International Journal of Computer and Information Technology (ISSN: 2279 – 0764)
Volume 10– Issue 3, May 2021

An Effective Service Mechanism to Achieve Low Query Latency along with reduced Negative Acknowledgement in iVANET: An Approach to Improve Quality of Service in iVANET

Mohd Akbar[1]
Dept. Computer Science & Engineering
Integral University, Lucknow, India

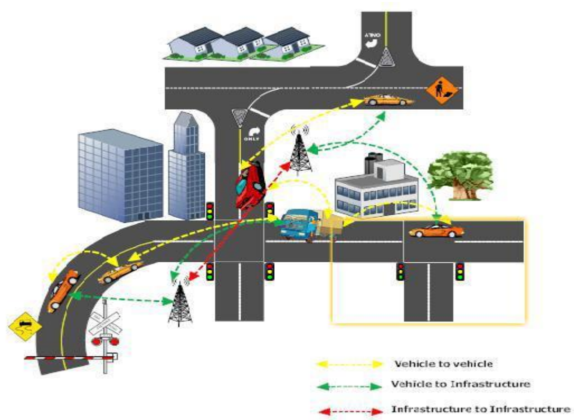
Shish Ahmad[2]
Dept. Computer Science & Engineering
Integral University, Lucknow, India

Abstract—**The Internet Based vehicular ad hoc network (iVANET) combines a wired Internet and vehicular ad hoc networks (VANETs) for developing a new generation of ubiquitous communicating. The Internet is usually applied in vehicle to infrastructure (V2I) solution whereas ad hoc networks are used in vehicle to vehicle (V2V) communication. Since vehicular networks is characterized by High speed dynamically changing network topology The latency is one of the hot issues in VANET which is proportional to the source-&-remote vehicle distance and the mechanism involved in accessing source memory. If the distance between data source and the remote vehicle is wittily reduced by using redefined caching technique along with certain cache lookup mechanism, the latency is likely to be reduced by a significant factor in iVANET. This paper studies and analyzes various cache invalidation schemes including state of art ones and come with a novel idea of fructifying network performance within the purview of query latency and negative acknowledgement in iVANET. In this paper the roles of the mediatory network component are redefined with associative service mechanism which guarantees reduced query latency as well as minimizes negative acknowledgements in iVANET environment.**

Keyword: Internet-based vehicular ad-hoc network, hybrid, cache invalidation, query latency, mobility, iVANET, acknowledgement, service mechanism.

I. Introduction

Vehicular Adhoc Networks (VANETs) are an advance form of Mobile Adhoc Networks
(MANETs) which comprises of both wired and wireless technology. The communication takes place for inter-vehicle communication (V2V) and vehicle to Infrastructure eg; roadside unit(V2I) [3][31]. V2V deploys the wireless technology for Communication and the rest works on wired technology. However the connection among the roadside units is kept wired because the bandwidth of wired technology is much higher when compared to that of wireless technology.



V2V Communication Fig: 1[3]

V2V deploys the wireless technology for Communication and the rest works on wired technology. However the connection among the roadside units is kept wired because the bandwidth of wired technology is much higher when compared to that of wireless technology. The communication equipments used for the vehicle are known as "OBU" abbreviated as On-Board Units. OBU is capable of computing the data received, sense the environment and adapt to the changes accordingly while providing the information related to current position of the vehicle. On-board unit uses DSRC channel (Dedicated Short Range Communication) for communication [4]. The roadside unit is also based on DSRC channel and interact with vehicles at particular fixed point by the road side. The roadside units are basically governed and maintained by the government or a private vending agency which devise their protocols and incorporate in into the network.
The roadside unit possesses components eg; access point(AP), foreign agent (FA), home agents (HA) and the data server (DS). Road-side infrastructure (RSI) has short range communication capacity by which it communicates with nearby vehicles. All road side units (RSUs) are deployed in proper place in a given region. Initially the region may be small, but as technology and economic conditions mature, those regions can be interconnected to form a large region. Such an aggregation can convert

districts to city or to a country and even to a global region eventually [1].

The roadside unit comprises of components namely access point (AP), foreign agent (FA), home agents (HA) and the data servers (DS). Access point acts as an interface between the vehicle and the server. In order to connect to the server, the vehicle has to first contact the access point. Home agent (HA) is a router on a mobile node's home network that maintains information about the vehicle's current location. A home agent (HA) may work in conjunction with a foreign agent (FA), which is a router on the visited network.

An access point (AP) is a device that allows wired communication devices to connect to a wireless network. Data server is meant to provide accessibility to the data stored locally at various local servers.

