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RESEARCH ARTICLE

Cache Replacement Algorithms for Coordinated Cooperative Social Wireless Networks

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Abstract: Cooperative caching is a technique used in mobile ad hoc networks to improve the efficiency of information access by reducing the access latency and bandwidth usage. Cache replacement policy plays a significant role in response time reduction by selecting suitable subset of items for eviction from the cache. In this paper we have made a review of the existing cache replacement algorithms proposed for cooperative caching in a social wireless networks. We made an attempt to classify existing replacement policies for social wireless networks based on the replacement decision taken. In addition, this paper suggests some alternative techniques for cache replacement. Finally, the paper concludes with a discussion on future research directions.
Keywords: Data Caching, Cache Replacement, SWNETs, Cooperative caching, content provisioning, ad hoc networks

1. INTRODUCTION

RECENT emergence of data enabled mobile devices and wireless-enabled data applications have fostered new content dissemination models in today's mobile ecosystem. A list of such devices includes Apple's iPhone, Google's Android, Amazon's Kindle, and electronic book readers from other vendors. The array of data applications includes electronic book and magazine readers and mobile phone Apps. The level of proliferation of mobile applications is indicated by the example fact that as of October 2010,Apple's App Store offered over 100,000 apps that are downloadable by the smart phone users.

Wireless mobile communication is a fastest growing segment in communication industry[1]. It has currently supplemented or replaced the existing wired networks in many places. The wide range of applications and new technologies [5] simulated this enormous growth. The new wireless traffic will support heterogeneous traffic, consisting of voice, video and data. Wireless networking environments can be classified in to two different types of architectures, infrastructure based and ad hoc based. The former type is most commonly deployed one, as it is used in wireless LANS and global wireless networks. An infrastructure based wireless network uses fixed network access points with which mobile terminals interact for communication and this requires the mobile terminal to be in the communication range of a base station. The ad hoc based network structure alleviates this problem by enabling mobile terminals to cooperatively form a dynamic network without any pre existing infrastructure. It is much convenient for accessing information available in local area and possibly reaching a WLAN base station, which comes at no cost for users.

Mobile terminals available today have powerful hard ware, but the capacity of the batteries goes up slowly and all these powerful components reduce battery life. Therefore adequate measures should be taken to save energy. Communication is one of the major sources of energy consumption. By reducing the data traffic energy can be conserved for longer time. Data caching has been introduced[10] as a techniques to reduce the data traffic and access latency. By caching data the data request can be served from the mobile clients without sending it to the data source each time. It is a major technique used in the web to reduce the access latency. In web, caching is implemented at various points in the network. At the top level web server uses caching, and then comes the proxy server cache and finally client uses a cache in the browser.

This paper provides algorithms, for Energy efficient cooperative cache replacement in wireless networks. The topic of caching in ad hoc networks is rather new, and not much work has been done in this area. The replacement policies for MANETs are classified into two groups uncoordinated and coordinated. In uncoordinated replacement, the data item to be evicted is determined independently by each node based on its local access information. In coordinated replacement policy, the mobile node which forms cooperative cache collectively takes the replacement decision. This paper discusses about coordinated replacement policy.

2. RELATED WORK

There is a rich body of the existing literature on several aspects of cooperative caching including object replacements, reducing cooperation overhead, cooperation performance in traditional wired networks. The Social Wireless Networks explored in this paper, which are often formed using mobile ad hoc network protocols, are different in the caching context due to their additional constraints such as topological insatiability and limited resources. As a result, most of the available cooperative caching solutions for traditional static networks are not directly applicable for the SWNETs. Three caching schemes for MANET have been presented [9][11]. In the first scheme, Cache Data, a forwarding node checks the passing-by objects and caches the ones deemed useful according to some predefined criteria. This way, the subsequent requests for the cached objects can be satisfied by an intermediate node. A problem with this approach is that storing large number of popular objects in large number of intermediate nodes does not scale well. The second approach, Cache Path, is different in that the intermediate nodes do not save the objects; instead they only record paths to the closest node where the objects can be found. The idea in Cache Path is to reduce latency and overhead of cache resolution by finding the location of objects. This strategy works poorly in a highly mobile environment since most of the recorded paths become obsolete very soon. The last approach in is the Hybrid Cache in which either

