this study, we shall analyze the LRU against Random and Semantic replacement strategies.

### A. Semantic Replacement

Semantic replacement can be said to be the replacement that adhere to a define syntax and rules. In Semantic replacement strategy, a cache administrator defines the tags, fileds and forms of condition. This conditions can be called the grammar nature of the replacement policies. In semantics, the envisioned disadvantage is the strong building in the set of rules defined. The rules are usually not flexible and thus may require a complete redesign if the needed content are unfairly replaced. See Adaptive cache deployment strategy in [3].

### B. Random Replacement

In Random (*Rand*) replacement policies, once data object or name data objects (*NDO*) are requested, a copy of the data is found and served known as cache-hit. The resulting data is then saved temporarily in a neighbor node based on the strategy adopted as discussed in Section III. However, the replacement in *Rand* uses a uniform distribution. According to the distribution, contents are thus replaced based on the uniform selection after exhausting the available memory and catalog sizes [3] in the nodes. Typically, researchers have thus challenged this replacement policy as sometimes the most important data are replaced in lieu of non-popular contents.

### C. Least Recently Used

Least Recently Used (LRU) replacement strategy has been agreed as the most efficient cache replacement policy in ICN [4], [17], [18], [19], [20]. LRU replaces contents in caches according to recency of usage. A popular content is usually demanded more than a least popular content in the network. The recency of a data or content is directly proportional to its usage which thus serves the main objective of adequate information sharing in and out of the network.

## V. Cache Management comparison with replacement policies

This section presents our empirical analysis and comparison of cache managements against replacement policies to verify the submission by several researchers about the sufficiency of LRU. ProbCache, LCD and LCE are presented as thus:

This work adopted the nature of traffic with the following parameters. The simulation was ran for forty (40) occurrences to attain an acceptable rates of instances in ICN traffic manageability using SocialccnSim [21].

**Simulation Parameters**

| Parameters | Value |
|---|---|
| Number of users | 3980 |
| Number of files | 10,000 |
| Mapping Algorithm | Random |
| Time limit | 86,400 |
| Social graph | Facebook |
| Number of communities | 5 |
| Cache replacement | LRU, Semantic and Rand |

### *A. ProbCache Comparison*

In ProbCache, the simulation was ran on an Abilene network topology with a randomly generated traffic using the social graph known as Facebook. The results shows that on several ran, the LRU was performing magnanimously to achieving better hit ratios. Figure 4 depicts the obtained results against the selected cache replacement policies in our analysis.

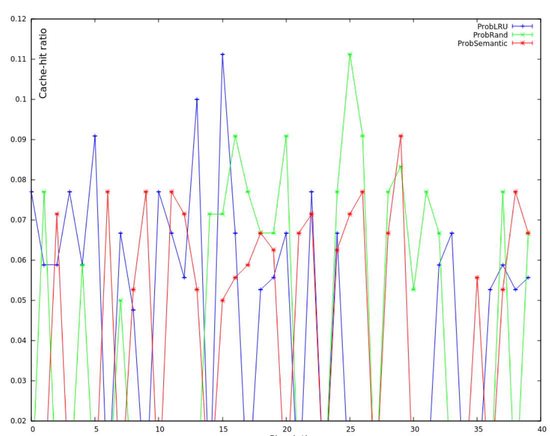



Figure 4: ProbCache and cache replacement policies

### *B. Leave Copy Down Comparison*

Leave Copy Down in our simulation shows the relationship of having a content only cached at an immediate neighbor after a cache-hit. However, when the operation of replacement is needed, *semantic, Rand and LRU* was tested and the obtained results shown on Figure 5 presents the facts of LRU being a more acceptable replacement concept in ICN. It is fair to note that from simulation run 8-25 LRU out-perform the other policies which can be concluded as the best also when using the LCD.

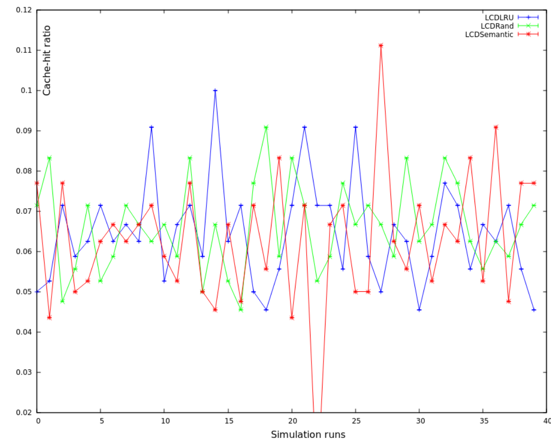



Figure 5: LCD and cache replacement policies

### *C. Leave Copy Everywhere Comparison*

The LCE is the most popular ICN management strategy as it was the initial designed in the first ICN proposal [1]. Since LCE deposits the copy of the demanded data on all nodes, this was challenged as a probable content and path redundancy causing practice. However, in a network that demands popular objects in nearly constant intervals, the LCE is still the best. But in terms of replacement, since it would barely be replacing all contents in its nodes, the simulation results shows that LRU is the optimal on LCE even though the *Rand* replacement was closely competitive given its uniform distribution nature. See Figure 6 for the obtained results.

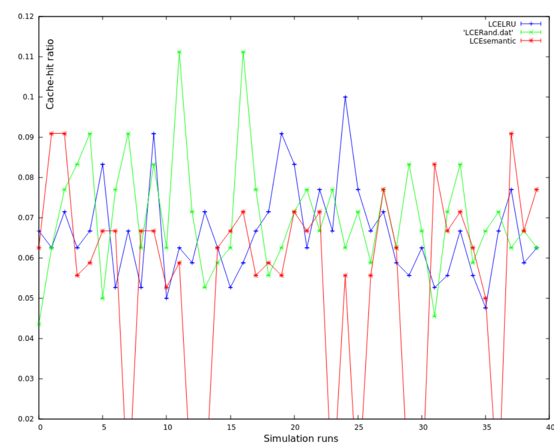



Figure 6: LCE and cache replacement policies

## VI. Conclusion

The study presented a highly simulated empirical comparison of different cache management strategies in ICN by analyzing the strength and weaknesses of each placement and replacement strategies. The study proved the conclusive submission by the leading ICN research communities in adopting the LRU as the finest replacement policy for an ICN design. Since ICN is still in its infancy in terms of standardization, the authors tried to present this study as an experimentally proven contribution to aid in future draft and design submission for the future Internet. The study therefore concludes its finding that LRU replacement policy has great significance to ICN performance in regards to minimal bandwidth consumption, better throughput by analogy since the cache-hit ratio are better with wide percentage against the others. Suggestion for the future will be to extend the simulation run to different network topology and other traffic generation platform.

## ACKNOWLEDGMENT

This research is one of the Malaysian Government funded projects under Ministry of Higher Education (MOHE) Long-Term Research Grant (LRGS) with reference number LRGS/TD/2011/UKM/ICT/02.

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