Like any other network, VANET has also been remain susceptible to many challenging issues namely, Routing, Security [2] and, Quality of Service issues like Query Latency time etc. When it comes to improve the quality of service (QoS), reducing the query latency time appears to be the primary concern, and the "Cache Invalidation techniques" are the one which are considered to be the best to do with the latency reduction in the network. Caching frequently accessed data is an effective technique to improve the network performance because it reduces the network congestion, the query delay and the power consumption [6]. There are many traditional Cache invalidation techniques which can be applied only in MANETs at present. These techniques cannot be adopted for VANETs because of the mere reason that VANETs deploy high speed random mobility in their infrastructure.

There are many cache invalidation schemes for mobile ad-hoc networks and Vehicular ad-hoc network]7][8][9]. To take into consideration a few NC[], ECCI[], EAS[] and GCCI[] are cache invalidation techniques which have been the state of art of its own time and each having some pros and cons of its own.

II. System Model

2.1 Heirarchical Network Model: As shown in Fig.-2, an iVANET is consist of Vehicles, APs(access points), GFA's (Gateway foreign agents), HAs (Home agents), and internet server of data item source (Database Servers). Each AP in the network covers a finite area within which vehicles are supervised and direct communication services is extended to these vehicles. The next level of hierarchy includes GFA's which includes several AP's under its supervision and communication. GAF are then in turn works with home agents to look after the affairs of vehicle's network registration affairs. The level of hierarchy connects GFA's and HA's to the Internet to establish connections between Data Servers. Moreover Vehicles are equipped with OBU(on board unit) facilitating communication services such as an IEEE 802.11-based dedicated short range communication (DSRC) transceiver [4]. Using this, they can either communicate with other vehicles or can get connected to the Internet based network.[34][35].

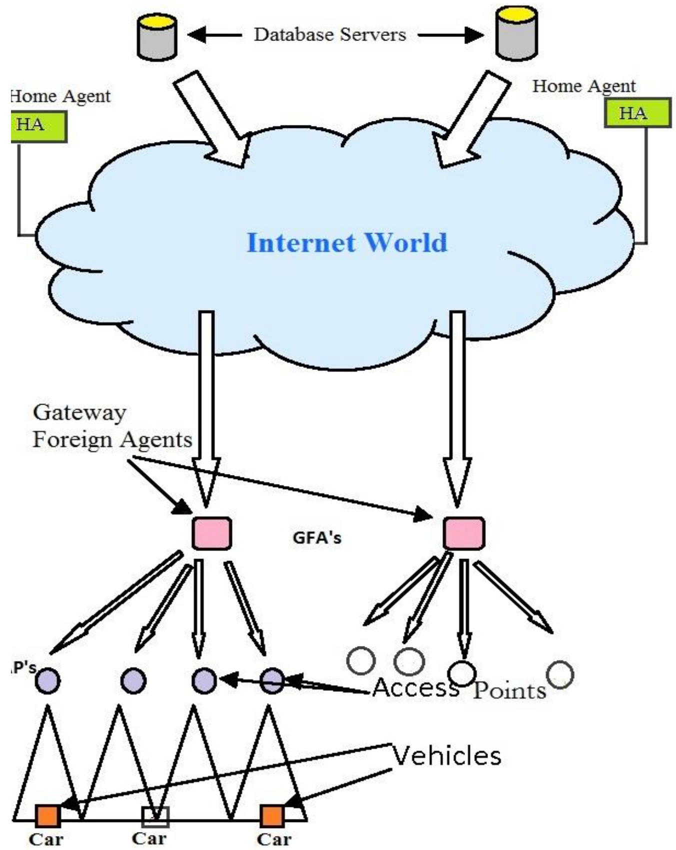


Fig: 2

2.2 Random Mobility Model: The Mobility Model governs the set of rules that define movement pattern of nodes in VANET.

Unlike cellular and MANET environments, where nodes move without restrictions, vehicles are bounded to the underlying fixed roads with speed limits and traffic lights in VANETS. Thus, it is quite simple to predict a likelihood movement of vehicles. For example, a vehicle is moving in the west direction along the road, while there is no exit or cross point for next several kilometers. The Vehicle movement is quick, random and highly unpredictable. The node mobility includes streets, lights, roads, buildings etc and is classified as Macroscopic, whereas the movement of vehicles and their behaviors are classified as Microscopic. In our case Microscopic classification is considered for simulation work.

III. Analysis: Past Related Work

A thorough study reveals that a good number of cache invalidation schemes have been introduced in numerous literature, all based on validation report eg; IR-based validation[10][11][12][13][14].

Whereby, servers send periodic broadcasts an IR, which includes a list of updated data items. Then mobile nodes (later in short, nodes) that receive the IR invalidate cached data items. An important design goal of these traditional cache invalidation techniques is to achieve a certain level of energy conservation, but it is not an issue in IVANETS because a vehicle is supported by its own built-in battery. Our concerns in developing a cache invalidation scheme in the context of IVANETS are mobility and cost of communication.

