Evaluating the Benefits of Caching and Stateless Forwarding in Mobile Information-centric Networks

Adita Kulkarni, Anand Seetharam
Computer Science Department, SUNY Binghamton
akulka17@binghamton.edu, aseethar@binghamton.edu

ABSTRACT
Caching content at storage-enabled network nodes is one of the salient features of Information-centric Networking (ICN). Most existing ICN caching and routing strategies have been designed for and evaluated in static networks [2], while mobile networks have received limited attention [1]. In this paper, we consider a mobile ICN and examine the benefits that in-network caching can provide in a mobile setting. From our experiments on mobile grid networks, we observe that approximately 43% of requests cannot be routed and hence are dropped in a mobile network due to absence of direct paths from users to the content custodian (origin server). For the requests served, we observe that while state-of-the-art caching strategies outperform the baseline Leave Copy Everywhere (LCE) strategy in static networks, all caching strategies including LCE tend to provide similar performance as network mobility increases. For requests that cannot be routed due to unavailability of paths from users to the custodian, we next explore the benefits of augmenting shortest path routing with a simple stateless random walk request forwarding strategy that enables a user to search neighboring caches. We observe that just using a simple random walk strategy when a direct path is unavailable increases the total percentage of requests served by 6% on average.

CCS CONCEPTS
• Networks → Network mobility; In-network processing; Mobile networks;

ACM Reference Format:

1 INTRODUCTION
By caching content at storage-enabled network nodes, ICN aims to improve user performance by serving requests for content from intermediate nodes in addition to the content custodian (origin server). Over the last decade, multiple routing and cache management strategies have been proposed for ICN, the most prominent ones being Leave Copy Everywhere (LCE), Leave Copy Down (LCD), Cache Less for More (CL4M), ProbCache, Hash-routing and Characteristic Time Routing (CTR) [2]. But, most existing strategies have been primarily designed for and tested on static networks.

In this paper, we first investigate the benefits of in-network content caching via experimentation on mobile grid networks. We observe that if users continue to route requests using shortest path routing, a significant portion of requests (43%) cannot be served due to route unavailability between users and the custodian caused by node mobility. For the requests served, we observe that while state-of-the-art caching strategies outperform the baseline LCE strategy in static networks, all caching strategies including LCE tend to provide similar performance as network mobility increases. We hypothesize that the main reason behind this is that node mobility negates the benefits obtained by carefully placing content along the shortest path from a user to the custodian.

Another potential benefit of adopting an information-centric architecture for mobile networks is that requests for content can be satisfied by exploring neighboring caches (that may have cached a copy of the requested content), even if a direct route between user and custodian is unavailable due to node mobility. In comparison, in a traditional network setting where network nodes do not cache content, absence of a route implies that no requests can be served. Therefore, for the requests that cannot be served due to unavailability of a route, we explore the benefits of a random walk based stateless request forwarding strategy. If a route between a user and custodian is available, requests are forwarded toward the custodian along the shortest path. In case a route is unavailable, the user randomly selects one of its neighbors to forward the request. This process is continued until either the requested content is obtained or a predefined number of hops (i.e., time-to-live threshold) is reached, at which point the request is dropped. Our experiments demonstrate that using a simple random walk strategy when a direct path is unavailable, increases the percentage of requests served by 4 to 8%.

2 SIMULATION SETUP
To evaluate the benefits of caching in a mobile ICN, we conduct experiments on a grid topology. We conduct experiments on Icarus, a simulator designed for ICN research. In our experiments, we consider different number of users...
We use 25,000 requests to warm up the caches and then use another 100,000 requests to measure performance. Network cache ratio (ratio of cache size considering all network nodes to the content universe size) ranges from 0.015 to 0.035. Each data point in our simulation is obtained as an average over 50 iterations. In each iteration, different number of users (ranging 2 to 6) are placed at different positions on the grid. We use a skewness parameter $\alpha = 0.7$. We use LRU as the cache eviction policy. We evaluate the performance of the baseline LCE caching strategy and multiple state-of-the-art caching strategies - LCD, CL4M and ProbCache.

We note that we perform experiments on 5*5, 6*6 and 7*7 grid networks with varying levels of user mobility (i.e., nodes move after every 5000, 10,000 and 25,000 requests). Our conclusions are based on all experiments, but we present results for 7*7 grid with node mobility after every 5000 requests.

3 RESULTS

From our experiments, we observe that 43% of the total requests are dropped in a mobile scenario due to route unavailability. For the requests served by the custodian or caches en route to the custodian, we study the hop count and the cache hit ratio. Hop count is defined as the average number of hops traversed by a request before it is served. From Figure 1(a), we observe that all the state-of-the-art caching strategies perform better than LCE in static networks. However, from Figure 1(b), we see that all caching strategies including LCE show similar performance in mobile networks. Additionally, we observe that the average benefit of in-network content caching for state-of-the-art caching strategies over a network that has no caches is only 9.2% in mobile networks in comparison to 19.6% in static networks. We also observe that the cache hit ratio is higher for static networks in comparison to mobile networks. We omit these results due to lack of space. We note that considering only the requests served, the number of hops needed to serve requests in mobile networks is lower than static networks. This is because node mobility causes route unavailability when the geographical distance between the user and custodian is relatively high.

For users that do not have a direct route to the custodian, we explore the benefit of using a random walk approach for serving requests by searching the neighboring caches. Figure 2 shows the additional percentage of requests served after using random walk. We study the performance gains of the random walk strategy by varying the search radius (i.e., 3, 4, 5 and 6 hops). From Figure 2, we observe a performance increase between 4% to 8% for different strategies.

Our results demonstrate that even a simple stateless forwarding strategy such as random walk can provide significant improvement in the percentage of requests served in mobile ICNs. As part of our future work, we plan to compare the performance of stateless forwarding (e.g., random walk, flooding) and stateful forwarding in mobile ICNs. We also plan to design efficient request routing and caching strategies to improve user performance in mobile ICNs.

4 CONCLUSION

In this paper, we studied the benefit of in-network caching in mobile ICNs. We found that the state-of-the-art caching strategies show similar performance as network mobility increases. We also observed that 43% requests were dropped because of absence of routes between users and custodian. For such requests, we studied that adopting a random walk approach for searching content in neighboring caches has an average increase of 6% in the number of requests served.

REFERENCES
