Optimal Content Downloading in Vehicular Networks

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Abstract: We consider a system where users aboard communication-enabled vehicles are interested in downloading different contents from Internet-based servers. This scenario captures many of the infotainment services that vehicular communication is envisioned to enable, including news reporting, navigation maps and software updating, or multimedia file downloading. In this paper, we outline the performance limits of such a vehicular content downloading system by modeling the downloading process as an optimization problem, and maximizing the overall system throughput. Our approach allows us to investigate the impact of different factors, such as the roadside infrastructure deployment, the vehicle-to-vehicle relaying, and the penetration rate of the communication technology, even in presence of large instances of the problem. Results highlight the existence of two operational regimes at different penetration rates and the importance of an efficient, yet 2-hop constrained, vehicle-to-vehicle relaying.

Keywords: Vehicular network, Content downloading, Process, Max-flow problem, Optimization, Density measurement.

I. Introduction

The communication-enabled vehicles are interested in downloading different multimedia contents from Internet-based servers. This system captures many of the infotainment services with effective information, such as navigation maps, news reporting service, and software updating, or multimedia content downloading. In this approach both the infrastructure-to-vehicle and vehicle-to-vehicle communication takes place. The major aim is to maximize the overall system throughput; we formulate a max-flow problem that accounts for several practical aspects, such as channel contention and the data transfer paradigm.

As a result, multimedia content downloading in vehicular networks shaves the vehicles’ received increasing attention from the research community. Initially, the availability of infrastructure-to-Vehicle (I2V) communication capabilities based on high-throughput Dedicated Short-Range Communication (DSRC) technologies, seen as an opportunity for the transfer of large data to mobile nodes that would not be possible through the existing 2G/3G infrastructure. Next, the availability of Vehicle-to-Vehicle (V2V) connectivity has fostered numerous proposals to make use of the cooperation among vehicular users so as to improve the downloading performance. In particular, V2V connectivity-based approaches are especially good when one considers that infrastructure coverage will be mooted at initial stages, and barely seamless even at later ones.

Previous work on content downloading in vehicular networks has dealt with individual aspects of the process, such as roadside APs deployment, the performance evaluation of V2V communication, then network connectivity, or V2V data transfer paradigms. Noone had tried to deal with the problem as a whole, trying to quantify the potential of all I2V/V2V-based content downloading process. In order to fill such a gap, we introduce the following questions: (i) which is the maximum download performance achievable through DSRC-V2F/I2F communication, in a given mobility scenario? (ii) What are the important factors that mainly determine such a downloading performance?

To answer these questions, we combine this downloading process to a mixed integer linear programming (MILP) known as the max-flow problem. The solution of this problem results in the optimal Access Point deployment over a given roadway layout and any possible combination of V2V and I2V data transmission.

Our framework introduces a DTN time-invariant graph. We do not undertake the contacts between mobile nodes and bus that allows them to access directly, and also report the presence of roadside infrastructure and channel contention. Such an approach allows us to significantly enhance the AP deployment over the given road layout, since we maximize throughput and also provide the optimal solution instead of an approximation.

At the result, the access point terminates the vehicle capability prior and sends the corresponding low-quality or high-quality file. This achieves the vehicle to receive the proper file resource. Vehicle density is calculated based on previous temporal changes and the vehicular density is calculated. The access points’ capabilities are adjusted so that it works more efficiently. Vehicular density environment and works less in low-vehicular density environment.

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This paper is organized as follows: Section II describes the previous work, while Section III discusses the contribution of work. In Section IV, we build the system model and assumption, while we generate the Dynamic Network topology graph in Section V. We formulate the max-flow problem in Section VI. Results, derived from the design guidelines described in Section VII, in Section VIII, we evaluate the vehicle density based data downloading. Section IX describes Security issues; finally, Section X summarizes our major findings and points out directions for future work.

II. Related Work

The authors U. Paul, M. M. Buddhikot, A. P. Subramanian, and S. R. Das were estated that the complete measurement analysis of network resource deployment and subscriber activities using a large-scale dataset collected within a nationwide 3G cellular network. The dataset keeps close to the number of subscribers over thousands of base stations. They also examined the capability of network resources, which can be reused by different subscriber calls as well as by different applications. They also find out the traffic in vehicular network from the point of view of the base stations and analyze the temporal and spatial variations in different kinds of the vehicular network. In order to address such coverage uncertainty, the authors Z. Zheng, P. Sinha, and S. Kumar were given an idea about new vehicular alternation coverage for mobile users, called vo-coverage, and examined how such coverage can be attained by systematic deployment of more APs to create an efficiently scalable infrastructure. In another way, deployment of APs is evolving in-coverage to network topology, if the road with a length of the given network resource meets with at least one AP that resource. The authors Z. Lu, Z. Zheng, P. Sinha, and S. Kumar were also stated that with increasing popularity of mediaenabled devices, there is a high demand for high-data rate services for mobile users is obvious. Large-scale Wireless LANs (WLANS) can offer such a service, but they are very expensive to deploy and maintain. The above results not only make the grade to provide any throughput assurance to a vehicular user, but can only provide opportunistic services to them.

