Evaluation of Caching Strategies in Content-Centric Networking for Mobile and Social Networking Environment

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***Abstract*—Users of the Internet are still using the basic network communication model that was created way back 1960s. The grand idea of migration from host-centric to information-centric has made Content-Centric Networking (CCN) one of the eminent candidates for the future internet. The extension of caching technology as one of the components in the networking itself require deeper thought than just plug and play of current web or server caching techniques. While most studies are focusing on new caching strategies, this study will highlight the gaps by comparing common caching strategies in different predicted scenario of the future. The evaluation was done using simulation tools known as SocialCCNSim focusing on six relevant caching strategies: Leave Copy Everywhere (LCE), Leave Copy Down (LCD), ProbCache, Cache "Less for More", MAGIC and Randomly Copy One (RCOne) in different network topologies: Tree and Diamond. Rank is given based on metrics such as Cache Hit, Stretch, Diversity and Eviction operations that represented the most commonly used metrics in networking. Results show that all caching strategies have their own behavior toward different network topology. However, Cache "Less for More" considered the best with balanced result for both performance and resource utilization metrics.**

***Index Terms*—CCN; Caching Strategies; Topologies; Tree; Diamond; Rank; Performance; Resource Utilization.**

I. INTRODUCTION

Current Internet architecture was founded upon a host-centric communication model that focuses on solving main issues of resource sharing in those days. Internet utilization has evolved tremendously and lately has been dominated by content dissemination in mobile and social networking [1] with exponential growth over the years. A conceptually simple yet transformational architectural shift is required as the first draft idea that change today's focus on where (addresses and hosts) to what (content that users and applications care about) [2].

A. Information-Centric Networking (ICN)

ICN has been researched by all since it was first initiated in Google Tech Talk [3]. The fundamental definition of basic ICN varied throughout research groups such as Data-Oriented Network Architecture (DONA), Publish-Subscribe Internet Technology (PURSUIT), Publish Subscribe Internet Routing Paradigm (PSIRP), 4WARD, Adaptive Internet solutions (SAIL), Content Mediator architecture for content-aware nETworks (COMET), CONVERGENCE, US-funded projects Named Data Networking (NDN) that is an adoption of CCN as well as MobilityFirst [4]. The main sets of key functionalities in ICN are naming, name resolution and data routing, caching, mobility and security. While others have different terminology of components in ICN but generally they are referring to the similar ideas with elements of named objects, routing and forwarding and caching with challenges in mobility and security [5].

PARC, a Xerox company, has introduced their novel ICN architecture known as CCN [6] as continuity of idea [3] proposed by their own researchers. Basic operation is by addressing and delivering Content Object purely by Name without addresses like the current Internet. The architecture of CCN comes with a build in Content Store that is just like the buffer memory in today's router as in Figure 1.

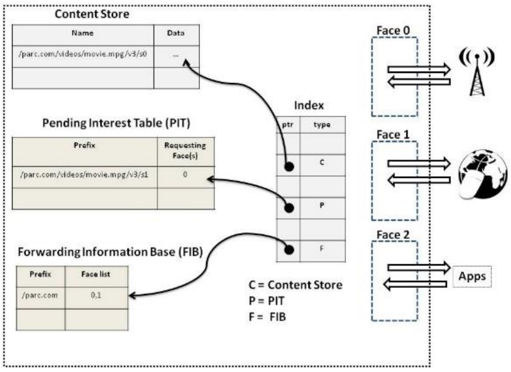

Figure 1: CCN Architecture

B. Caching

Caching strategies, especially in-network caching has attracted researchers in recent years. Nodes that store the data can be crucial as could serve more than just as communication nodes with servers' capabilities as well. Thus, lots of novel caching strategies have been proposed pioneering by considered default strategy known as Leave Copy Everywhere (LCE) [7] and followed by other popular strategies such as Leave Copy Down (LCD) [7], ProbCache [8], Cache "Less for More" [9], MAGIC [10] and Randomly Copy One (RCOne) [11]. LCD works based on LCE except the content is cached at one node below the original content is hit. Meanwhile ProbCache and RCOne cache content based on probability and random value. Cache "Less for More" apply the concept of betweenness-centrality while MAGIC use the Gain concept.

