Comparative Analysis between Cooperative Caching and Non-Cooperative Caching in VANETs

Dr. Meenu Dave,
Dean, Faculty of Information &Technology,
Research Sc,JaganNath University, Jaipur.
Ms. Nisha Wadhawan,
holar
JaganNath University, Jaipur.

Article Info
Page Number: 1269-1278
Publication Issue:
Vol. 71 No. 3s (2022)

Article History
Article Received: 22 April 2022
Revised: 10 May 2022
Accepted: 15 June 2022
Publication: 19 July 2022

Abstract:
ITS (Intelligent Transportation System) has become an important research field in recent years. One of the important components of Intelligent Transportation System is Vehicular networking, promising numerous, new applications for efficient road traffic, safety, and, infotainment. The dissemination of updated and consistent data in VANETs is very crucial as moving vehicles change their positions frequently. Cache inconsistency and outdated data can increase communication cost, and can result in higher query latency. This study's goal is to provide creative proactive caching strategies to lower communication latency in VANETs. We have considered the paradigm of cooperative caching, in which Roadside Units (RSUs) cooperate with remote servers to increase the rate of transfer of information and reduce overall network latency.

1. Introduction

Road transportation has been one of the main modes of transportation for millions of people across the world. Vehicles on the roads has increased drastically in the recent past, leading to heavy road traffic and related problems like road congestion, accidents, and high levels of fuel consumption. The main objectives of Intelligent Transportation System is to reduce traffic congestion, road accidents, and to improve the road environment. VANETs are the major component of ITS. Adhoc infrastructure and mobility are the major characteristics of VANETs. Researchers have a great research interest in VANETs, where thousands of vehicles access the network.

IVANETs (Internet-based Vehicular Ad hoc Networks) are MANETs (Mobile Adhoc Networks) evolving areas, where vehicles equipped with Internet accessibility act as mobile nodes. Vehicular Ad hoc Communication can be applied for entertainment, road safety applications, and mobile Internet access. The authors in (Rajeev Tiwari, Neeraj Nehra, 2015) discussed in their research that in VANETs, vehicles form a network using communication links among themselves so that they can share the information regarding road congestion, weather conditions, and Internet-related applications. Vehicles access the Internet using IEEE 802.11g standards for short communications and every vehicle in VANET behaves like an MT (Mobile Terminal). Vehicles collect and share data with other vehicles in the network.

Though VANETs have become popular in the recent past and have become known for their effectiveness, but still users are unsatisfied with their current performance due to nonavailability of the latest and updated data and intermittent connectivity. There are constant topological changes due to moving vehicles in VANETs which results in long delays and higher communication costs. VANETs performance can be improved by caching frequently accessed popular content in the vehicle's cache. Smart vehicles have OBUs (On-Board Units) and large storage, which can be used to store data for future retrieval. However, the main issue is the accessibility of the updated and consistent data.

Updated and consistent data dissemination from the remote server to the moving vehicle is complex and crucial. It may increase the number of data requests, and, query latency time. The major concerns in VANETs are: reduced query latency time and uplink requests. The best solution for longer delays is Cooperative Caching. It will increase the efficiency of VANETs and will reduce bandwidth consumption. Studies have proved that cooperative caching is more efficient as compared to its counterpart, non-cooperative caching.

In this paper we discussed the cooperative caching technique which is based on mobility prediction and demand patterns of users. In II section we have done extensive literature review and find out that most of the caching techniques in VANETs have not utilized demand pattern information and some have not even considered mobility. Section III is dedicated to the importance of mobility and demand pattern calculation in VANETs. In this section we have provided the detailing regarding the proposed scheme and study assumptions. In the IV section we have compared the cooperative caching with its counterpart non-cooperative caching. Section V is dedicated to result & analysis. We have concluded the paper in section VI, discussing the future scope.

2. Literature Review

Providing the latest and updated data in IVANETs is quite important as the vehicles at great pace and get disconnected from the RSUs frequently.