Cache Data or Cache Path is used based on the properties of the passing-by objects through an intermediate node. While all three mechanisms offer a reasonable solution, and that relying only on the nodes in an object's path is not most efficient. Using a limited broadcast-based cache resolution can significantly improve the overall hit rate and the effective capacity overhead of cooperative caching. According to the protocols the mobile hosts share their cache contents in order to reduce both the number of server requests and the number of access misses. The concept is extended in for tightly coupled groups with similar mobility and data access patterns. This extended version adopts an intelligent bloom filter-based peer cache signature to minimize the number of flooded message during cache resolution. A notable limitation of this approach is that it relies on a centralized mobile support center to discover nodes with common mobility pattern and similar data access patterns. The work, on the contrary, is fully distributed in which the mobile devices cooperate in a peer-to-peer fashion for minimizing the object access cost. In summary, in most of the existing work on collaborative caching, there is a focus on maximizing the cache hit rate of objects, without considering its effects on the overall cost which depends heavily on the content service and pricing models.Two object replacement mechanisms are formulated to minimize the provisioning cost, instead of just maximizing the hit rate. Also, the validation of our protocol on a real SWNET interaction trace with dynamic partitions, and on a multiphone Android prototype is unique compared to the existing literature. Its impacts and mistreatment on caching. A mistreated node is a cooperative node that experiences an increase in its access cost due to the selfish behavior by other nodes in the network. In, Chun et al study selfishness in a distributed content replication strategy in which each user tries to minimize its individual access cost by replicating a subset of objects locally (up to the storage capacity), and accessing the rest from the nearest possible location. Using a game theoretic formulation, the authors prove the existence of a pure Nash equilibrium under which network reaches a stable situation. Similar approach has been used in which the authors model a distributed caching as a market sharing game.

The work in this paper has certain similarity with the above works as we also use a monetary cost and rebate for content dissemination in the network. However, as opposed to using game theoretic approaches. Analysis of selfishness in the work is done in a steady state over all objects whereas the previous works mainly analyze the impact of selfishness only for a single data item.

3. Network Model, Cache Replacement Policies

3.1 NETORK MODEL

Fig. 1 illustrates an example SWNET within a University campus. End Consumers carrying mobile devices form SWNET partitions, which can be either multi-hop (i.e., MANET) as shown for partitions 1, 3, and 4, or single hop access point based as shown for partition 2. A mobile device can download an object (i.e., content) from the CP's server using the CSP's cellular network, or from its local SWNET partition. Two types of SWNETs are considered. The first one involves stationary SWNET partitions. Meaning, after a partition is formed, it is maintained for sufficiently long so that the cooperative object caches can be formed and reach steady states. Second type is also investigated to explore as to what happens when the stationary assumption is relaxed. To investigate this effect, caching is applied to SWNETs formed using human interaction traces obtained from a set of real SWNET nodes.

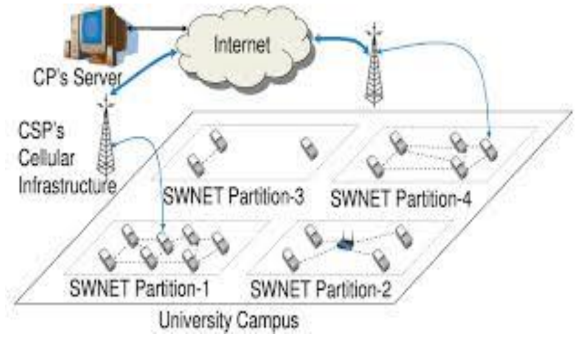

Fig. 1. Content access from an SWNET in a University Campus.

3.2 Cache Replacement

Caching in wireless environment has unique constraints like scarce bandwidth, limited power supply, high mobility and limited cache space. Due to the space limitation, the mobile nodes can store only a subset of the frequently accessed data. The availability of the data in local cache can significantly improve the performance since it overcomes the constraints in wireless environment. A good replacement mechanism is needed to distinguish the items to be kept in cache and that is to be removed when the cache is full. While it would be possible to pick a random object to replace when cache is full, system performance will be better if we choose an object that is not heavily used. If a heavily used data item is removed it will probably have to be brought back quickly, resulting in extra overhead. So a good replacement policy is essential to achieve high hit rates. The extensive research on caching for wired networks can be adapted for the wireless environment with modifications to account for mobile terminal limitations and the dynamics of the wireless channel.

3.3 Cache Replacement Policies in Ad hoc networks

Data caching in MANET is proposed as cooperative caching. In cooperative caching the local cache in each node is shared among the adjacent nodes and they form a large unified cache. So in a cooperative caching environment, the mobile hosts can obtain data items not only from local cache but also from the cache of their neighboring nodes. This aims at maximizing the amount of data that can be served from the cache so that the server delays can reduced which in turn decreases the response time for the client. In many applications of MANET like automated highways and factories, smart homes and appliances, smart class rooms, mobile nodes share common interest. So sharing cache contents between mobile nodes offers significant benefits. Cache replacement algorithm greatly improves the effectiveness of the cache by selecting suitable subset of data for caching. The available cache replacement mechanisms for ad hoc network can be categorized into Coordinated and uncoordinated depending on how replacement decision is made. In uncoordinated scheme the replacement decision is made by individual nodes. In order to cache the incoming data when the cache is full, replacement algorithm chooses the data items to be removed by making use of the local parameters in each node.

3.4 Split Cache Replacement

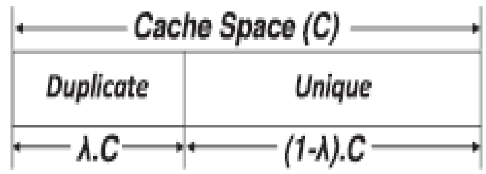

Fig.2. Cache partitioning in split cache policy.