This paper aims at addressing gaps in the evaluation of the caching strategies especially based on common evaluation framework. Most of the researchers focus on their own novel caching strategy and trying to prove that they are contributing to the body of knowledge which maybe bias to certain viewpoint while survey papers focus on strengths and weaknesses of the caching strategies [5], [12]. Contributions of this work listed as below: -

1. Comparison for all selected caching strategies with common setups in mobile and social networking (Section IV);
2. Analysis on performance and resource utilization metrics (Section V).

II. BASELINE SCENARIO AND NETWORK TOPOLOGY

There are some researches similar to this kind of analysis but with different environment and parameter settings [13] and also simulation tools [14]. Selection of the simulation tools has to be based on the suitability of the chosen environment. There are few commonly used simulators such as ndnSIM, ccnSim, Icarus and others as well [15] as in Figure 2.

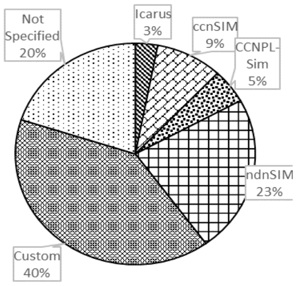

Figure 2: Simulation Tools usage

SocialCCNSim [16] on the other hand is a network simulator designed for caching evaluation and developed based on utility tools that generate social network traces known as SONETOR [17]. Using CCNSim as the base of this simulator makes it the most appropriate simulator to be used as it combined CCNSim and custom version of simulator that have been considered as the highly used simulation tools in CCN architecture [15]. It can be used to represent social network behavior or just any basic client-server interaction and supports multiple types of network topologies that also fit with large-scale simulations.

CCN architecture remarkable growth has made Internet Research Task Force (IRTF) to come out with Request for Comments (RFC): 7476 [18] about these baseline scenarios. Varieties of scenarios go under researches justified the need for standard guidance. The baseline scenario that has been listed are social networking, real-time communication, mobile networking, infrastructure sharing, content dissemination, vehicular networking, delay and disruption tolerance, internet of things and smart city. Social networking with based on overlay content dissemination has been considered a “natural-fit” with supports in [19]. Meanwhile, mobile networking consists of wireless and mobile devices will account for two-thirds of total IP traffic by 2020 leave wired devices for just 34% of IP traffic [1].

A. Social Networking Scenario

Online social networks (OSNs) have been dominated the cyber world since the beginning of this millennium. The Facebook has been the current trendsetter followed by others such as Twitter, Instagram, Google+ etc. There are many things users can do in the OSNs such as expanding their friendship or marketing networking while the governments use OSNs platform to monitor their citizen or netizen. However, content dissemination always been dominating the world of OSNs especially on messaging communication and content sharing. Combination of caching and multicast delivery has been observed and shows how efficient messages sent between multiple users in CCN architecture.

While some of the researchers suggest a new network topology based on their assumptions, most of them still depending on conventional network topology with some adjustments on replicating and representing the environment itself. Tree-based topology always considered as highly regular structure [9] and been popular especially in CCN that mostly related to content dissemination or even deeper in social networking scenarios. Based on ICN Twitter architectures, caching near to the requesters is considered the most efficient with low hit ratio while depending on the network Tree itself. Meanwhile, in a considered basic caching content dissemination experiment, hierarchical Tree topology is considered reasonable fixed with the assumption of shortest path routing [20]. Enjoying a real-time networked music performance also has been achieved the best by combining shortest path between publisher and subscriber and multicast it into a Tree [21]. Content dissemination itself is about caching in the best location, most popular content tends to be cached at the leaves of the network and Tree-based topology could give the best view in terms of how deep it should be cached in a network. The basic idea of how content dissemination is widely used in OSNs as shown in Figure 3.

