Cooperative Caching Schemes in MANETs and VANETs: A Comparative Analysis

Nisha Wadhawan
Research Scholor
Jagannath University, Jaipur

Dr. Y.S Shishodia
Pro V.C,Faculty of IT
JaganNath University, Jaipur

Dr. Meenu dave
Dean, Faculty of IT
JaganNath University, Jaipur

Menu.s.dave@gmail.com
anisha.wadhawan@yahoo.co.in

Abstract:
Vehicular Adhoc Networks area subset of Mobile Adhoc networks,formed by high-speed moving vehicles without any permanent infrastructure. Vehicles in the network can share information with each other regarding road traffic, weather conditions, and other security information. As vehicles move at speed, frequent disconnections and dynamic topology are the main features of VANETs. Data dissemination in such an environment is quite difficult. One solution to this problem is caching. Proactively caching the data before it is requested minimizes the latency and also reduces the number of uplink requests to the server for the latest data. In this paper, we are discussing a number of cooperative caching techniques existing in VANETs.

DOI Number: 10.14704/NQ.2022.20.12.NQ77216 **NeuroQuantology2022;20(12): 2400-2407**

1. Introduction

VANETs have become a popular area of research in the recent past. In VANETs vehicles communicate with each other to share information (Rajeev Tiwari, Neeraj Nehra, 2015). In VANETs, Vehicles have Internet accessibility through IEEE 802.11, and each vehicle act as a node thatshares its data with other vehicles in the network. At the same time, it can also collect information from them. VANETs are characterized by dynamic topology as vehicles move at high speed. Continuous changing topology causes higher delays. Network delay can be reduced and the overall performance of Internet-based VANETs (IVANETs) can be improved, if requested data items can be prefetched in the vehicle's storage. In VANETs, vehicles don't have storage constraints as they have their own storage space. So caching of data is not a problem with vehicles but the main issue is the dissemination of the latest and most consistent data. All nodes must have latest and consistent data, so that vehicles don't use any old and inconsistent data. Caching and prefetching of data nearer to the vehicles reduce requests to the server and decrease communication costs.It will reduce latency and improve QoS (Quality of service).

The ideal solution to longer delays is cooperative caching. It will not only increase the efficiency of VANETs but also reduce bandwidth consumption a. It is the technique that impacts caching efficiency. In Cooperative caching mobile nodes cache the popular data and share it with other nodes in the vicinity. In mobile ad hoc networks, if there will be a cache miss, it may initiate a series of cache misses. A cache miss can be avoided by prefetching data,which plays an important role to reduce delay. Moving vehicles may have a common interest as mobile nodes in ad-hoc networks. So vehicles can prefetch the data, can store them in their cache andcan share this data, so that the data requests to the server can be reduced. Combining caching with prefetching can further improve response time. Cooperative caching schemes discussed here assumes the integration of both strategies to improve the network performance. Cooperative caching strategies of MANETs guide for the study of Cooperative Caching strategies in VANETs also.

In this paper, we are providing detailed information regarding cooperative caching schemes in MANETs and VANETs. In section II we have discussed the concept of cooperative caching. Section III gives detailed information about caching techniques in MANETs. In section IV we have provided details regarding caching schemes in VANETs and in section V we have concluded the paper.

2. Cooperative Caching

Data availability and data discovery in mobile environment is very important. Latest and updated data is a key requirement in adhoc network environment. The major concern in mobile computing environments is data availability. In mobile networks, availability of consistent and latest data is possible through caching. In Adhoc networks where nodes are continuously changing their location and sharing the information, cached environment would be more beneficial. As the requested data items are being made available by vehicle's local cache, frequency of data requests to the server will be reduced. Cooperative caching has the potential to improve efficiency of the caching techniques. Cooperation among the peer vehicles as well as between the neighbouring gateways can also enhance the efficiency and can reduce the uplink requests.

In cooperative caching, multiple nodes are associated with each other as a group or cluster and they share their cached data to improve the data availability. As these node clusters have distributed caches, it further improves their performance. The nodes in a cluster cooperate with each other. It is the individual node or control node which decides what to store and for how long. In different caching techniques, nodes that participate in cooperative caching are selected based on different criterion. In a geographical area, Cooperative caching allows neighbour nodes to share their cached content locally to reduce uplink requests to server. It also reduces the network congestion, improves bandwidth and reduces cost. The requirement here is that each node must be aware of the presence of required data in its vicinity. In cooperative caching, network's node serves data requests from its local cache, as well as it shares its data with its neighbouring nodes to serve data requests.