III. My Contribution

The density measurement in vehicular network my contributions to this problem are as follows:

- The access point relay tracks the vehicle capability and sends the corresponding low-quality high-quality file. This achieves the vehicle to receive the proper file resource.
- Vehicle density is calculated based on previous temporal changes, and the new vehicle density is calculated.
- The access points' capabilities are adjusted so that it works more in high vehicle density environments and works less in low vehicle density environment.
- Vehicle density-based downloading scenarios applied to Access Points.

Proposed method where the Roadside infrastructure i.e., access points are reworking at different capabilities irrespective of vehicle density.

IV. System Model and Assumptions

4.1. Network Model

We create a network composed of fixed roadside APs and vehicle users, where some of them are downloaders. They are interested in downloading multimedia content from the Internet through the APs. We consider the general case in which every download may be interested in different content. They can either use relays or establish direct connectivity with APs. In particular, we consider the following data transfer paradigms:

- Direct transfers. A direct communication between an AP and a downloader. This shows the typical way how the mobile users communicate with the infrastructure. in today’s wired networks;
- Connected forwarding. The result shows communication made through honeymores vehicles that create a multithop path between an AP and a downloder. This is the conventional approach to traffic delivery in ad hoc networks;
- Carry-and-forward. The communication made through honeymore vehicles that store and carry the data and delivering them either to the target downloder or to another relay which meets such downloaders sooner.

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Our approach allows stop processing around layout and an associated vehicular mobility trace, so as to build a time-expanded graph that represents the temporal network evolution (Sec. V). By using this graph, we formulate a max-flow problem; the solution of this problem matches our goals.

V. Dynamic Network Topology Graph

Dynamic network topology graph (DNTG) generates a different vehicular mobility trace in a network topology, considering that on the corresponding road layout there are: (i) a set of candidate locations \( k \), \( i = 1, \ldots, V \) where APs could be placed; (ii) a set of vehicles \( i = 1, \ldots, V \) traveling over the road layout; (iii) a set of vehicles that wish to download data from the APs.

![Figure 1. A sample DNTG, with one Accesspoint A and three vehicles v1, v2, v3, the vehicle (v1) is a downloader while the others (v2, v3) are actuators. In the above graph, we show up to path that are agent for the carry and forward (A), connected forwarding (B), and direct transfer (C).](image)

The major aim of this topology graph is to model all possible ways through which data can flow from either direct AP to the downloader or possibly via relays. With known mobility trace, we identify the contact events between any pair of nodes such as V2I/V2V.

Each contact event is characterized by:

- Link quality. The quality of the link between two nodes; specifically, the achieved data transfer rate on the network layer, which depends on the distance between the possible two nodes.
- The contact starting time. The time at which the link between the two nodes is established or already established link that has quality level with new value;
- The contact ending time. The time at which the quality level of the link changed when the link is removed or discarded.

The time interval between any two contact events in the network is called a frame. Within a frame, the network is static, i.e., the link quality levels change as the means no link is created or removed. A contact event is established. We denote the number of frames by \( F \), and the duration of each frame is \( k(1 \leq k \leq F) \). By now, all contact events during each frame are said to be active in that frame of the vehicle. The vehicle shares information with other vehicles within each frame, or moves to a vertex \( 1 \leq k \leq F \). We denote by \( V \), and the subset of vertices representing the downloaders that exist in the network at frame \( k \) denoted.

Within each frame, a directed edge \((v, v')\) exists from vertex to vertex if a contact between two nodes occurs during that frame. Each edge of this frame is associated with a weight \( w(v, v') \), equal to the ratio of that corresponding contact event. The set of such edges is denoted.

Similarly, a directed edge \((v, v')\) comes from vertex to vertex if a contact between the candidate AP and the vehicle inactive during frame \( k \). These edges are related with weights \( w(v, v') \), equivalent to the contact event, and the set of such edges is defined as \( A \). A directed edge \((v, v')\) is also drawn from many

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Finally, in order to originate a max-flow problem over the DNTG, we introduce two virtual nodes, denoted as and , respectively representing the source and destination of the total flow of the graph. Then, the graph is finished within infinitesimal edges , from to any vertex, and , from any vertex, .

The DNTG is therefore a weighted directed graph, representing the network topology development over time. An example of DNTG is given in Fig. 1, representing one AP and three vehicles v1, v2, & v3, with v1 being considered as a downlink and v2, v3 vehicles acting as relays. To minimize the graph size, in the above example, we assume the possible network-layer rate w to be constant during the complete lifetime of the AP. Note that the graph allows the capture of all the data transfer paradigms previously discussed. It is possible to identify paths in the graph that correspond to (1). In path (1), direct download from the Access Point to the downlink (2). In path (2), the B connected forwarding through 3-hops (frame 2) and 2-hops (frame 5) and (3). In path (3), the A carry-and-forward through the movement of the relay vehicle v3.