It is required to prefetch data in advance before the data request arrives. The data items can be prefetched by predicting the vehicle position, which requires mobility prediction. The techniques to identify the mobility patterns of multiple vehicles were developed in **[4]** and **[5]**. The requirement for these techniques is statistical information which is provided by the RSUs and also the mobility information from individuals. The network coordinator needs this data to create a profile, which will then be used to forecast each user's future travel patterns **[6]**, proposed a new caching scheme "scope" to effectively prefetch and replace broadcast and "mobility specification". In the proposed scheme, cache system is numerically evaluated based on the road traffic environment. This model is implemented to emulate a system so that location-aware data delivery can be evaluated. This method provides scope for a realistic vehicular application that provides geographic road map for the car navigation system. **[7]** proposed a caching technique which takes advantage of the location management scheme to reduce broadcast messages to the vehicles and corresponding query delay. **[8]**proposes a hybrid prefetch scheme in vehicular telematics network enhance the network's performance by exploiting temporal and spatial locality. **[9]** provides a scheme of RSU-based Node Tracking (RBNT) to find out the vehicles which are connected with the given RSU. In this scheme, with a given predetermined road framework, RSU chooses the vehicles as the relay nodes to collect information about the connected vehicles by forming a hierarchical structure. **[10]** proposed a Cooperative Content Distribution System for Vehicles (CCDSV) scheme

where RSUs collaboratively distribute content to the vehicles. A representative-based prefetching mechanism is proposed to fully utilize the bandwidth. In **[11]** , a prefetching scheme is proposed in vehicular cloud systems. In this study a route-based prefetching scheme is proposed, and which ensures the effectiveness of data dissemination. The authors proposed a greedy algorithm to prefetch a set of data items of interest from a data center to roadside RSU, for deterministic and stochastic cases.
In [12], to handle QoS issues, the authors proposed a data prefetching technique, in which data is prefetched from the cloud server to edge components like Aps, RSUs which are connected to the infrastructure. The authors have proposed six prefetching techniques which are based on the advance information about the driver’s file access history. This framework gives the cloud server and the edge server the freedom to switch between multiple prefetching strategies if one doesn't function well with the user's access pattern.
Data Prefetching and data dissemination has been taken to the new horizon with the advent of the VEC (Vehicular Edge Computing), where the service providers are trying to provide data to the close proximity of the smart vehicle users to reduce the latency and increase the QoS in [13]. In [13] [14], it is mathematically proved that providing the data in the proximity of moving vehicles reduce the latency and improves the QoS.

3. Background

Though in [10, 11, 12, Sample], authors have incorporated mobility considerations to develop effective and improved caching schemes, but researches have not been carried out to incorporate demand history and mobility patterns. Numerous studies have demonstrated that people once adhered to everyday routines including travelling to work and browsing well-known websites [4], [5] [15] These researches proved that the mobility patterns and individual accessibility behavior is not predictable but confirmed. This valuable information enhances the caching effectiveness.
In [4]and [5]. , various techniques have been proposed to identify the mobility patterns of multiple users. This approach is based on collecting numerical data of the vehicles from the RSUs along the road taken by the vehicles.
Based on the data received from the RSU, the network coordinator, construct a user profile and later utilize this profile to forecast future routes of the nodes. In the similar manner, a demand profile can be calculated depending upon the visited website history of individuals. In the similar manner, a demand profile can be calculated depending upon the visited website history of individuals. . Similar approach was considered in [15], to support a system that is based on the user’s demand prediction. .
Our goal is to utilize demand prediction and mobility pattern approaches in a proactive caching environment., so to prove that cooperative caching technique reduce communication latency in IVANETs under the freeway model as compared to its counterpart, non-cooperative caching scheme.

3.1 Mobility and Demand Prediction

Based on vehicle mobility and demand trends, we have presented a proactive cooperative caching strategy. This scheme makes effective use of information related to mobility pattern. We consider two paradigms: cooperative and non-cooperative. In cooperative environment multiple RSUs cooperate to reduce the delay and accelerate the information transfer to the vehicle. However, in a non-cooperative environment, every RSU functions independently of the others. We have formulated optimization problems for both the scenarios. The impact of the vehicle's velocity and demand is taken into account in the suggested schemes to decide on the best caching strategy. NP-hardness applies to the developed formulations. As a result, these issues are challenging to resolve. To evade this difficulty, we used an optimization framework. Our numerical calculations show that the proactive caching systems that have been proposed are significantly better than the corresponding no-caching baselines, and that cooperative caching techniques are comparatively better than non-cooperative caching schemes.