To realize the optimal object placement under homogeneous object request model The following Split Cache policy is proposed in which the available cache space in each device is divided into a duplicate segment (**λ** fraction) and a unique segment (see Fig. 2). In the first segment, nodes can store the most popular objects without worrying about the object duplication and in the second segment only unique objects are allowed to be stored. The parameter **λ** in Fig. 2 ($0 \leq \lambda \leq 1$) indicates the fraction of cache that is used for storing duplicated objects.
With the Split Cache replacement policy, soon after an object is downloaded from the CP's server, it is categorized as a unique object as there is only one copy of this object in the network. Also, when a node downloads an object from another SWNET node, that object is categorized as a duplicated object as there are now at least two copies of that object in the network.

For storing a new unique object, the least popular object in the whole cache is selected as a candidate and it is replaced with the new object if it is less popular than the new incoming object. For a duplicated object, however, the evictee candidate is selected only from the first duplicate segment of the cache. In other words, a unique object is never evicted in order to accommodate a duplicated object.

3.5. Performance Metrics

Caching in wireless networks deals with data items of different costs and sizes. Performance measures used should consider this non uniformity. It is not possible to identify a best replacement policy as different schemes uses different optimization strategy. The typical measures used to analyze the cache replacement policy are hit ratio, byte hit ratio and delay Savings ratio [1]. Let Si be the size of the data item i, Ci the cost of fetching the data item i into the cache, Ri the total number of references made to data item i, Hi the number of hit references made to data item i and Di is the delay time to fetch the data item i from the original data source to cache. Cache hit ratio defines the number of references made from the cache over the total number of references. It is a metric used in traditional caching systems like operating systems and database which handles data of uniform size, which may not be reliable metric for data items with varying size and cost. Byte hit ratio represents the number of bytes saved from retransmission by using the cache over the total number of bytes referenced. Delay savings Ratio represents the reduced latency by using a cache over the total latency when cache is not used. Due to the inconsistency in download time due to traffic variations, performance results based on this metric may vary.

$HR = \sum Hi / \sum Ri$

$BHR = \sum Si.\ Hi / \sum Si.\ Ri$

$DSR = \sum Di\ Hi / \sum Di.\ Ri$

4. Dynamic Partitioning Coordinated Cooperative Cache Replacement Algorithms for Social Wireless Networks

4.1 Coordinated Cache replacement Policies

Coordinated cache replacement strategy for cooperative caching schemes in mobile environments should ideally consider cache admission control policy. Cache admission control decides whether the incoming data is cacheable or not. Substantial amount of cache space can be saved by proper admission control, which can be utilized to store more appropriate data, thereby reducing the number of evictions. If a node doesn't cache the data that adjacent nodes have it can cache more distinct data items which increase the data availability. There is coordination between the neighboring nodes for the proper placing of data. Another feature of coordinated replacement is that the evicted data may be stored in neighboring nodes which have free space. Some of the replacement policies which make use of coordinated cache replacement are given below.

4.1.1 N-chance

The N-chance algorithm dynamically partitions the cache of each client between blocks needed by the local client and the cooperative cache. Managers are responsible for maintaining consistency and block location information. The replacement policy in N-chance uses a combination of local LRU information and duplicate avoidance to decide the best block to replace. Clients always replace the oldest block on their LRU lists. Whether the client forwards or discards the oldest block depends on the number of copies of the block. Blocks with more than one copy are discarded, while blocks with only one copy, or *singlets* are forwarded to another client at random. If a client does not know whether or not one of its blocks is a singlet, it simply asks the manager.

5. Discussion and Future Work

Most of the replacement algorithms used in ad hoc networks is LRU based which uses the property of temporal locality. This is favorable for MANET which is formed for a short period of time with small memory capacity. Frequency based algorithms will be beneficial for long term accesses. It is better if the function based policies can adapt to different workload condition. In these schemes if we are using too many parameters for finding the value function, which are not easily available the performance can be degraded. Most of the replacement algorithms mentioned above uses cache hit ratio as the performance metric. In wireless network the cost to download data item from the server may vary. So in some cases this may not be the best performance metric. Schemes which improve cache hit ratio and reduce access latency should be devised. In cooperative caching coordinated cache replacement is more effective than local replacement since the replacement decision is made by considering the information available in the neighboring nodes. The area of cache replacement in cooperative caching has not received much attention. Lot of work needs to be done in this area to find better replacement policies.

Algorithm	**N-chance**	**GMS**
Cache Consistency	Block-based	None
Block Location	Manager-based	Manager-based
Replacement Policy	Random Client	Manager-based LRU
Duplicate Avoidance	Non-singlets deleted	Non-singlets deleted
Server Caching	Traditional	Traditional

Table.1 key features of the N-chance, GMS

6. Conclusion

General comparisons were made of the major replacement policies in wireless networks and summarized the main points. Numerous replacement policies are proposed for wireless networks, but a few for cooperative caching in ad hoc networks. The operation, strengths and drawback of these algorithms are summarized. Finally some alternatives are provided for cache replacement and identified topics for future research.

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