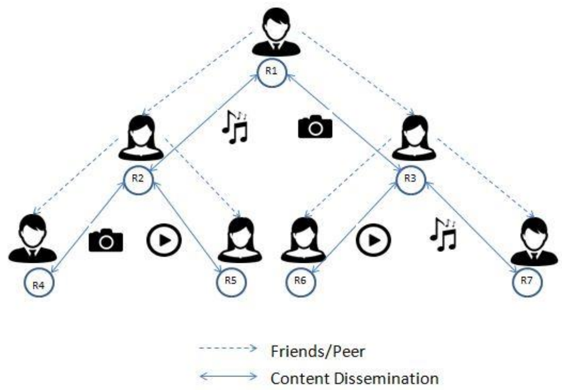

Figure 3: Content Dissemination in OSNs

B. Mobile Networking Scenario

Mobile networking has been one of the serious issues in networking since the introduction of wireless networks. Nowadays, high usage of mobile phones applications gives big challenges in mobile networking, especially for the future CCN. Mobility has been identified as components and challenges in CCN [4]. Some researchers in this scenario focus on mobile ad hoc networks (MANET), vehicular ad hoc networks (VANET), wireless sensor networks and recently in the Internet of Things famously known as IoT. There are also diverse ways of addressing caching issues in mobile networking and need proper investigation such as Web Services in mobile wireless ad-hoc networks and many more.

Network topology in mobile networking also gets a lot of attention on using the best topology to describe real mobile networks. Most of the researchers come out with their own topology with specific node placement as to describe the scenario they want to simulate while some use tree topology with different placement of nodes [22]. However, Diamond topology is mostly used that described mobility near to the real applications or scenarios such as in ad-hoc network in military, deployment of wireless sensor network, Load-Balancing in Content Network [23] and also congestion control [24]. The usage of mobile networking with Diamond topology in social networking can be viewed in Figure 4.

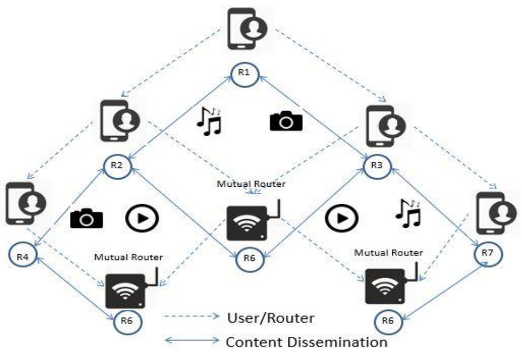

Figure 4: Social Networking using Diamond Topology in Mobile Networking

III. SIMULATION SETUP

SocialCCNSim is used to evaluate CCN selected caching strategies (LCE, LCD, Cache "Less for More", MAGIC, ProbCache and RCOne) with Least Recently Used (LRU) as cache replacement policy [13].

Regarding the parameters settings, we considered everything as needed by SocialCCNSim such as Catalog size, content Popularity Model, topologies and Cache size. In this case, we chose a common value in all the parameters. Only two topologies will be evaluated as to showcase the scenarios that are social networking and mobile networking with the caching strategies performed on it. Simulation has been done with Tree topology followed by Diamond topology. Both scenarios will be evaluated with the Facebook type of traffics.

The scenarios also consist of a Catalog with 10,000 files and average of 100 chunks per file. The cache size is also fixed at 1,000 chunks for each node [25]. Content Popularity Model using the probability distribution function such as Zipf or MZipf based on the idea proposed [26] with α parameter 0.65. The α parameter ranges largely from 0.6 to 2.5 [13], but for this experiment, we consider just α parameter 0.65 that refers to a low popularity scenario to avoid bias for any popular content. LRU that worked based on page selection for replacement is the one that has not been referenced for the longest time considered mostly used as in [7], [9]. Table I shows the summary of parameter setting in simulation environment.

Table 1
Parameter Setting in Simulation

Parameters	
Catalog	10^6
Popularity Model	MZipf {α=0.65, β=0}
Topology	{Tree, Diamond}
Cache Size	10^{-3}
Evaluation Metric	Cache Hit, Stretch, Diversity, Eviction

In evaluation of caching strategies in CCN, many metrics have been used widely but mostly focuses on performance metrics such as Cache Hit and number of Hops Reduction. Therefore, we considered other metrics that could determine the resources utilization in caching especially in terms of memory and computing resources. We chose Cache Hit and Stretch as the basis for performance metric while Diversity and Eviction operation as resource utilization metric to get more results for better analysis for all selected caching strategies.