In another scheme by Sunho Lim et al[10] works on triangular routing system based on Mobile IP. They proposed cache invalidation scheme integrated with a mobile IP based location management. The server asynchronously sends an IR to a home agent (HA) rather than blindly broadcasts it to the vehicles. Then the HA judiciously refines and distributes the IR to appropriate gateway foreign agents (GPAs) based on triangular routing method similar to Mobile computing. When a vehicle moves into a coverage area within the same regional network, it sends the location update to the GFA.

An Aggregate Cache based On Demand (ACOD) scheme is proposed for cache invalidation by altering two existing scheme modified timestamp (MTS) scheme and MTS with updated invalidation report (MTS + UIR) scheme, respectively.

ACOD scheme proved to efficient providing high throughput, low query latency, and low communication overhead in iMANET environment.[10][15][16]. Meanwhile in this proposal the security governing privacy still remains an issue which could be addressed by Privacy Enhancing Communications Schemes [17].

In a classified work three Caching strategies namely **POD**(Pull on demand), **MOD**(Modified Amnesic Terminal) and **PAT**(Pull Based Amnesic Terminal)schemes were proposed [20][21][22].

Where

POD: query latency is low but the cache hit ratio query latency is low and the query message cost is high.[18]

MAT: Shows a higher cache hit ratio and lower query message cost, but it suffers from long query latency [19].

PAT: a pull-based strategy which only maintains delta-consistency of cached data[20].

In a work of sunho lin et al [24] an Aggregate Caching scheme is proposed which combines the local cache of each individual user (Mobile Terminal), like an unified cache, and tries to alleviate the limited data accessibility and longer access latency problems.

The same has been implemented along with a simple search (SS) algorithm ensures that a requested data is obtained from the nearest MT or AP.

Besides above mentioned schemes there are few more approaches for cache invalidations suggested by Sunho Lim, Chansu Yu† Chita R. Das[25] they proposed poll-each-read (PER) scheme, and an extended asynchronous (EAS) scheme. with reference to these two schemes, authors proposed a state-aware cooperative cache invalidation schemes along with hierarchical network model where network-server and network-agents coordinate the cache invalidation operation.

The proposed CCI[ ] (where the impact of mobility on the performance is minimized) and ECCI[ ] schemes provide better performance than others with respect to the query delay, cache hit rate, and communication cost overhead.

Continuing the analysis of various schemes , in a work, authors[26] have designed and proposed three schemes: CachePath, CacheData, and HybridCache.

In Cache-Data, intermediate nodes cache the data to serve future requests instead of fetching data from the data center.

The Cache-Path, mobile nodes cache the data path and use it to redirect future requests to the nearby node which has the data instead of the faraway data center [27].

While having been studied above many schemes cache cooperation still have not achieved a remarkable improvement in the query latency reduction. Continuing this effort, Rajeev Tiwari et al [31] has proposed Cooperative Gateway Cache Invalidation Scheme for Internet-Based Vehicular Ad Hoc Networks. The designed scheme introduces the concept of placing caches at gateways along with the vehicles cache.

Furthering the ongoing research of the same authors Rajeev et al. have defined new heights of hypothesis regarding cache invalidation techniques and presented a work [36] called adaptive cache invalidation technique (ACIT)[36]. The proposed scheme uses different thresholds update rates for adaptive IR, and BT intervals. Only hot data updates in IR are recorded which results a less query delay, and bandwidth consumption. The scheme "ACIT" performs 150% better in query response time with a reduction in IR size to 25 % in comparison to other existing techniques (eg; CCI, ECCI etc.). Also, there is a reduction of 119.89 % in broadcast time interval using the proposed scheme.

IV. Problem Outline

When vehicle initiates query request to the server, the main problem is recognized as delayed response at vehicle end and Negative Acknowledgements at server end. Vehicles are moving at a higher speed therefore there is likelihood of a chance that the vehicle after initiating the request would not remain there within the range of AP or even that of GFA range and thus it won't be able to receive the data responded by the then home AP/GFA. Because of the fact it would have moved in the other network. Secondly the server will get a negative acknowledgment (NACK) because vehicle didn't receive data. Because of this vehicle would again try to access the same data and this process may keep going on this way and consequently there would be a massive increase in the query latency of the overall system and the overhead on the server would also be high resulting in lowering of the bandwidth.