3. Cooperative caching scheme in MANETs

MANETs are Mobile Adhoc Networks in which mobile nodes form spontaneous networks without any infrastructure. As the nodes are moving there are frequent disconnections. Availability of updated and latest data is a challenge. Caching is an ideal solution for such an environment. Data cached at one node can be shared among nodes in the network. It will reduce the number of requests to the server. The mobile nodes in MANETs have storage constraints and stored data will be inconsistent with the passage of time. Updating the data is another challenge.A number of caching strategies have been discussed in MANETs considering all such issues. The cooperating caching schemes in MANETs assume that the moving nodes interact with each other and form a group and they share information when required. These cooperating schemes are different from each other in the context of architecture, Cache Discovery, Cache Admission and Cache-Control policies and can be categorized as follows:

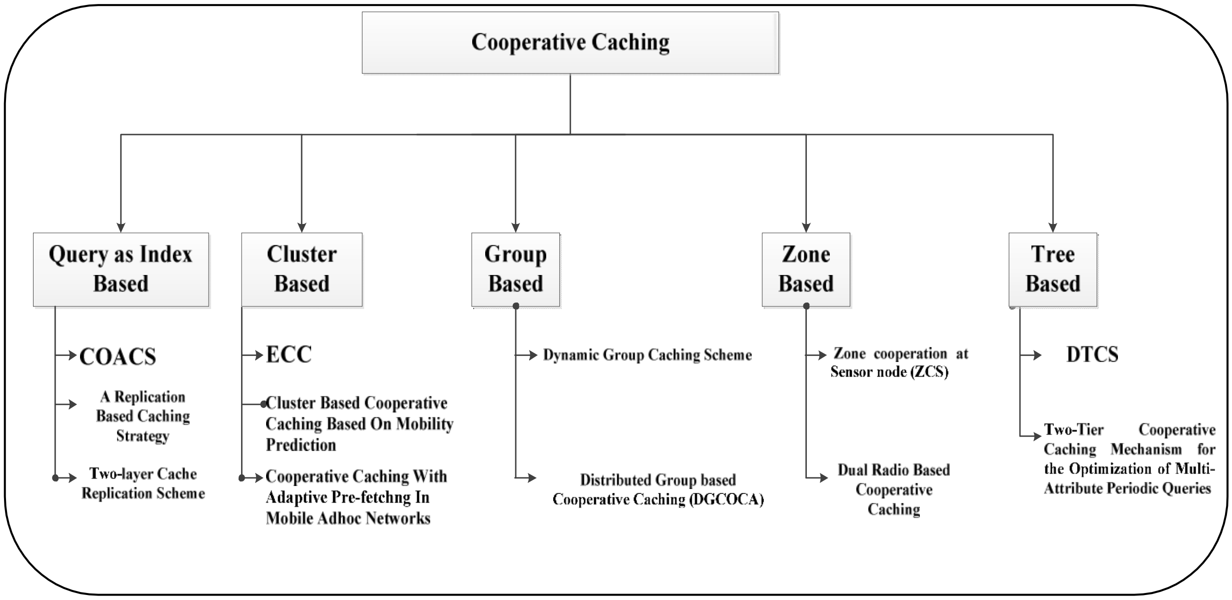

Figure 1Categorization of Caching Schemes in MANETs

In (Artail, 2008), three main caching schemes were discussed: CachePath, CacheData, and HybridCache. The idea behind was to analysethe data requests. Depending upon the data item request it is decided whether tocache data or cache the path of the node, where the requested data is stored.If the data request comes to a node, the node can provide the data or can forward the request through the stored path. CachePath scheme saves space by storing the path to the data, whereas CacheData reduces the query time by storing the data instead of the path. The third scheme is Hybrid Cache,which is an enhancement to the previous two schemes and it includes the benefits of both schemes. In this scheme, node either stores the data items or the path to the required data items depending upon certain criteria. These criteria are the size of the data item, the popularity of the data item, and their TTL (Time to Live) value. If the size of the data item is small, CacheData is used, as small data items can be easily incorporated into the available cache. If the data items are of large size, Cache Path is used.

(Artail, Safa, Mershad, Atme, & Sulieman, 2008)have introduced in their paper, a cooperation-based database caching system, COACS, for Mobile Ad Hoc Networks (MANETs), which stands for Cooperative and Adaptive Caching. In this scheme the nodes that cache submitted queries. The queries are used as indexes to data cached in nodes that previously requested them. The main idea is to create a cooperative caching system to minimize delay and maximize the possibility of finding data that is cached in the ad hoc network, without encouragingunreasonable large traffic at the nodes.

