MobiStore: Achieving Availability and Load Balance in a Mobile P2P Data Store

Mohammad A. Khan* Laurent Yeh† Karine Zeitouni† Cristian Borcea*

* Department of Computer Science, New Jersey Institute of Technology, University Heights, Newark, New Jersey, 07102, USA
Email: mak43@njit.edu, borcea@njit.edu

† Department of Computer Science, University of Versailles Saint-Quentin-en-Yvelines, Versailles 7800, France
Email: laurent.yeh@prism.uvsq.fr, karine.zeitouni@prism.uvsq.fr

***Abstract*—MobiStore is a P2P data store for decentralized mobile computing, designed to achieve high availability and load balance. MobiStore uses redundant peers to compensate for churn and high link variability specific to mobile wireless networks. It structures the P2P network into clusters of mobile peers that replicate stored content, thus achieving high availability. Load balance is achieved through consistent hashing, randomization of request distribution, and load adaptive cluster management. Furthermore, MobiStore can route lookup requests in $O(1)$ hops. Simulation results show MobiStore achieves an availability, i.e., lookup success rate, between 1.2 and 5 times higher than a baseline system built over the well-known Chord P2P protocol; it also reduces the latency up to 5 times compared with the baseline.**

Keywords*—*Mobile P2P storage, availability, load balance.

I. Introduction

Smart phones and tablets are quickly becoming the main computing devices in our daily life. The amount of mobile user-generated content and mobile sensing data will become very large in the near future. Instead of letting service providers collect user data, many users would like to own and control their mobile data. This scenario lends itself naturally to mobile peer-to-peer (P2P) computing which enables direct and scalable collaboration among mobile users.

Despite all the advances in traditional P2P networks, there is still a dearth of efficient solutions for mobile P2P networks in which peers connect to the Internet over cellular or WiFi links. The technical difficulties arise from two main aspects: (1) higher churn due to short wireless sessions, which are the results of mobility or user choice (e.g., turning off the device to save power), and (2) link quality variability as bandwidth and latency change drastically based on the current point of attachment. The question, then, is: can existing P2P solutions for wired devices work well in a mobile environment?

Structured P2P solutions using DHTs maintain rigorous geometric topologies for routing resiliency. But these topologies require constant maintenance which substantially increases the overhead in the presence of high churn. Furthermore, churn can make routing tables inconsistent, and this increases lookup latency and failure rates and can even partition the network [1]. Unstructured P2P solutions do not work in this type of environment due to their low efficiency. Thus, current P2P based solutions are inadequate for mobile P2P computing.

As the number of mobile devices is ever increasing, MobiStore explores the idea of using redundant peers and clustering to compensate for P2P churn and link level variability. While these techniques are well known, our main contribution is on the novel way of applying them to design and implement an efficient mobile P2P data store.

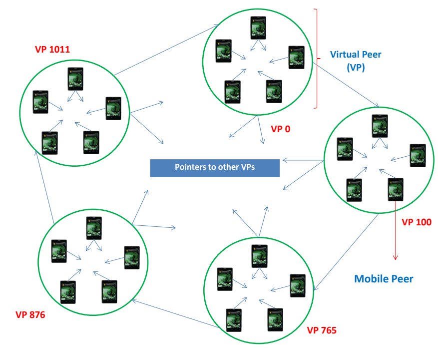

Fig. 1: Structural overview of MobiStore

II. Overview of MobiStore

MobiStore structures the P2P network into a stable ring of Virtual Peers (clusters of multiple peers) using DHT. Figure 1 shows the high level structure of MobiStore. The mobile peers in each Virtual Peer (VP) replicate the keys and data assigned to their VP. Thus, any VP member can answer queries for its VP. VPs are not affected by high churn as long as at least one mobile peer assigned to each VP is online. A lazy protocol is used to maintain weak consistency of the stored content among VP members. As multiple members can answer the same queries, the effect of individual churn is minimized.

Routing on the outer ring is fast, $O(1)$, and has very high probability of success. To simplify routing, the VPs have static IDs, managed by MobiStore seamlessly in a decentralized manner. Similarly, mobile peers are assigned static IDs at the time they first join the network, thus decoupling peer naming from IP addresses. In this way, rejoining the network incurs reduced overhead because under normal conditions mobile peers re-join the same VP they have previously left. To minimize the required bandwidth for topology management update propagation, MobiStore uses a hierarchical update process (intra-VP and inter-VP).

Load balance is achieved through three methods: (1) consistent hashing to store data in VPs, (2) randomization for each operation to spread to load evenly (exploiting redundancy) and to limit the effect of temporary failures, and (3) load adaptive VP management which varies the number of peers in the VP proportional to the bandwidth needed to answer the queries.

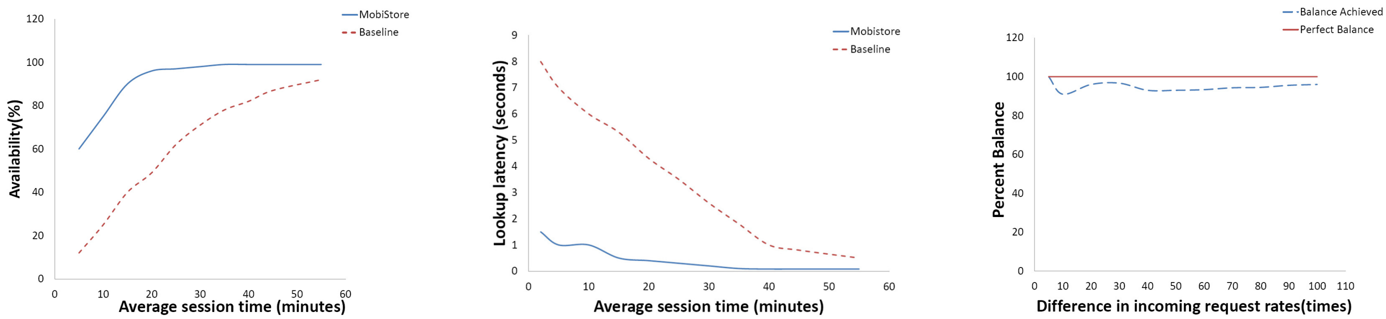

Fig. 2: From left to right: (1) Availability of MobiStore vs. Baseline as measured by lookup success rate; (2) Lookup latency of MobiStore vs. Baseline; (3) Fraction of peers in MobiStore receiving almost the same load ($\pm 10\%$ mean-load)