IV. RESULT AND FINDINGS

Comparison of selected caching strategies for CCN has been made by using the same simulator tool and common evaluation scenario and metrics. Simulation experiments have been performed for one full day and ten most optimum runs have been taken as the most assurance result. As discussed in the previous chapter, the comparison of selected caching strategies is made in two scenarios. First, we go to the social networking scenario that is simulated by using Tree topology. Later we used Diamond topology in the adaption of mobile networking scenario.

A. Social Networking Scenario

All four evaluation metrics have been considered on the same runs of the simulation to eliminate bias results between the caching strategies strengths and weaknesses.

Results for the Cache Hit are as illustrated in Figure 5. This shows that Cache "Less for More"has the highest value along with LCE. However, LCE and MAGIC have a more consistent result. This indicates that LCE and MAGIC produced the best Cache Hit ratio persistently and made them the top caching strategy of all. Meanwhile, Cache "Less for More" produced average result of all. This follows by LCD that have low result but high consistency shows that LCD produced bad Cache Hit ratio. The bottom of this metric produced by ProbCache and RCOne shows that random or probability value do not perform well in this scenario.

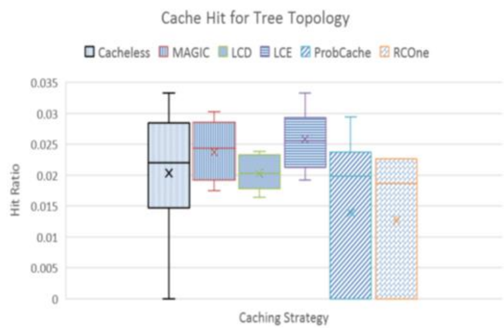

Figure 5: Cache Hit for Social Networking scenario

The illustration of results for the Stretch metric is shown in Figure 6. MAGIC and LCE are dominating this metric by producing lowest Stretch value. However, MAGIC performed better with the more consistent result as shown with more high result each simulation run. Meanwhile, ProbCache and RCOne fit in the middle of all six caching strategies with average result most of the time. Cache "Less for More" and LCD produced the lowest value with 1 value most of the time.

Figure 7 shows the result for Diversity evaluation metric. Cache "Less for More" dominates this metric with not just highest value but also with high consistency and persistency. LCD and RCOne become the second best with average result and highly consistent. Meanwhile, ProbCache got average value from all. Lastly, MAGIC and LCE produced the lowest value that indicates they have the most number of copy throughout the network.

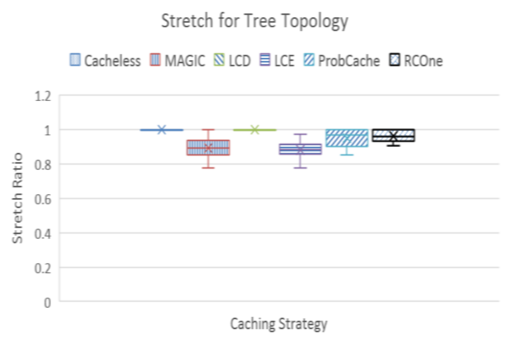

Figure 6: Stretch for Social Networking scenario

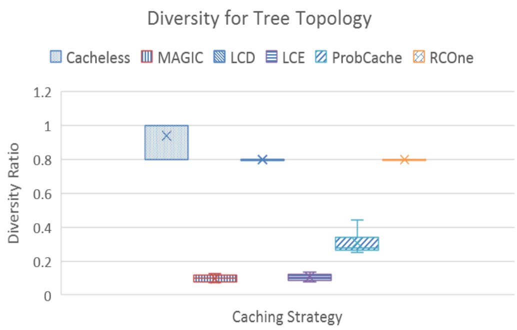

Figure 7: Diversity for Social Networking scenario

Eviction operation metric results as shown in Figure 8. Cache "Less for More", LCD and RCOne have produced the least number of eviction operation each time indicating that these caching strategies consume less computing resources for each simulation run. ProbCache still produced average value from all of the caching strategies. Meanwhile, MAGIC produced the highest number of eviction operation with most of it are more than 30 eviction operation. LCE also behave on the same value as MAGIC but with less number of eviction operation.