In Aggregate caching scheme, proposed in (Lim, Lee, Cao, & Das, 2003).In this scheme, MTs (Mobile terminals) are divided in to groups or clusters. Mobile nodes can cache the data locally and their local caches can be aggregated as a unified large cache. A MT cannot make a decision regarding caching a data item, as this will be the decision of neighbouring nodes, because there is an aggregated cache of these nodes. In this scheme, data discovery is done by broadcasting the required data request to all the neighbor nodes of requester node. If a neighbor node has a data item, then a reply will be sent by the neighbor node. Otherwise, it will forward the request on the route. In this way, a request is broadcasted to nodes in the network and eventually fulfilled by some nodes which have the requested data item in their caches.

Proactive Cooperative Caching approach, Zone cooperative caching discussed in (Chand, Joshi, & Misra, 2006) proposes a scheme in which MTs will cooperate in a zone and a controller node called zone manager will keep a CIT (Caching Information Table). A Zone consists of neighbor nodes that have onehop distance from each other. So a cooperative cache system is formed of mobile nodes belonging to the same zone. The zone manager decides which data is to be cached and stores it in the CIT. The data items in the client's cache answers client own requests as well as the requests from the neighbor clients, passing through it. If there is a cache miss, MT first searches for the data in its zone. The request will be forwarded to the zone manager instead of the server.

Group Caching (GC) scheme proposed in (Joonho, Oh, & Jeemyoung, 2003) assumes that each node will maintain the status of local as well as group cache. A group consists of node's 1-hop neighbors. This group will be formed by the mobile node and its 1-hop neighbors by sending the "Hello" messages to each other. Group caching status is maintained by the nodes in the group as they periodically update their caching status in a group. In this way, the cache space of each node in a group is utilized. Each mobile node is aware of cache space of its neighbor node by checking the cache status of the group, the IDs and timestamp values of data items cached in neighbor nodes. By checking this status a mobile host is selected for cache placement and cache replacement. The cache replacement is done on the basis of Least Recently Used (LRU) policy and a cache consistency is verified by Time to Live (TTL) factor.

Narottam Chand et. al proposed GCC (Group Cluster Cooperation) scheme in (Chand, Joshi, & M, 2006) which is an enhancement of zone caching. GCCP (Global Cluster Cooperative Caching with Prefetching) proposed in (P R & Kumar, 2015) was further improvement to GCC, by including data prefetching with caching. In this scheme prefetching is proposed. Prefetching reduces the query delay and improves cache hit.In their research they proposed the exploitation of caching and prefetching strategies to improve the

Caching Scheme Categories	**Caching Schemes Specifications**				
	Centralized/ Decentralized	**Cache admission Control**	**Data Discovery**	**Cache Replacement**	**Cache Consistency**
Cache Data /Path Hybrid cache	Decentralized	Based on no of hops	By message exchange	Based on distance and access frequency	TTL based
COOP	Decentralized	Based on no of hops	Adaptive flooding	LRU	TTL based
Neighbor Caching	Decentralized	Not Present	Neighbor nodes address stored in local node	LRU	Not Present
Zone Cooperative	Decentralized	Based on distance no of hops	Broadcast request to neighbors	Value Based	TTL based
Group Caching	Centralized	Based on group member status	Search in local table and group table	LRU	TTL based
Aggregate Cache	Decentralized	Based on No of hops	Broadcast based simple search	Based on distance and access frequency	Not Present

Table 1 Specifications of Caching Scheme in MANETs

performance of MANETs. Future data needs of MTs can be sensed and data can be pre fetched and can be kept in the cache. They have shown that GCCP approach is more effective than GCC scheme.

Dynamic Tree-based Consistency Scheme of cooperative caching, called DTCS, is proposed to address this issue. The nodes in MANET that host cooperative caches are organized into a ring with Chord as group management protocol. A virtual binary tree, called Chord tree, can be computed from the ring and then be adjusted into a temporary updating tree according to the location and routing information of the MANET nodes when an updating data item appears. The updated data item can be transmitted along the updating tree from the source nodes to the nodes hosting cooperative caches.

These caching major specifications and differences of these schemes are given in the above table.

4. Cooperative caching scheme in VANETs

VANETs are a subset of MANETs but with certain differences. VANETs are the networks formed by high speed moving vehicles, which doesn't have any energy constraint as vehicles have their own battery. VANETs are equipped with OBUs (On Board Units) so they have their own storage too. Though OBUs have storage and computing facilities still they need some sort of infrastructural support, which is provided by RSUs (Road Side Units) or base stations. There are two type of communication in VANETs, Vehicle to Vehicle i.e. V2V and Vehicle to Infrastructure i.e. V2I. In both cases, the challenge is the updated and consistent data. Data dissemination in VANETs is quite difficult due to frequent topology changes and disconnections.