3.2 Assumptions for the proposed scheme

Here we are assuming two types of proactive cooperative caching schemes. We are considering freeway models. The expressway model is proposed in [16].In this model we assume the set R = (1, 2, 3 ,….R) of RSU's those are located at equidistance, with distance L_r,along a certain road.as in the following figure

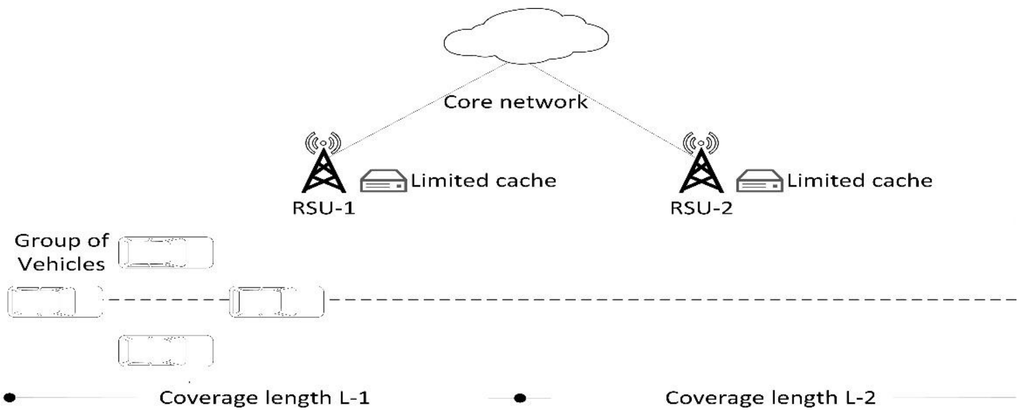

Fig 1 Freeway model

Each RSU $r \in R$ has a cache of size Z_r. It is assumed that the set of vehicles V = (1, 2 ,3,….. V), travel along the road. These vehicles can demand a set N not mutually connected data items, where N = (1, 2, 3, …N). The Nth data item is of size C_N bytes as per our assumption.. Each RSU $r \in R$ is connected a number of the vehicle, which are traveling in its coverage area. The data rate of r-th RSU with the v-th vehicle is of D_{rv} bytes/ second. As the vehicles move at a great pace, they will be in the coverage area of a RSU for a limited duration. There will be hands-off operation and vehicle will connect to the next RSU along its path. This contact time vector is represented as $T^R = (T_1^R , T_2^R , \ldots\ldots T_V^R)$, where T_V^R is the connection time between RSU, R and vehicle V in secs.

In this study we presume that, RSU's have information regarding the behavior of every vehicle moving within its coverage area and also can learn and predict its mobility pattern. Based upon this information, RSU can construct the demand function for each vehicle. The user's data requests history, and the demand function provides the probability, whether the user will access a file or not. Specifically let's assume the demand function of a vehicle V is denoted by vector $P_V = (P_V^1, P_V^2, \ldots\ldots P_V^N)$, where P_V^N, is likelihood that the vehicle V will

request information from N (The set of uncorrelated data items). We assume that the RSUs are prefetching data from each automobile on their own. In other words, we can state that a user's demand pattern at one point in time differs from other users' demand patterns and from the needs of the same user at different points in time.
Assume x_r^n is the prefetching decision of data item n at RSU's that is :

$$x_r^n \epsilon \ (0, 1) \text{ for all } n \epsilon N \text{, and for all } a \epsilon A \qquad \text{Equation -4.1}$$

The size of prefetched items must satisfy a storage constraint, whereby the total size of these items must be less than or equal to the RSU storage Z_r, so we have setting $x_r^n = 0$ to indicate that the data item n is prefetched by the r-th RSU, and setting $x_r^n = 1$ to indicate that this data item is not prefetched by the r-th RSU, therefore we have:

$$\sum_{N=1}^{n} C_N \ x_A^N \leq Z_A, \quad \text{for all } r \epsilon R \qquad \text{Equation 4.2}$$

We have described the basic and necessary prefetching framework. Now we will discuss the communication scenario to the freeway model.

3.3 Communication state

In this section, an optimization problem for the average latency of the network is formulated considering freeway model. In this section, we have assumed that each vehicle s connected with a specific RSU. This assumption is based on the fact that in VANETs, when RSU operate over high frequencies, their coverage zone is small. So a vehicle can be in the coverage area of a single RSU at a time. It is to avoid interference and this assumption is realistic. To describe the latency with which N-th data item is delivered to a vehicle in the freeway model,
We formulate that the time required to deliver a data item of size C_N, when the transmission rate between the r-th RSU, and the v-th Vehicle is T_{AV}, is given by $\frac{C_N}{t_{rv}}$, If the data item is available in prefetched cache of the RSU and ($\frac{C_n}{t_{av}}$, + Δ_n) , if this item is not available in prefetched cache, where Δ_N , is the time delay required for the RSU to prefetch the data from the network backhaul.