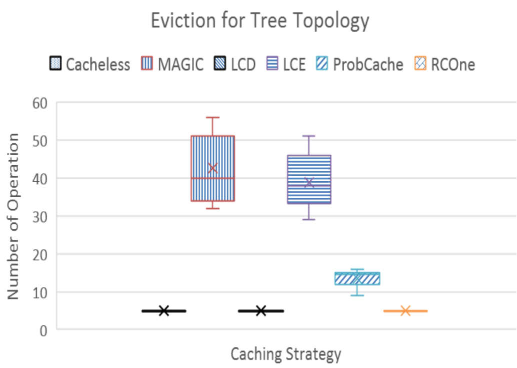

Figure 8: Eviction for Social Networking scenario

B. *Mobile Networking Scenario*

Considering for four evaluation metrics, all simulation runs at the same time to eliminate bias results between all the six caching strategies.

Results for Cache Hit metric in mobile networking scenario as illustrated in Figure 9. MAGIC, Cache "Less for More", ProbCache and RCOne produced the same highest Cache Hit ratio but MAGIC come on top of all by also having high Cache Hit consistently with also highest value for even minimum Cache Hit for it. The size of the box for MAGIC in Figure 11 shows that most of the value was produced within that high value of Cache Hit ratio. LCE and LCD come second with more consistent Cache Hit even though without having the highest value. This followed by Cache "Less for More" with average Cache Hit ratio and then ProbCache. RCOne produced the worst value of Cache Hit ratio with mostly range below than 0.1.

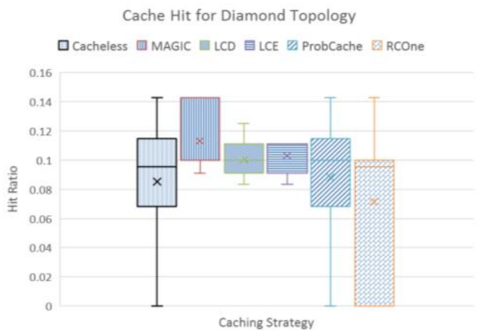

Figure 9: Cache Hit for Mobile Networking scenario

Figure 10 shows the result for Stretch metric in mobile networking scenario. MAGIC clearly have the best Stretch value with low ratio and consistently produced below than 0.9. Next is LCE with quite a similar result but less consistent than MAGIC. The average value was produced by ProbCache and RCOne with a fair value but poor in consistency. Cache "Less for More" and LCD have the worst value for Stretch with most of it produced 1 value indicates that it must travel to all hops most of the time.

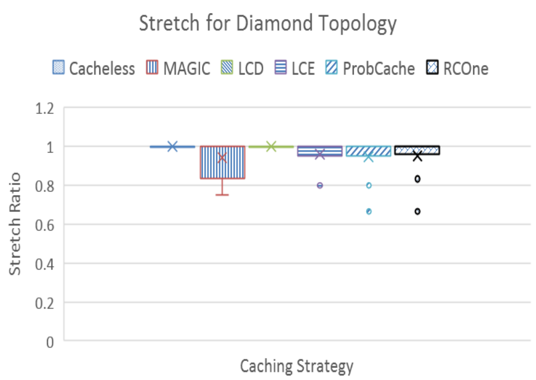

Figure 10: Stretch for Mobile Networking scenario

Results in Figure 11 show the output for Diversity metric. Cache "Less for More" and LCD dominating this metric with high and consistent value. RCOne comes next with less consistent than those two. ProbCache placed in the middle with a combination of good and bad result. This followed by MAGIC. LCE is the worst with lowest Diversity in all runs.

Eviction operation metric results as illustrated in Figure 12. RCOne has shown that random value can produce good result with the least number of eviction operation with persistent. LCD and Cache "Less for More" comes next but just LCD has better in terms of consistency. Then, followed by ProbCache that produced average value most of the time. Next, MAGIC also average value but worse than ProbCache. Lastly, LCE has the most number of eviction operations with mostly more than 8 times.

