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A Survey on Optimization Techniques for Content Downloading in Vehicular Networks

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***Abstract*— We consider a road scenario where users aboard equipped with communication-enabled interfaces in vehicles are requesting for data access or downloading an altogether different content (different from that of the other vehicular users) from internet servers or roadside Access Points (APs). Downloading an altogether different content from the Internet is a topic of increasing interest in vehicular networks. We will review the techniques used for increasing the performance limits of such vehicular communication system for downloading content and accessing data which is unique for the other users by considering the downloading process as an optimization problem and thus we can maximize the overall system throughput by leveraging both Infrastructure-to-Vehicle (I2V) and Vehicle-to- Vehicle (V2V) communication. We will see the various methods used to investigate the impact of various factors like traffic intensity of vehicular users in the given region, deployment of roadside infrastructure, V2V relaying technique and penetration rate of the system. Our main objective will be to introduce traffic relaying by one or more vehicles creating a multi-hop between the user and the AP along the roadside so that the data flow is maximize across the whole network.**

***Keywords*— Vehicular communication, downloading, penetration rate, traffic relaying.**

I. Introduction

The use of high-end navigation system, information as well as other entertainment related applications is increasing day-by-day which will definitely lead to a drastic growth in bandwidth demand by the vehicular mobile users. Vehicular Network is a communication system in which vehicular users communicate with the roadside units (Access Point) and provide information to each other. Vehicular Networks also comprise of vehicle-to- vehicle communications as well as other examples of applications of vehicular communication abound and that varying from accessing news or weather reports, updating and navigating road maps, updating a software or even downloading some multimedia file, for instantly getting information of traffic conditions of a region or point of interest. This will urge the vehicular user to turn to resource intensive applications equal to the amount as today's cellular mobile customers.

Many observations and studies have agreed that neither the existing nor the upcoming cellular technology will adequately fulfil the increasing demand of high resource applications in wireless network. A recent study deduced that the cellular infrastructures have been extremely overloaded by internet traffic and the network is slowing down due to the large growth in mobile data traffic from smartphone users showing that the mobile data has now exceeded mobile voice in terms of traffic volume. This is a major problem and a wake up call for all service providers.

A recent measurement analysis of the internet traffic, that is, the network resource usage and subscriber behaviour, collected using a large scale data set within a nationwide 3G and 2G cellular data network showed that smartphone users represented only a few percent of the total subscribers, but surprisingly is draining more than two third of the total network resources[1].

To outline a network model that will support the demand of the increasing number of vehicular users, one possibility is to deploy a Dedicated Short-Range Communication (DSRC) and thus divide part of the data traffic to DSRC through direct communication, which is roadside infrastructure to vehicle (I2V) data transfer as well as through vehicle-to-vehicle data relaying. Such type of model is basically applicable for accessing or downloading huge amount of delay-tolerant data due to its lack of strict time constraints. Such type of network that does not have any type of time-constrained data to be transmitted and thus can make the use of discontinuous connected or carry-and-forward data transfer paradigms for communication are called as Delay Tolerant Networks (DTNs). In DTNs, contact between nodes come and go over time and communication takes place by multi-hop transmissions and where network partitions and node disconnections are likely to happen beyond the range of an AP.

In this paper, we will review the previous work on content downloading in vehicular mobile networks for data traffic communication and how these works have dealt with different aspects of the system such as deployment of roadside infrastructure (APs), performance review of I2V transfers, utilization and selection of specific V2V transfer paradigm. During considering such a downloading system we assume ideal conditions from a system's engineering point of view, i.e., availability of predefined knowledge of vehicular trajectories and scheduling mechanism to be used for data transmission. We will discuss the impact of important factors in vehicular communication such as AP deployment, selecting I2V or V2V transfer paradigm along with their working and the technology penetration rate. We stress that our objective is to target the general idea of providing user an optimized and high performance best effort downloading of different data content from the internet and not a content of common interest of other users. Our aim is not to study data dissemination or cooperative caching but to investigate the performance of various factors on content downloading and maximize the overall throughput as well as minimizing delays.

This paper is organized in various sections: Section II compromises of some previous related work, which is divided into three parts namely deployment of roadside units or infrastructures (APs), data transfer paradigms and penetration rate of the system. Section III highlights the system model of our proposed work and how it is different from other related works. Section IV enumerates the conclusions of this system.

II. Related Work

Our work basically relates to roadside infrastructures (APs) deployment, efficient optimization of data downloading and performance evaluation of the system, and to increase the overall system throughput, thus minimizing delays.

A. Roadside Units or Infrastructures (APs)

A deployment of roadside units (APs) is a crucial aspect for data communication in vehicular networks, its impact and placement scenario are discussed in other works as well. Infrastructure deployment strategies are proposed up to date that can be able to maximize the amount of time a vehicular user remains within the radio range of an access point.