III. Evaluation

We evaluated MobiStore with simulations over 10,000 peers. A number of 2^{22} keys are stored in the network. The number of peers inside VPs are varied from 5 to 25. On average, 30% of peers use cellular communication at 500 Kbps, while the rest use WiFi communication at 8 Mbps. The speed of the peers varies randomly in the range 0.2-20 meters per second. The peers leave the network at exponentially distributed intervals with session time ranging from 2 minutes to 1 hour to mimic the short session time of mobile devices. After completing an active session, peers leave the P2P network for periods ranging from 0 to 20 minutes.

In order to understand the benefits of MobiStore's design over existing P2P solutions, we compared MobiStore against a Baseline data store built over Chord [2]. The number of peers, content replication policy, and lookup failure policy (3 retries before declaring a failure) are the same for both systems.

Availability The first graph in Figure 2 shows that MobiStore has a substantially higher availability than the Baseline, especially for shorter sessions. For example, MobiStore has 90% success rate for a 15-minutes session time, while Baseline has 40%. Also, MobiStore has high availability for sessions longer than 20 minutes. The results confirm that well managed redundancy improves the availability significantly.

Latency: The second graph in Figure 2 shows that MobiStore achieves a latency as low as 5 times the latency of the Baseline. This is due mostly to the routing done in $O(1)$ hops. We also observe that MobiStore's latency is quite acceptable for most mobile applications. Even for an average session of 15 minutes, the latency is as low as half a second.

Load Balance: The third graph in Figure 2 shows that 90%-95% of the peers receive a load close to the hypothetical perfect load. This result demonstrates the benefits of the three techniques used to balance the load in our system.

IV. Related work

Load balancing for P2P systems has been discussed [3], but these solutions increase the background traffic too much to work for wireless systems. Systems such as [4] also use multiple peers to address the issues of churn, but do not consider content availability or load balance. C-Chord [5], Chordella [6], and MR-Chord [7] are comparatively newer mobile P2P systems. C-Chord is not general enough for a mobile P2P platform as it is a cellular network only solution. Chordella, on the other hand, relies on fixed devices (PCs) to maintain the DHT ring, while MobiStore provides a mobile-only solution. MR-Chord improves the consistency of the original Chord routing at the expense of extra-overhead. MobiStore reduces the impact of inconsistency using less bandwidth. Furthermore, unlike all these systems, MobiStore improves the content availability and balances the load in the network.

V. Conclusion

This paper presented MobiStore, a mobile P2P data store for sharing user-generated mobile content. The results demonstrate that MobiStore achieves high availability, low latency, and good load balance, without incurring high overhead that could impact negatively the performance in relatively large scale networks. MobiStore is ideal for applications which can tolerate worst case key-value update delays of several seconds.

Acknowledgment

This research was supported by the National Science Foundation under Grant No. CNS 1409523. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

References

[1] S. Rhea, D. Geels, T. Roscoe, and J. Kubiatowicz, "Handling Churn in a DHT," in *Proceedings of the USENIX Annual Technical Conference*, 2004, pp. 127–140.

[2] I. Stoica, R. Morris, D. Karger, M. F. Kaashoek, and H. Balakrishnan, "Chord: A Scalable Peer-to-peer Lookup Service for Internet Applications," *ACM SIGCOMM Computer Communication Review*, vol. 31, no. 4, pp. 149–160, 2001.

[3] B. G. Karthik, K. Lakshminarayanan, S. Surana, R. Karp, and I. Stoica, "Load Balancing in Dynamic Structured P2P Systems," in *Proceedings of IEEE INFOCOM*, 2004, pp. 2253–2262.

[4] J. W. Lee, H. Schulzrinne, W. Kellerer, and Z. Despotovic, "mDHT: Multicast-augmented DHT Architecture for High Availability and Immunity to Churn," in *Proceedings of IEEE Consumer Communications and Networking Conference*, 2009, pp. 1–5.

[5] M. Zulhasnine, C. Huang, and A. Srinivasan, "Towards an Effective Integration of Cellular Users to the Structured Peer-to-Peer Network," *In Peer-to-Peer Networking and Applications*, vol. 5, no. 2, pp. 178–192, 2012.

[6] Q. Hofstatter, S. Zols, M. Michel, Z. Despotovic, and W. Kellerer, "Chordella - A Hierarchical Peer-to-peer Overlay Implementation for Heterogeneous, Mobile Environments," in *Proceedings of the 8th International Conference on Peer-to-Peer Computing*, 2008, pp. 75–76.

[7] I. Woungang, F.-H. Tseng, Y.-H. Lin, L.-D. Chou, H.-C. Chao, and M. S. Obaidat, "MR-Chord: Improved Chord Lookup Performance in Structured Mobile P2P Networks," *IEEE Systems Journal*, pp. 1–9, 2014.