Many researchers have proposed caching schemes considering mobility, location awareness, content popularity, and user demand patterns. In (Misra & Tourani, 2014) author proposed a broadcast base cache discovery scheme where the request is broadcasted in the network and the nodes having the request data will respond to the request. It is quite a simple technique but poses communication overheads in terms of bandwidth consumption (Varvello, Schurgot, & wang, 2013), proposed a server-based approach that is based on requesting the data at intermediate nodes encountered by request packet en route to the server.Group caching proposed in (Trambadiya, Ghosh, & Rathod, 2013) based on tracking the 1-hop neighbors. The nodes keep track of the cache contents of their 1-hop neighbors and cache their contents based on this information. These schemes reduce the delay and communication costs as compared to broadcast-based schemes.

A non-cooperative caching scheme is proposed in (Loulloudes, Pallis, & Dikaiakos, 2010). Caching is done at every intermediate node along the data delivery path. In (Hartenstein & Laberteaux, 2008)discussed the caching scheme in which caching is done at static nodes like RSUs at the intersections of the road.In (Camp & Davies, 2002) content popularity is considered. The caching is done considering the content popularity and the location of the requester and the receiver.
[13, social] talked about cluster caching where a node is considered as CH (Cluster Head).The cluster head is responsible for taking caching decisions.CH also communicates with the other vehicles through beacon messages. In (Ding, Wang, Song, Han, & Wu, 2015), three algorithms were proposed to reduce the network latency-optimal algorithm, sub-optimal algorithm andd greedy algorithm. In (Mahmood, Casetti, Chiasserini, Giaccone, & Harri, 2016)split caching is proposed. It will take much time to download a whole file, so split caching is proposed to break down a file in downloadable chunks. (Ma, Wang, Liu, & Fan, 2017) proposed cloud based vanets. In (Guan, Xiao, Feng, Shen, & Cimini, 2014) mobility impacts on caching are discussed.

Proactively prefetching popular data in Vehicle's cache is an impressive method to improve vehicular adhoc networks performance. Researches have done comparatively less work on cache prefetching methods in VANETs. . (Venkata, Padmanabhan, & Mogul, 1996) have discussed that prefetching is widely implemented in web environment to reduce query response time. (Jiang & Kleinrock, 1998)) had also put light on web prefetching .There are a number of techniques which concentrate on approximation of each file access probability in future. But these techniques are not appropriate. (Cao, 2002)has suggested a prefetching technique, where nodes count the number of times a cached data item is being accessed. They also record the number of times it is being prefetched. Then the prefetch access ratio (PAR) is calculated by dividing the no. of prefetches by the no. of accesses for each data item. If the value of PAR is less than one, then prefetching is beneficial otherwise it is not. A prefetching scheme proposed by (Gitzenis & Bambos, 2002) considered the wireless channel quality. It says that when signal strength is good clients prefetch aggressively but prefetch rate goes down when the signal strength is reduced.

(Yin & Cao, 2004)suggested a prefetching scheme termed value-based adaptive prefetch (VAP). This prefetch technique is a power aware scheme. This scheme considers the current energy level of clients. This scheme allows mobile nodes to dynamically adjust the no. of prefetches according to their existing energy level to lengthen the system running time. But all of these techniques have not considered the association between the Data items. (Song & Cao, 2004) stated in their research that cache misses have deep impact on data fetching events because a cache miss results in a number of cache misses. They proposed a cachemiss-initiated prefetching scheme. This prefetching technique is based on data mining. A prefetching strategy suggested by (Denko, 2007) has two levels. One level Prefetching is between caching agent and mobile node and second level is among caching node and a cluster head. There is another prefetching algorithm based on popularity prediction of data item. In this scheme the popularity of a data item is calculated and it is based on data item past access history. Another cooperative caching scheme was proposed by (Sailhan & Issarny, 2003).The aim of this scheme was to reduce the communication overheads and power consumption in fetching a web object. The communication is based on the concept of terminal profile. But if requested data correlation between mobile nodes is small, the impact of terminal profile will be lost.

5. Conclusion and Future Scope

In this paper, we have studied the existing caching techniques in MANETs and VANETs. In spite of certain differences, MANETs provided the base forcaching techniques in VANETs. It is observed that researchers have worked on the caching techniques considering the broadcast method. They also worked on cooperative caching and discussed cluster-based and zone based caching. But researchers have not talked much about location awareness and demand patterns of the users. The location awareness and demand prediction can further improve the existing caching schemes and reduce the communications overhead. In future, we will propose a caching technique depending on user's location and his data demands.