It is obvious that longer duration of time instances within an AP coverage can surely support the downloading mechanism of vehicular users. The conception of non-continuous coverage for vehicular user called α-coverage, which provides worst-case guarantees on the interconnection gap at the same time using fewer APs than needed for normal coverage [2], thus guarantying a minimum coverage requirement.

As the popularity of high-resource services is increasing, Wireless LANs (WLANs) is gaining popularity but they are expensive and only offer opportunistic services without any guarantee on short-term throughput. Deployment of roadside WiFi is economically scalable and can be presented to design an efficient deployment method that maximises the worst-case contact opportunity [3]. A random distribution of roadside units (APs) over a road layout cannot help routing data in urban vehicular networks being highly populated with vehicular users because such type of scheme is only suitable for scenario where APs are to be employed as static cache for content items that need to be delivered to the vehicles visiting the AP at different times irrelevant of their position.

An infrastructure deployment strategy favouring content downloading with the help of vehicle-to-vehicle relaying in vehicular networks is introduced in [4] which explain cooperative downloading in dense vehicular network region. In this scenario, a vehicle downloads a part of the required content from one AP that is in its radio range and the relay downloads the other remaining part of the same content from another AP in its radio range. Later on when the two vehicles meet or encounter each other at some point, the relay transfers the data carried to the user, i.e., the target downloader. This type of system requires the pre-emptive knowledge of vehicular trajectory of the vehicles that acts as downloader and relays as well as the candidate APs must be in constant communication of one another to help coordinate with each other and informing the other AP of about the location, required content and other scheduling parameters. This scheme aims at maximizing the use of V2V communication but it could not avoid the mutual interference caused among concurrent traffic transfers.

Another relevant work related to roadside unit deployment or AP placement is briefly stated in [5] where the objective is dissemination of data or information in shortest possible time where as our concern is different content downloading in vehicular environment.

B. Data Transfer Paradigms

We are discretely outlining a general case where every vehicular user wants to access or download a resource-rich file or application that is of uncommon nature of interest among other users. The downloader can either communicate through direct communication with the AP, if possible, or be able download it by being assisted by another vehicles acting as relays. One of the studies focuses on accessing the web search and makes it highly efficient using the pre-fetching mechanism of the scheduling techniques. The work in [6] points out the pre-fetching with traffic scheduling techniques. Its objective is to maximise the content downloading amount by vehicular users through APs that form a wireless mesh network. But here the knowledge of vehicle trajectory over the road space needs to be known and most importantly multi-hop data transmission with the help of relays was not investigated [6].

The cooperative downloading can be used in this scenario as well where the vehicular trajectory of the user and the relay must be known beforehand. In this context the work in [7] aims to establish a swarming protocol for Vehicular Ad Hoc Networks (VANETs) called as SPAWN, which is economic and scalable for peer-to-peer content delivery mechanism or file sharing protocol that makes the use of parallel downloading among a mesh of cooperating peers in the VANET. But this is restricted to allow vehicles to share a content of common interest only.

Some of the important data transfer paradigms that are established using I2V or V2V communication are:

- Direct transfer which is the direct link between the roadside unit (AP) and a downloading user vehicle.
- Connected forwarding, i.e., traffic relaying with the help of one or more vehicle that will form a multi-hop path between the AP and the downloading user vehicle.
- Carry-and-forward, which is similar to connected forwarding but relays store and carry the data, ultimately delivering it to the destination downloader or to another relay vehicle to meet the downloader sooner.

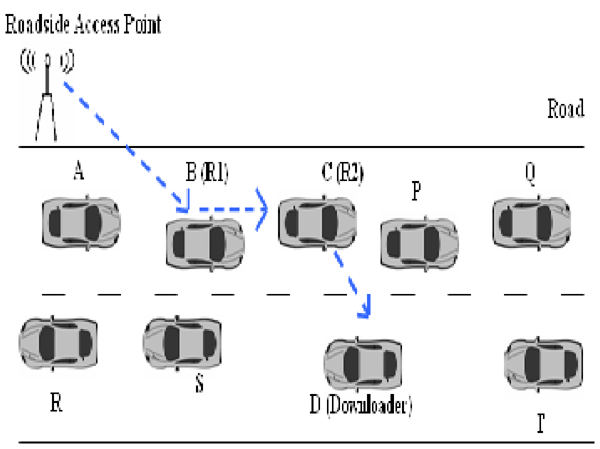

Fig. 1 Vehicular Network Scenario showing the use of V2V relaying for content downloading. Vehicle D wants to download some content from the internet, vehicle B and C act as relays R1 and R2 respectively, as they are idle. Vehicle A, R, S cannot act relay as they are not in idle state.

A vehicle that can act as an intermediate relay needs to be the state of idle condition, that is, it must not be itself downloading any data or using the network resources or internet services at the time of data transmission.