The second problem is identified as increased cost of hardware by introducing caches at Gateways (GFA)[30] and bandwidth overhead due to frequent location management of fast moving vehicles in the network[11][13]. When requested query data is not found in cache then it is sent to server so that server can feed data into the cache. This data-id is not maintained in the registry of home agent. Meanwhile vehicles move with high speed hence there is maximum chance of the vehicle moving into the other network. Since the vehicle has moved into the other network and wants to access the requested data, now GFA will look-up its cache, and will respond back after validation or it will simply forward the request to the server. In addition to this, location management work will also needs be managed to identify which GFA and HA the vehicle is befalling with. Now all these will lead to increased cost of hardware (Gateway Cache) and also marginally high query latency in the network. In this paper location management work will be set off and GFA cache will be eliminated to get over with cost overhead. A new service mechanism is proposed which cope up with vehicle location management and fine tunes the query latency with reduced NACK(-ve Acknowledgment).

V. Proposed Work

5.1 Approach Overview: In normal VANET scenario while generating a query vehicle sends the query packet which includes the vehicle-id as well as the home network-id to the Access Point (AP). But in our case query packets includes additional piece of information. Since state-full servers are set free from location management task, the query pack needs to be well directed between source to destination. For this purpose every packet will include the current **speed(v)** of vehicle, **direction(d)** of movement and the **timestamp(t)**.

The access point includes its own id along with DVT (direction, velocity & Time) and passes on the query packet to the GFA. The GFA again adds its own id along with DVT into the packet and finally the complete packet is sent to the data server. In this way the packet would be consisting of information eg-vehicle id, home network id, access point id and the GFA id and DVT.

Using DVT parameter, at any point of time, the linear location of vehicle can be calculated an approximated after elapsing time *'t'* and so is the likelihood of befalling GFA or HA of vehicle. The server would also get to know the overall path of the requested query along the way it has reached to the server. The server will search the requested data and send back to concerned GFA(likelihood approximation). This packet would be sent back to the GFA by the server. Also the server will be able to calculate and send the vehicle-id and the data id to the home network of the vehicle (a per calculation). HA maintains a record of the vehicles in its network range therefore after receiving the data-id which corresponds to the particular vehicle it will broadcast the packet and update the registry accordingly for that particular vehicle as long as it stays in HA's network range. The GFAs will also work in same way. If the vehicle still remains in the same network then there is no problem, however if the vehicle would have crept into another network then the respective GFA will get to broadcast the packed responded by data server.

Hence this approach mitigates two of the challenges as discussed in problem statement. Firstly it reduces the cost of additional cache on GFA's & optimizes bandwidth overhead be setting off location management task. Secondly it reduces the negative acknowledgements by guaranteed delivery of query response packet to the vehicle.

A. Proposed Algorithm: Better Cooperative Cache Invalidation(BCCI):

Query_Request_Response(V_y, d_x,

1. Vehicle V_y requests the data item d_x **// Searching Local Cache**

{

2. ***if*** (data d_x is not found in V_y cache) **//Search in range or nearby vehicles(V2V)**

{

3. Vehicle V_y sends the query request for data d_x to all adjacent vehicles and server.

3.1 Adjacent vehicles perform BCCI lookup to their local CACHEs.

3.2 ***if*** *(*adjacent vehicles do not find the data (d_x))

{

It forwards the requested data id to the concerned APs and GFAs for Cache admission control policy.

3.3 Concerned GFA would receive and obtain the requested data from Data Server and call response function:

RESPONSE_V( );

}

else {

If Data is found within the adjacent vehicles then these vehicles id's are grouped and prioritized according to the seek parameter (eg; distance from source, position within the network, direction and speed) Vehicle having top priority would be preferred to response the requested data.

5. On receiving data, call procedure-

DATA_VALIDATION ( );

} }

6. **if** (vehicle found the data from the neighbor vehicle)

{ Data is stored in cache and forward the acknowledgement to server so that server can stop sending the data any more.

}

7. **else if** (data dx is found in Vy Local Cache)

{

Call function **DATA_VALIDATION( );** // Vehicle send data id to GFA for data validation.

}

}

}

8. **Stop**

Procedure: 1

RESPONSE_V( );

1. Calculate the current location of requester vehicle by estimating the speed and direction of it after lapsing time "**t**".

2. If (Vehicle position is in home network under the serving GFA)

{

Forward the packet to the vehicle along the nearby AP.

}

3. else

{

Locate the expected GFA to be fall in the estimated location of requester vehicle after elapsing time **"t"**.