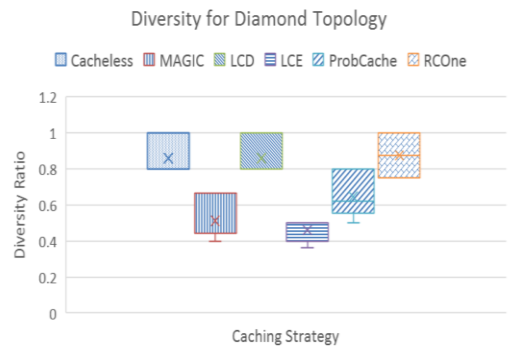

Figure 11: Diversity for Mobile Networking scenario

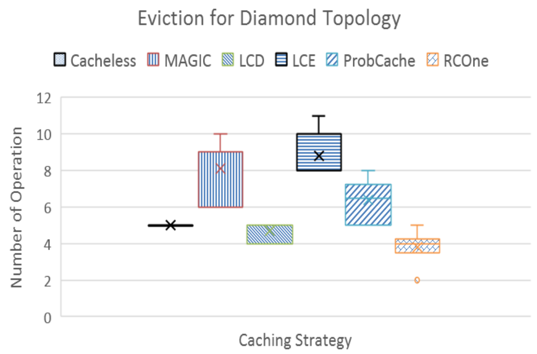

Figure 12: Eviction for Mobile Networking scenario

V. DISCUSSION

Results clearly show both Tree and Diamond topologies that represent social networking and mobile networking produced so many differences in terms of the performance for all selected caching strategies. Most of the value produced by evaluation for both scenarios indicates that all caching strategies performed better in mobile networking scenario compared to social networking scenario. These have been shown by the range of value that has been produced and analyzed in all the performance and resource utilization metrics as in Table 2.

Table 2
Range Value for Both Social Networking and Mobile Networking

Metrics	Baseline Scenario Social Networking	Mobile Networking
Cache Hit	0-0.034	0-0.14
Stretch	0.8-1	0.7-1
Diversity	0.1-1	0.4-1
Eviction ops	5-55	4-11

As for Cache Hit and Diversity, higher value means better results while Stretch and Eviction operations with lower value considered the best. Based on Table 2, all Diamond topology produced higher results for Cache Hit and Diversity with lower result for Stretch and Eviction operations indicated that it performed better than Tree topology. This is based on the placement of nodes between both topologies whereby Diamond topology have more paths while interconnecting between the nodes while Tree topology works by expanding down the root as discussed in Section III.

Between all the selected caching strategies, MAGIC considered the best in terms of Cache Hit. However, LCE and Cache “Less for More” are not far behind just with also considered acceptable value for both topologies. Stretch metric also shows that MAGIC performed the best for both topologies. Thus, LCE produced quite a similar result with MAGIC in Tree topology but with a poor result in Diamond topology. Cache “Less for More” and LCD consistently performed poorly in Stretch metric. However, in Diversity Cache “Less for More” and LCD outperformed other strategies, especially in a Tree topology. While in Eviction operations, Cache “Less for More”, LCD and RCOne considered the best with less number of operations with huge gaps with MAGIC and LCE. Therefore, ranking of the caching strategies as shown in Table 3 and Table 4.

Table 3
Caching Strategies Ranking for Social Networking Scenario

Caching Strategy	Cache Hit	Stretch	Diversity	Eviction	Overall	Rank
	Metric Ranking					
Cache “Less for More”	3	5	1	1	10	**1**
MAGIC	1	1	5	6	13	**2**
LCD	4	6	2	2	14	**3**
LCE	2	2	6	5	15	**4**
ProbCache	5	3	4	4	16	**5**
RCOne	6	4	3	3	16	**5**

Table 4
Caching Strategies Ranking for Mobile Networking Scenario

Caching Strategy	Cache Hit	Stretch	Diversity	Eviction	Overall	Rank
	Metric Ranking					
MAGIC	1	1	5	5	12	**1**
Cache “Less for More”	4	5	1	3	13	**2**
LCD	3	6	2	2	13	**2**
RCOne	6	4	3	1	14	**4**
LCE	2	2	6	6	16	**5**
ProbCache	5	3	4	4	16	**5**

VI. CONCLUSION

MAGIC came on top for performance metrics but performed poorly under resource utilization metrics while RCOne as the opposite of it. MAGIC also lead the ranking for mobile networking scenario but lose a bit with Cache “Less for More” in terms of overall ranking for both social and mobile networking scenarios. Cache “Less for More” also considered the best of all because of the balanced and acceptable result between all the caching strategies with stable and consistent results with MAGIC considered as the closest rival. Meanwhile, other probability-based caching strategies such as ProbCache and RCOne suffers from an inconsistency of all.

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