Our objective is to find the optimal prefetched caching policy (x_r^n) where n= 1 to N, Since RSU has the finite cache size. It is to determine the data item to be prefetched at each RSU. Specific data items are to be prefetched to keep network latency at the minimum.

3.4 Proactive cooperative caching for IVANETs using freeway model

This section discusses the proactive cooperative caching in the IVANETs through prefetching at gateway level. Here we will discuss two different schemes, non - proactive cooperative caching and proactive Cooperative caching schemes.
In the non-proactive non cooperative caching scheme, every RSU takes its best caching decision independently of other RSUs, i.e., it would prefetch the data items from the backhaul server depending upon the data requests from its connected vehicles. The RSUs are taking optimal prefetching decisions, without taking into account neighborhood RSUs. Whereas in the proactive cooperative caching scheme, the RSU's prefetch data by exchanging information signals with other RSUs in the neighborhood. Particularly, in this model the RSU

is updating the location, direction and demand function of each vehicle based on the information received from proceedings RSU's. Our aim here is to find the ideal proactive cooperative caching policy, for each RSU in at the gateway level in the network. To achieve this, we formulated an optimization problem for each scheme. To overcome the computational difficulty, we have proposed an efficient greedy algorithm for each scheme.

4 Proposed mathematical model for the scheme

The freeway model is depicted in fig. 1. For simplicity, we consider the case of R = 2 RSU, though, this scheme can be readily extended, by assuming more than 2 RSUs.

Let δ_v be the likelihood that the v-th vehicle entered the motorway in order to depict the proactive cooperative caching structure in the freeway model. A vehicle that is within the RSUs' coverage area at the entry point is assured to link with the following RSUs along the freeway since in this model vehicles can only move in one direction.

For simplicity, we assume the case that in the freeway, the traffic density will be low. The speed of the vehicles will be independent of each other and identically distributed. With this supposition, a truncated Gaussian distribution can be used to show the random velocity (u) of any vehicle (v ϵ V). We're assuming that every automobile travels along the road at the same constant speed, u_v. Without sacrificing generality, we assume that u $(u_{maximum}, u_{manimum})$, in this case for each vehicle v ϵ V, the truncated Gaussian distribution with mean μ, and variance σ^2, can be written as :

$f_u(u) =$

$$\left[\frac{2\exp\left(\frac{-(x-\mu)^2}{2\sigma^2}\right)}{\sqrt{2\pi\sigma^2}\left(\mathrm{erf}\left(\frac{u_{max}-u}{\sigma\sqrt{2}}\right)\right) - \left(\mathrm{erf}\left(\frac{u_{min}-u}{\sigma\sqrt{2}}\right)\right)} \right.$$

0, **otherwise** Equation 4.3

A unique instance of the city model is the highway model. wherein more than one road is taken into account, and each road is two-way. The section after this one will detail this model.

4.1 Non Cooperative caching networks

In reactive networks, the user's requests are sent directly to the backhaul servers. The RSU's don't cache the data in advance. Such networks provide a reference point to evaluate the benefits and costs of implementing the RSU's with proactive caching capabilities. Towards portraying these reactive networks let N_v^a be the maximum number of data items that can be guaranteed to be received by the v-th vehicle from the r-th RSU. The size of the data item (C_n), where n is equal to 1 to N and (Δ_n) is the time delay to retrieve these items from the backhaul networks. (Δ_n) where n= 1 to N. since the Nth item takes overall time $(\frac{Cn}{T_{rV}}, + \Delta_N)$, to be delivered in the absence of proactive caching. Then we have

$$N_v^r = \mathrm{Min}\left(\frac{T_v^r}{\mathrm{Max}\, N \in N \ \left(\frac{C_n}{T_{rv}}, + \Delta_n\right)} \right) . N \qquad \text{Equation 4.4}$$

We can say that the v-th vehicle can receive k data items from the r-th RSU, only if that k lies in the set (1, 2, 3, …..N_v^r). A user may not be aware of N_v^r, and can build its demand function based on N. In particular the request function of v-th vehicle includes the probabilities δ_V^k, where k = 1 to N that is requests K ε ((1, 2, 3, …..N_V^r), data items. In addition to the probability of demand of the N-th data item δ_V^r, N = (1, 2, 3, …..N_V^r),.