4. Forward the response packet to this GFA for delivering the requested data to vehicle

}

5. Stop

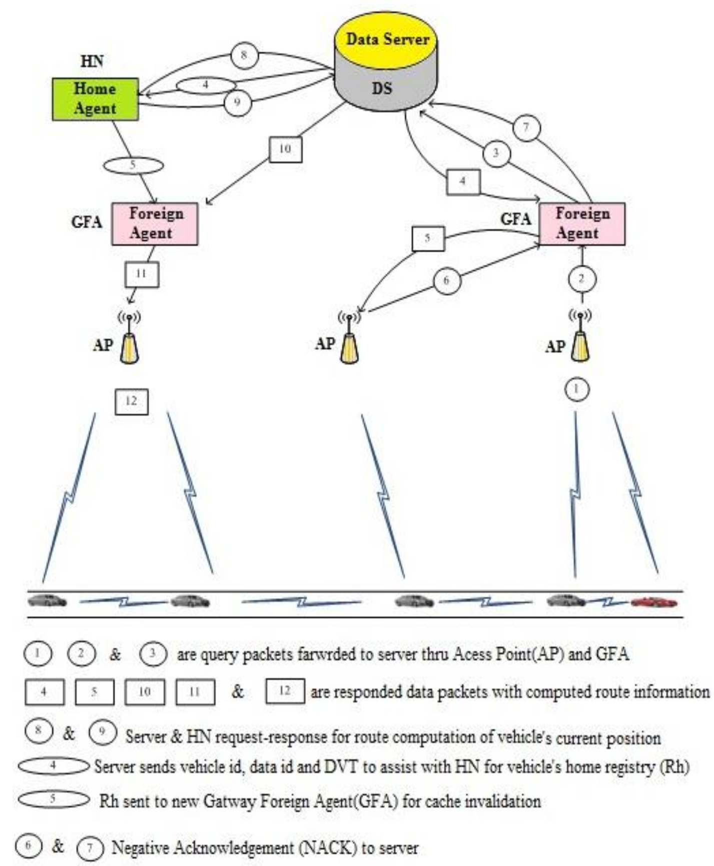


Figure 3: The BCCI Algorithm Scenario

Procedure: 2

DATA_VALIDATION ( );

1. *if* (data is valid)

{

Send the positive acknowledgement

}

else

{

Send the query request to the server.

}

2. Stop.

VI. SIMULATION SETUP

In simulation it is assumed that RSU (road side unit) is installed on highways and each AP has a diameter (L) of 750 meter and each GFA(Gateway Foreign Agent) consists of 5 APs. Initially, the vehicles are randomly populated in the simulation area. The network size is considered to be around 18.85 km. aprpox. Total number of vehicles for the simulation is 100 and the random speed of vehicles are kept varying from 60 km/h to 90 km/h. Query data (dx) item size vary from 1 to 1500 Kbytes. The bandwidth of wired network and wireless network is assumed to be 1000 Mbps and 2 Mbps respectively. The communication range of the vehicle has been set as 375meter. Both vehicle to vehicle (V2V) and vehicle to infrastructure (V2I) communication are taken into consideration in this simulation.

Parameter	Value
Network size(km)	15000 m
Diameter of AP coverage(m)	400 m
Coverage area of vehicle(m)	150 m
Velocity(km/h)	60-90 Km/h
Number of vehicles	100
Data base size(item)	500
Data item size(Kbyte)	1-500
bandwidth of wired network(Mbps)	1000 Mbps
bandwidth of wireless network(Mbps)	2 Mbps
Number of AP each GFA	5
No. of GFA in the network	5

Table-1

Table-1 shows the simulation parameters used to evaluate the performance of the BCCI protocol.

Assuming that '***S'*** is the diameter of the communication range between vehicle to vehicle and ***d*** is the distance between two vehicles V_1 and V_2. Vehicles communicate with each other if $d \leq S$.

Case-1: When vehicles are moving in the same direction with velocities v_1 and v_2, then initial communication time will be-

$$\left| \frac{S}{V1-V2} \right|$$

Case-2: When vehicles are moving in opposite direction with velocities v_1 and v_2, then initial communication time will be-

$$\left| \frac{S}{V1-V2} \right|$$

VII. PERFORMANCE EVALUATION

A. *Query Delay v/s Data Size*

In the simulation, the proposed algorithm is implemented under varying parametric values. To show performance of proposed BCCI scheme we have validated 3 more schemes namely NC, EAS, GCCI which are prevalent earlier. We have considered the test case techniques as CCI, EAS and ECCI as described in section 3. Then query delay is evaluated as a function of data size using BCCI approach and illustrated the comparative analysis with our technique on Query Latency, network throughput with respect to –ve Acknowledgement by varying mean query generation time and Data size.