References

1. Camp , J., & Davies, V. (2002). A survey of mobility models for adhoc network research. *Wireless Communications and Mobile Computing*, 483-502.

2. Ding, R., Wang, T., Song, L., Han, Z., & Wu, d. (2015). "Roadside-unit caching in vehicular ad hoc networks for efficient popular content delivery. *IEEE Wireless Communications and Networking Conference*, (pp. 1207-1212).

3. Hartenstein , H., & Laberteaux, L. (2008). “A tutorial survey on vehicular adhoc Networks. *IEEE Communications Magazine,*, 164-171.

4. Artail, H., Safa, H., Mershad, K., Atme, Z., & Sulieman, N. (2008). Coacs: A Cooperative and Adaptive Caching system for MANETs. *IEEE Transaction on Mobile Computing*.

5. Cao, G. (2002). Proactive Power aware cache management for mobile computing systems. *IEEE Transactions on Computers*, 608-621.

6. Chand, N., Joshi, R., & M, M. (2006). Efficient cooperative caching in Adhoc networks. *IEEE Transaction*, 1-8.

7. Chand, N., Joshi, R., & Misra, M. (2006). Efficient Cooperative Caching in Adhoc Networks. *Communication System, software and Middleware*.

8. Denko, M. (2007). Cooperative Data caching and Prefetching in wireless Adhoc Networks. *International journal of Business Data communications and Networking*, 1-15.

9. Gitzenis, S., & Bambos, N. (2002). Power Controlled Data prefetching/caching in wireless packet networks. *INFOCOM.*

10. Guan, Y., Xiao, Y., Feng, H., Shen, C., & Cimini, L. (2014). “Mobicacher:Mobility-aware content caching in small-cell networks,”. *IEEE Global Communications Conference*, (pp. 4537-4542).

11. Jiang, Z., & Kleinrock, L. (1998). An adaptive Prefetch Scheme. *IEEE Sel Area Communication*, 358-368.

12. Joonho, C., Oh, S., & Jeemyoung, K. (2003). Neighbor Caching in Multihop Wireless adhoc networks. *IEEE communication Letters, 7*(11), 525-527.

13. Lim, S., Lee, W., Cao, G., & Das, C. (2003). A novel caching scheme for Internet Based Mobile adhoc Networks. *ICCCN.*

14. Loulloudes, N., Pallis, J., & Dikaiakos, M. (2010). Caching dynamic information in Vehicular Adhoc Networks. *Parallel Processing Springer*, 516-527.

15. Ma, J., Wang, J., Liu, G., & Fan, d. (2017). “Low latency caching placement policy for cloud-based vanet with both vehicle caches and rsu caches,”. *IEEE Globecom Workshops*, (pp. 1-6).

16. Mahmood, A., Casetti, C., Chiasserini, C., Giaccone, P., & Harri, d. (2016). “Mobility-aware edge caching for connected cars,”. *12th Annual Conference on Wireless On-demand Network Systems and Services*, (pp. 1-8).

17. Misra, S., & Tourani, R. (2014). Split Cache:A holistic Caching frameworkfor improved Network performancein wireless Adhoc Network. *IEEE Globol communications Conference*, (pp. 137-142).

18. P R, P., & Kumar, K. (2015). 2-Tier CoCS:a 2 tier cooperative caching scheme for Internet based Vehicular adhoc Netowrks. *Procedia computer science*, 84-90.

19. Rajeev Tiwari, Neeraj Nehra. (2015). Minimizing query delay using co-operation in IVANET. *Procedia Computer Science 57.*

20. Sailhan, F., & Issarny, V. (2003). Cooperative Caching in Adhoc networks. *International conference on Mobile data Management, springer.*

21. Song, H., & Cao, G. (2004). Cache miss initiated prefetch in Mobile enviroments. *IEEE international conference on IEEE.*

22. Trambadiya, S., Ghosh, P., & Rathod, J. (2013). Group Caching: A Novel proactive Caching schemefor Mobile Adhoc Networks. *International JournalEng. Res.Develop.*, 23-30.

23. Varvello, M., Schurgot, M., & wang, L. (2013). Scale: A Content-Centric MANET. *IEEE Conference on Computer Communications Workshop.*

24. Venkata, N., Padmanabhan, N., & Mogul, J. (1996). Using predictive caching to improve World wide web latency. *Computer Communication review*.

25. Yin, L., & Cao, G. (2004). Adaptive Power aware prefetch in wireless networks. *IEEE transactions on wireless communications*, 1648-1658.