We know that probabilities (δ_V^N) will allow us to take into account an improved demand function, which is the combination of the chance that a specific vehicle will require k times and the probability that this vehicle will request a specific combination of k times. To illustrate this profile, we notice that there are $G_K = (\frac{N}{K})$ possibilities of data items that the v-th vehicle may ask for each number of demand k. Let K requested files, starting with the i-th combination, be indexed by

$$S_{VK} = (l_1, l_2, \ldots\ldots l_{vk}) \text{ and let}$$

Let M_{VK}^l represents the conditional probability that V-th vehicle requests the items in S_{VK} .assuming that the requests are independent

$$M_{VK}^l = P_V^l, \text{ if } l \in S_{VK}, \quad \text{and} \quad M_{VK}^l = (1 - P_V^l), \text{ If } l \notin S_{VK}, \qquad \text{Equation 4.5}$$

If all vehicles were to be served by the A-th RSU, the following equation gives the overall anticipated delay for all vehicles:

$$w_A^R = \sum_{V=1}^{V} (\theta_V \sum_{K=1}^{M_l} \theta_V^K \sum_{l=1}^{S_{VK}} M_{VK}^l \sum_{l \in A_{VK}} (\frac{C_l}{p_{sv}} + \Delta_l) \qquad \text{Equation 4.6}$$

In equation 4.6, the inner summation denotes the anticipated delay brought on by the requests of the v-th vehicle, where R is intended to identify the reactive model. The outer summation is the overall delay experienced by the cars served by the A-th RSU, whereas the average over all combinations of data items and demand functions is the inner summation.

Proactive Networks

Each RSU from this network proactively cache select data items in its available memory. These data items are selected on the basis of mobility and demand functions of individual users. Our aim is to calculate the best choice for the data item that reduces expected over all delay in the network. In this process, we find that as in non-cooperative network model when the Nth requested data item by the v-th vehicle, is not available in the cache of a-th RSU, delay is given by $(\frac{C_N}{T_{AV}}, + \Delta_N)$,

However when there will be cache hit i.e. the data item is in the cache, the delay reduces to $(\frac{C_N}{T_{AV}})$, The total number of data items present in the cache of the a-th RSU can be expressed as $\sum_{N=1}^{N} C_N \; x_A^N$.

Now since v-th vehicle will be in the coverage area of the a-th RSU for T_V^A seconds, the maximum number of data items that can be delivered to the v-th vehicle by the RSU, when all requested data are available in the cache is given by :

$$N_V^A = \text{Minimum} \left(\left| \frac{T_V^A}{\text{Max } m \in M \quad (\frac{C_N}{T_{AV}})} \right|, \sum_{N=1}^{N} x_A^N \right) \qquad \text{Equation 4.7}$$

The v-th Vehicle may request items that are missing from the cache in addition to cache items. Only if the connection time T_V^A is longer than the amount of time needed to transport the N_V^A cached items, the RSU will be able to deliver those items i.e $T_V^A \geq N_V^A$

$\text{maximum}_{N\ \varepsilon\ N}\ (\frac{C_N}{T_{AV}})$.

The maximum amount of uncached data items that can be sent to the V-th vehicle in this instance can be represented as follows:

$$N_V^A = \left| \frac{T_V^A - N_V^A \quad \text{Max}\ N\ \varepsilon\ M \quad (\frac{C_N}{T_{AV}})}{\text{Max}\ m\ \varepsilon\ M \quad (\frac{C_N}{T_{AV}} + \Delta_N)} \right| \qquad \text{Equation 4.8}$$

Note: $\left| \frac{T_V^A}{\text{Max}\ N\ \varepsilon\ M \quad (\frac{C_N}{T_{AV}})} \right|$ is the maximum limit on $N_V^A \geq 0$,

Combining (4.7) with (4.8) indicates the maximum number of data items that each vehicle can receive.

$$N_V^A = \text{Min}\ (N_{V1}^A,\ N_{V2}^A, \ldots\ldots N) \qquad \text{Equation 4.9}$$