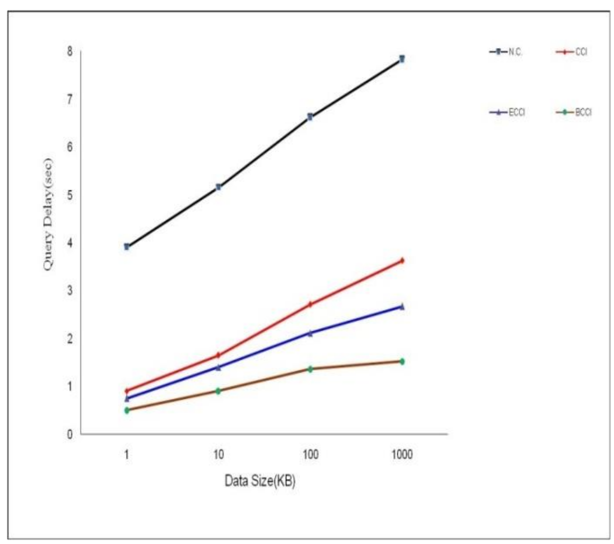


Figure 4: Query delay as a function of data size.

Figure-4 shows the effect of query delay as a function of data size. The non-caching (NC) scheme takes the higher query delay in comparison to cooperative and enhances cooperative caching (ECCI). The new BCCI proposed scheme outperforms the others and achieves lowest query delay for all data sizes.

B. Effect of No. of Vehicles:

The number of vehicles varies from 100 to 500 and data item size is fixed at 100 K bytes. Under the simulation setup BCCI performs way batter than the other 3 schemes.

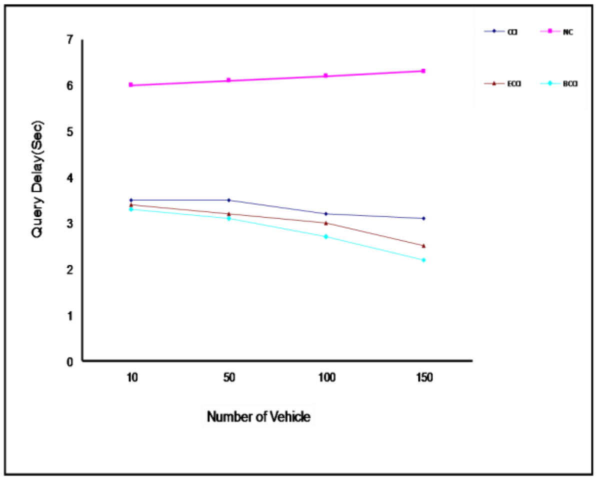


Fig 5: Query delay as a function of number of vehicles

C. Query Delay v/s Data Size:

Simulation setup is executed iteratively for data query which resulted in some cache miss and cache hit. The overall hit ratio is measured by taking an average of 250 attempts made for 5 successive mean time intervals.

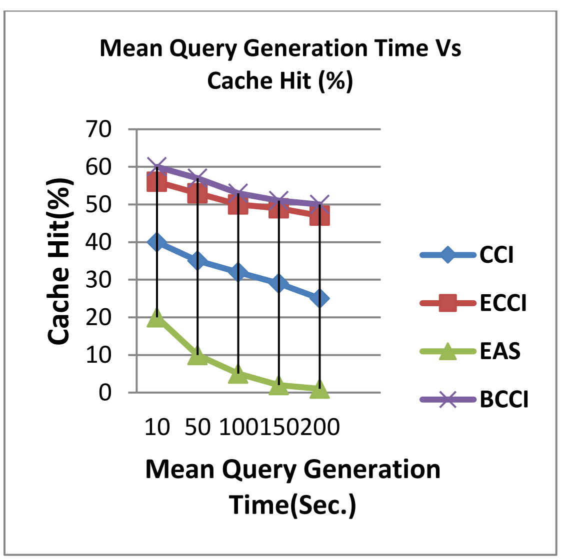


Fig 6: Cache hit as a function of mean query generation time

BCCI has shown a remarkable behavior with respect to cache hit ratio and achieved higher performance in comparison to other three schemes

VIII. Conclusion

In this paper, for solving the problems related to Query latency and NACK in iVANET, BCCI mechanism has been proposed, tested and compared along with extended asynchronous (EAS), cooperative cache invalidation (CCI), enhance cooperative cache invalidation (ECCI) and the base case (NC) where there is no cache and the query request is forwarded directly to server. While implementation consistency of data has been maintained and validated. The query latency has been minimized. Negative Acknowledgement and the overhead on the server have been reduced significantly. The systems overall network performance thus got fructified and it is now able to offer improved quality of service in terms of query delay and reduced NACK in the network.