C. *Penetration Rate of the System*

Penetration rate of the system in the context of a vehicular network environment can be defined as the fraction of vehicles that are well equipped with communication interfaces and are willing to participate and get involved in the content downloading process, possibly as relays. We need to evaluate the effect that this penetration rate, *p*, has on the system performance and how it impacts the overall system throughput as well as the per-user throughput. Per-user throughput is the ratio of the amount of data received to the complete downloader trip duration.

Delay in data transfer is another important effect of the penetration rate. The higher the penetration rate, the higher will be the delay due to the more frequent V2V transfer taking place in a communication process. We also calculate the fairness in the system, that is, to obtain an analysis of how the system throughput is shared among the individual downloaders in the network.

The higher the penetration rate of the system, the higher is the chances that the technology uses V2V data transfer paradigm thus causing a large number of hops that are used for a single transmission leading to delayed transmission. The lower the rate of penetration of the technology the higher is the amount of I2V communication taking place, thus having to deploy APs with maximum coverage capacity.

In a low penetration regime, the AP placement in early stages is crucial. Lower penetration is not only observed when there are fewer number of users who can act as relays, but it also occurs when there is only a few active APs. Thus, the policy that is selected for roadside infrastructure deployment has a dramatic impact on the per user throughput because optimal AP deployment yields throughput more than twice than that obtained with random AP placements. Activation of few more or less APs drastically influences the system throughput, delay and fairness of the system. Conversely, on the other hand, large number of APs being activated has a small impact on the system performance as well as it also increases the deployment and maintenance cost.

III. SYSTEM MODEL

The working of the proposed system is started by considering the most important factor that affects the network performance.

A. *Measure the Traffic Intensity*

The amount of user that have communications-enabled interfaces in their vehicles or are requesting for data access or wanting to download some content from Internet, such users can act as relays or downloaders respectively defines the traffic intensity of the given road layout. The intensity of vehicular traffic will be different at different road segments. We will measure the traffic intensity for the reference scenario from different places like the urban region, rural region and a suburban area.

B. *Dynamic Network Graph and Maximum Flow*

When the vehicular user requests for some content that he wants to access or download, the nearest AP is activated and then the AP unit looks up at the number of vehicles that can act as intermediate relays. These APs, downloaders and relays are taken in various positions in different time frames considering the locations as imaginary locations. Using these imaginary frame locations a Dynamic Network graph is created using the vehicular mobility instances. Vehicles can be continuously added or removed from these graphs because the vehicles are moving at a fixed speed.

A Maximum Flow Problem is taken into account to perform an action of letting the flow from the AP to the downloader through the relays be maximized. This is applicable to more than one downloading user and huge number of relays that are involved in respective communications

C. *Deployment of APs*

Using the dynamic network graph and the max-flow problem, the graph is then divided into sub-graphs which are called as Sampled graph. Using these Sampled graphs, the sub-graph in which the flow is maximum with faster downloading speed indicated by lesser time frames for complete download to take place, are plotted and the candidate location helps to decide the placement of the roadside Access Point. This method of sampling helps to deploy APs at optimal location that can provide best coverage and easier allocation of relays.

D. *Performance Evaluation*

Once the APs are deployed and they are activated we need to evaluate the performance of the system in order to calculate the overall throughput, delay, V2V data transfer fraction and fairness of the network. Penetration rate of the technology and the user density is considered to formulate the performance graph. Depending on the location of the downloading user, relay vehicles and AP locations, the system must be able to transfer the content to the target user using the appropriate transfer paradigm, which is, either the I2V or V2V data transfers. If the penetration rate is high then most of the transfer of data will take place by the help of one or more than one relays creating a denser multi-hop communication, leading to delays but the rise in fairness and per-user throughput. In case of low penetration rate, data communication will mostly take place through direct communication between the infrastructure and the downloader, i.e., I2V communication thus needing to increase the coverage capacity of the APs and accurate AP deployment is crucial.

IV. CONCLUSIONS

Downloading of internet applications, files and services that are unique in terms of its content and different from that of other vehicular users is a topic of increasing attention because of the high scale demand for resource-intensive files, applications and other services in vehicular networks. Our system is designed in such a way that it not only enhances the overall system throughput and minimizes the delays but it also helps to give a high performance limits and optimized vehicular network model.

The penetration rate has a major impact on the performance of the system as it helps to decide the optimal locations for the deployment of APs according to the system requirement. In a low penetration regime AP deployment is crucial for higher throughput whereas in high penetration regime even a random deployment of roadside infrastructures can work correctly as maximum data transfer distance is covered by traffic relaying itself. V2V traffic relaying plays a major role to decide the performance of the system as it can enhance as well as slow down the network dramatically. The pre-hand knowledge of vehicular trajectories is vital since most of V2V traffic relaying takes place using carry-and-forward data transfer paradigm.

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