Now using 4.5 and 4.9 We derive a proactive model and a reactive model, and we obtain an expression for the anticipated total delay:

$$w_A^R = \sum_{V=1}^{V} \left(\theta_V \sum_{K=1}^{M_l} \theta_V^K \sum_{l=1}^{S_{VK}} M_{VK}^l \sum_{l\ \varepsilon\ A_{VK}} \left(\frac{C_l}{p_{sv}} + \Delta_l\right) \right) \qquad \text{Equation 4.10}$$

5 Result and Analysis

The objective of our study is to prove that a cooperative caching scheme reduces latency as a comparison to a non-cooperative environment. We have assumed the freeway framework where the vehicles move in one direction and with the velocity independent of each other. Finding the best prefetched caching policy for each RSU to ensure that network latency is kept minimal. The numerical investigations prove that the proactive prefetched cooperative scheme significantly outpaces non-cooperative caching.

6 Future Scope

In the future, we will implement this caching scheme in the city model where there may be the number of road intersections and the speed of vehicles may also vary. In the future we will try to improve this caching scheme, to make it feasible for the city model.

References

[1] Rajeev Tiwari, Neeraj Nehra, "Minimizing query delay using co-operation in IVANET," in Procedia Computer Science 57, 2015.

[2] P. F. Spiekermann S, "Technology Paternalism wider implications of ubiquitous computing," in Poiesis & Praxis, 2006.

[3] M. F and F. C, "From the Internet of Computers to the Internet of Things," in Informatics spectrum, 2010.

[4] C. Song, Z. Qu, N. Blumm and A. Laszalo Barabasi, "Limits of Predictability in Human mobility," in Science, Science Magzine, 2010, pp. 1018-1021.

[5] F. Akyildiz and W. Wang, "The Predictive User Mobility profile Framework for wireless multimedia networks," IEEE/ACM, pp. 1021-1035, 2004.

[6] S. Kenya, T. Koita and A. Fukuda, Eurasip Journal of embedded Systems, vol. 2007, p. 11, 2007.

[7] L. Sunho, S. H. Chae, C. Yu and C. Das, "On cache invalidation for internet-based vehicular ad hoc networks," in IEEE International Conference on Mobile Ad Hoc and Sensor Systems, 2008.

[8] J. Lee, G. Leen Park, S. Wook Kim , H.-j. Kim and S. Y. Shin, "A hybrid prefetch policy for the retreival of link associated information on Vehicular Networks," in ACM Symposium on Applied Computing, 2010.

[9] W, K. W, Y. Tung and S. Fang, "A Node management scheme for R2V connectionsin RSU-SupportedVehicular Adhoc Networks," in International onference on computing,Networking and Communication, 2013.

[10] D. Zhang and C. Kiat Yeo, "Enabling efficient wifi-Based Vehicular Content distribution," IEEE Transactions on Parallel and distributed Systems, vol. 24, pp. 479-492, 2013.

[11] R. Kim, H. Lim and B. Krishnamachari, "Prefetching-Based Data Dissemination in Vehicular Cloud Systems," IEEE Transactiions on Vehicular Technology, vol. 65, pp. 292-306, 2016.

[12] A. Abouaomar, A. Filali and A. Kabbane, "Caching, device-to-device and fog computing in 5th cellular networks generation : Survey,," in nternational Conference on Wireless Networks and Mobile Communications (WINCOM), 2017.

[13] M. R. Mahmud, K. Ramamohanarao and R. Buyya, "Edge Affinity-based Management of Applications in Fog Computing Environments," in 12th IEEE/ACM International Conference on Utility and Cloud Computing, Auckland, New Zealand, 2019.

[14] M. Alkhalaileh, R. N. Calheiros, Q. V. Nguyen and B. Javadi, Performance Analysis of Mobile, Edge and Cloud Computing Platforms for Distributed Applications, 2021.

[15] O. FIkir, I. Yaz and T. Ozyer, "A Movie rating Prediction Algorithm with Collaborative filtering," in Internation Conference on Advances in Social networking Analysis and Mining, 2010.

[16] Y. Alnagar, S. Hosny and A. El-Sherif, "Towards Mobility Aware Proactive Caching for Vehicular Adhoc Networks," in IEEE Wireless Communication Networking Conference workshop, 2019.