IX. Future Work

Although several caching mechanisms have been studied and analyzed, some issues are still yet to be addressed. Though proposed BCCI protocol provides better performance in terms of throughput, lowest query delay and less overhead on the server, it is confined with parametric range under microscopic schemes. on other aspects such as increased cost, low bandwidth utilization and boosted traffic due to frequent query to data server and frequent lookups in GFA's caches.
So, theses issue could be addressed as future research challenge. Also, there is a fair chance of coming up with even better solution for reducing query latency using cache invalidation approach for above mentioned bottleneck of CGCI (Cooperative Gateway Caching Invalidation) technique Since different VANET protocols, mechanisms and applications are based on different architectures and assumptions, it would be worth to see if a common evaluation framework is possible or not. Simulation results are often offered to evaluate current proposals. However, a common scenario to evaluate alternatives does not exist till date.

REFERENCES

[1] NoW, "Network on Wheels," http://www.network-on-wheels.de, 2005. [Online]. Available: http://www.network-on-wheels.de

[2] Tim Leinm¨uller+, Elmar Schoch

and Christian Maih¨ofer, "Security Requirements and Solution Concepts in in vehicular ad hoc networks", Wireless on Demand Network Systems and Services, 2007. WONS '07.

[3] W. Franz, H. Hartenstein, and M. Mauve, Eds., Inter-Vehicle-Communications Based on Ad Hoc Networking Principles-The FleetNet Project. Karlshue, Germany: Universitatverlag Karlsuhe, November 2005.

[4] Measuring Communication Performance of Dedicated Short Range Communications (DSRC) in MANET's, http://www.leearmstrong.comlDSRCIDSRC Homeset.htm.

[5] Vehicular Ad Hoc Networks" ————————————————Universi ty of Ulm, Institute of Media Informatics, pp. 103–112, 2007.D. B. Johnson, D. A. Maltz, and Y. C. Hu, "The dynamic source routing protocol for mobile ad hoc networks (dsr)," Published Online, IETFMANET Working Group, Tech. Rep., February 2007.

[6] S. Lim, W. Lee, G. Cao and C.R. Das, "A Novel Caching Scheme for Improving Internet-based Mobile Ad Hoc Networks Performance," Ad Hoc Networks Journal, Vol. 4, No. 2, pp. 225–239, 2006.

[7] Nikolaos Frangiadakis and Nick Roussopoulos, "Caching in mobile Environments: A New Analysis and the Mobile-Cache System," The 18th Annual IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC), 2007.

[8] S. Lim, W. Lee, G. Cao and C.R. Das, "Cache Invalidation Strategies for Internet-based Mobile Ad Hoc Networks," Computer Communications Journal, Vol. 30, No. 8, pp. 1854-1869, 2007.

[9] Sunho Lim, Soo Roan Chae, Chansu Yu and Chita R. Das, "Cooperative Cache Invalidation Strategies for Internet-based Vehicular Ad Hoc Networks," IEEE International Conference on Mobile Ad Hoc and Sensor Systems, pp. 712 – 717, 2008.

[10] Sunho Lim, Chansu Yu and Das, C.R., "Cooperative Cache Invalidation Strategies for Internet-Based Vehicular Ad Hoc Networks," IEEE International Conference on Computer Communications and Networks, pp. 1 – 6, 2009.

[11] B. Zheng, J. Xu and D.L. Lee, "Cache Invalidation and Replacement Strategies for Location Dependent Data in Mobile Environments," IEEE Trans. on Computers, Vol. 51, No. 10, pp. 1141-1153, 2002.

[12] G. Cao, "A Scalable Low Latency Cache Invalidation Strategy for Mobile Environments," IEEE Transactions on Knowledge and Data Engineering, Vol. 15, No. 5, pp. 1251-1265, 2003.

[13] J. Xie, S. Tabbane and D. Goodman, "Dynamic Location Area Management and Performance Analysis," in Proc. IEEE VTC, pp. 536-539, 1993.

[14] J. Xu, X. Tang and D.L. Lee, "Performance Analysis Location-Dependent Cache Invalidation Schemes for Mobile Environments," IEEE Transactions on Knowledge and Data Engineering, Vol. 15, No. 2, pp. 474-488, 2003.

[15] Nicholas Loulloudes, George Pallis and Marios D. Dikaiakos, "On the Evaluation of Vehicular Communication Systems and its Applications," IEEE International Conference on Mobile Data Management, pp. 218-220, 2010.

[16] Jose Santa, Antonio F, Go. Mez-Skarmeta and Marc Sanchez-Artigas, "Architecture and evaluation of a unified V2V and V2I communication system based on cellular networks," Computer Communications Journal, Vol. 31, pp. 2850-2861, 2008.

[17] T.W. Chim, S.M. Yiu, Lucas C.K. Hui and Victor O.K. Li, "SPECS: Secure and Privacy Enhancing Communications Schemes for VANETs," First International Conference, ADHOCNETS, Vol. 28, pp. 160-175, 2010

[18] Narottam Chand, R.C. Joshi and Manoj Misra, "Efficient Mobility Management for Cache Invalidation in Wireless Mobile Environment," Springer-Verlag 3741, pp. 536-541, December 2005.

[19] Narottam Chand, R.C. Joshi and Manoj Misra, "Energy Efficient Cache Invalidation in a Mobile Environment," International Journal of Digital Information Management (JDIM) special issue on Distributed Data Management, Vol. 3, No. 2, pp. 119-125, June 2005.

[20] Narottam Chand, R.C. Joshi and Manoj Misra, "A Zone Cooperation Approach for

Efficient Caching in Mobile Ad Hoc Network," International Journal of Communication Systems, Vol. 19, No. 9, pp. 1009-1028, Nov 2006.

[21] Narottam Chand, R.C. Joshi and Manoj Misra, "Energy Efficient Cache Invalidation in a Disconnected Wireless Mobile Environment," International Journal of Ad Hoc and Ubiquitous Computing (IJAHUC), Vol. 2, No. 1/2, pp. 83-91, 2007.

[22] Narottam Chand, R.C. Joshi and Manoj Misra, "Cooperative Caching in Mobile Ad Hoc Networks Based on Data Utility," International Journal of Mobile Information Systems, Vol. 3, No. 1, pp. 19-37, 2007.

[23] Narottam Chand, R.C. Joshi and Manoj Misra, "Data Caching in Mobile Ad Hoc Networks," In: David Tanier, ed. Encyclopedia in Mobile Computing and Commerce. USA: IDEA Group Publishing (IGP), 2007.

[24] Sunho Lim, Wang-Chien Lee et. al. "A novel caching scheme for improving Internet-based mobile ad hoc networks performance" Ad Hoc Networks Volume 4, Issue 2, March 2006, Pages 225-239

[25] Sunho Lim, Chansu Yu† Chita R. Das, "Cooperative Cache Invalidation Strategies for Internet-based Vehicular Ad Hoc Networks"

[26] Prashant Kumar, Naveen Chauhan, Lalit Awasthi and Narottam Chand, "Proactive Approach for Cooperative Caching in Mobile Adhoc Networks," International Journal of Computer Science Issues, Vol. 7, No. 8, pp. 21-27, May 2010.

[27] Liangzhong Yin and Guohong Cao "Supporting Cooperative Caching in Ad HocNetworks", National Science Foundation (CAREER CCR-0092770 and ITR-0219711-2011).

[28] J. Morillo, J. M. Barcelo, O. Trullols, and J. Garcia-Vidal, "A Cooperative ARQ for Delay-Tolerant Vehicular Networks," in to be published in DTMN 2008, 2008.

[29] M. Conti and S. Giordano, "Multi hop Ad Hoc Networking: The Theory," in IEEE Communication Magazine, Vol. 45, Issue 4, pp 78-86, Apr. 2007.

[30] Rajeev Tiwari , Neeraj Kumar, "Cooperative Gateway Cache Invalidation Scheme for Internet-Based Vehicular Ad Hoc Networks", Wireless Personal Communications: An International Journal archive Volume 85 Issue 4, December 2015 Pages 1789-1814

[31] M. Torrent-Moreno, M. Killat, and H. Hartenstein, "The Challenge of robust Inter Vehicle Communications," in 62nd IEEE Semiannual Vehicular Technology Conference (VTC-Fall), 1, pp. 319-323, Dallas, Texas, Sept 2005.

[32] Rajeev Tiwari , Neeraj Kumar, "Minimizing Query Delay Using Co-operation in IVANET", 3rd International Conference on Recent Trends in Computing(ICRTC-2015), 21 August 2015.

[33] J. Zhao and G. Cao, "VADD: Vehicle-Assisted Data Delivery in Vehicular Ad Hoc Networks," in 25th Conference on Computer Communications (IEEE INFOCOM'06), Barcelona, Spain, April 2006.

[34] J. Harri, F. Filali, and C. Bonnet, "Mobility Models for Vehicular Ad Hoc Networks: A Survey and Taxonomy," in Eurecom Sophia-Antipolis, pp. 06-168, March 2007.

[35] M. Fiore, "Mobility Models in Inter Vehicle Communications Literature," in Technical Report, Nov 2006.

[36] Rajeev TiwariNeeraj Kumar,"An adaptive cache invalidation technique for wireless environments", Proceeding MobiCom '00 Proceedings of the 6th annual international conference on Mobile computing and networking Pages 200-209.

[37] Anurag Singh, Narottam Chand, Lalit Kr Awasthi,"Enhancing Cache Invalidation Techniques in IVANET", International Conference on Communication Systems and Network Technologies, 2011.