[17] Preetha Theresa Joy,K.Poulose Jacob.” Cooperative Caching Techniques for Mo bile Ad hoc Networks”. IEEE , 2012,175-180.

[18] Prashant Kumar, Naveen Chauhan ,LKAwasthi ,Narottam Chand . Proactive Approach for Cooperative Caching in Mobile Adhoc Networks ,IJCSI International Journal of Computer Science Issues,21-27 Vol. 7, Issue 3,No.8,May 2010.

[19] Han Ke, “Cooperative caching algorithm based on grouping nodes in mobile ad hoc networks”, ICIA, IEEEJune 2010.

[20] Dedicated Short Range Communications (DSRC) Home,http://www.leearmstrong.com/DSRC/DSRCHomeset.htm.

[21] Mattern F., Staake T, Weiss M (2010) ICT for Green How Computers Can Help Us to Conserve Energy, 1st International Conference on Energy-Efficient Computing and Networking e-Energy2010:1-10.

]22] Liangzhong Yin and Guohong Cao. ”Supporting Cooperative Caching in Ad hoc

Networks", IEEE INFOCOM,2537-2547,March 2004.
[23] Yu Du and Sandeep K.S. Gupta,"COOP-a Cooperative Caching Service in MANETs", IEEE Computer Society, 2005.
[24] Narottam Chand, R.C. Joshi and Manoj Misra, "Efficient Cooperative Caching in Ad Hoc Networks", IEEE Transactions, pp.1-8, August 2006.
[25] Kumar,P, Chauhan,N, Awasthi,L and Chand,N., "Proactive Approach for Cooperative Caching in Mobile Ad hoc Networks", International Journal of Computer Science ,2010, Volume 7,Issue 8, 21-27.
[26] Parvathy P.R, K.S.A Kumar,"2TierCoCS: A two-tier cooperative caching scheme for Internet-based vehicular ad hoc networks", Procedia computer science 57 (2015)84-90, Elsevier.
[27] Kumar,P, Chauhan,N, Awasthi,L and Chand,N., "Proactive Approach for Cooperative Caching in Mobile Adhoc Networks", International Journal of Computer Science ,2010, Volume 7,Issue 8, 21-27.
[28] Chan E, Liw, Lus, "Movement Prediction Based Cooperative Caching For Location Dependent Information Service In Mobile Adhoc Network", Journal of Supercomputing ,2012, Volume 59, Issue 1, 297-322.
[29] Yanmin Zhu,Chao Chen and Min Gao ." An evaluation of vehicular networks with real vehicular GPS traces", Springer, EURASIP Journal on Wireless Communication and Networking ,2013
[30] Preetha Theresa Joy,K.Poulose Jacob." Cooperative Caching Techniques for Mo bile Ad hoc Networks". IEEE , 2012,175-180.
[31] Prashant Kumar, Naveen Chauhan ,LKAwasthi ,Narottam Chand . Proactive Approach for Cooperative Caching in Mobile Adhoc Networks ,IJCSI International Journal of Computer Science Issues,21-27 Vol. 7, Issue 3,No.8,May 2010. Han Ke, "Cooperative caching algorithm based on grouping nodes in mobile ad hoc networks", ICIA, IEEE June 2010.
[32] Deepak Mathur, N. K. V. . (2022). Analysis & Prediction of Road Accident Data for NH-19/44. International Journal on Recent Technologies in Mechanical and Electrical Engineering, 9(2), 13–33. https://doi.org/10.17762/ijrmee.v9i2.366
[33] Philip, A. M., and D. S. . Hemalatha. "Identifying Arrhythmias Based on ECG Classification Using Enhanced-PCA and Enhanced-SVM Methods". International Journal on Recent and Innovation Trends in Computing and Communication, vol. 10, no. 5, May 2022, pp. 01-12, doi:10.17762/ijritcc.v10i5.5542.
[34] Goar, . V. K. ., and N. S. . Yadav. "Business Decision Making by Big Data Analytics". International Journal on Recent and Innovation Trends in Computing and Communication, vol. 10, no. 5, May 2022, pp. 22-35, doi:10.17762/ijritcc.v10i5.5550.
[35] Agarwal, D. A. . (2022). Advancing Privacy and Security of Internet of Things to Find Integrated Solutions. International Journal on Future Revolution in Computer Science &Amp; Communication Engineering, 8(2), 05–08. ttps://doi.org/10.17762/ijfrcsce.v8i2.2067