VI. The Max-Flow Problem

With the above topology graph, our next step is to formulate the optimization problem. The main goal of this problem is to maximize the flow from to , i.e., the total amount of data downloaded by the downlink’s. Denoted by ( , ) the traffic flow over an edge connecting two generic vertices, our intention can be expressed as:

\[ \sum \sum \]

The max-flow problem needs to be solved taking into account several constraints such as, maximum number of APs that can be activated, channel access, nonnegative flow, and flow conservation. We detail such constraints below.

A. Constraints

Non-negative flow and flow conservation: the flow on each existing edge in DNTG must be greater than or equal to zero. Also, for any vertex in the graph, the amount of ingoing flow into the vertex must equal the amount of outgoing flow.

Channel access: In view of the fact that we consider an IEEE 802.11-based MAC scheme with RTS/CTS and a wake up scheme, the following events cannot take place simultaneously for a tagged vehicle, and the time of the frame must be shared among the tagged vehicle:

1) The vehicle transmits to a neighboring vehicle;
2) A neighboring vehicle receives from any relay;
3) The vehicle receives from a neighboring relay;
4) A neighboring relay transmits to any vehicle;
5) The vehicle receives from a neighboring AP;
6) A neighboring AP transmits to any vehicle.

The above constraints allow a vehicle under AP coverage area to utilize either 2V or V2V communication within the same frame. Next, we consider a vehicle under the coverage of either one AP is not connected to work in ad hoc mode, which means the communication with other vehicles is not possible. Then, for every frame and, such that ( , ), the following constraints hold:
Figure 2. Simulation scenario: (a) road layout and average density of vehicles computed over a weekday; (b) giving out of the AP candidate locations over the road layout.

\( x(i) \quad (\quad ) (\quad ) \)

Where \( i = 1 \ldots A \), are Boolean variables, if the candidate AP is activated the value is 1 and the value becomes 0 otherwise.

**Maximum number of active APs:** The final set of constraints imposes that no more than one candidate AP is selected, through the variables \( y_i \). Then, for \( y_i \), we can write:

\[ \sum \]

Where \( M \) is a randomly large positive constant.

**VII. Deriving Design Guidelines**

When influence the problem formulation obtained in the previous section to illustrate which factors concern the mobility constraints and vehicular networks and to provide realistic insights for the design of systems. We consider a real-world road topology, covering an area of 10 km² in the urban area. The vehicular mobility trace is generated synthetically, using traffic mini-simulators. In Fig. 2(a), we describe the road layout which explains the different traffic methodology observed over each road layout.

We consider the traditional VANET technology penetration rate, which means that only a fraction of the vehicles in the network, namely 20%, is equipped with communication interface communication devices and is already participating in the content downloading process. Either a relay or a downlink’s. Also, the number of vehicles downlink’s that concurrently request content is assumed to be 1% of the vehicles participating in the network. AP locations are selected along the road such that the distance between two adjacent APs is slightly equal to 150 m resulting in 92 candidate locations, shown in Fig. 2(b). The value of the achievable traffic network’s layer rate between any two nodes is attuned according to the distance between them. We bounded the maximum node transmission range to 200 m; this distance allows the establishment of reliable communication in 80% of the cases.

Since we make use of a realistic mobility model, in each road topology, the intensity of the vehicular traffic varies depending on the road segment and time period of the day. In Fig. 3a, 3b, and 3c, we describe the road layout of the urban, village, and suburban environments, stressing different traffic volumes observed over each road segment. Thicker, highlighted density segments identify road layout characterized by high vehicular density. As far as vehicular traffic variations in govenroad layout is concerned, we consider only time periods corresponding to the density of vehicles.

In the urban, village, and suburban road layout traces, each during about 6 hours, this leads to an average density of 90, 62.5, and 33.5 vehkm, respectively. The value of the attainable network layer rate is between every two nodes is adjusted according to the distance between them. To this end, we refer to the 802.11a experimental results that obtain the values shown in Fig. 3d, and we use them as a sample of the achievable network layer rate. Note that we end up with the maximum node transmission range to 200 m, because this distance allows the establishment of reliable communication in 80% of the cases.

Given that A’ locations have been activated, the resulting max-flow problem in Sec. 4 provides the AP deployment that maximizes the aggregated downlink throughput. We benchmark the performance of our optimal Max-flow strategy against the following AP deployment policies:

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**Random:** According to uniform distribution, AP locations are randomly selected among the candidate.
**Crowded:** It selects the AP locations whose coverage area exhibits above the highest vehicular density.
**Contact:** It picks up the AP location that maximizes the addition of the contact opportunities between vehicles and APs.

![Figure 3: Road layout in the (a) urban, (b) village, and (c) suburban scenarios, and achievable network-layer rate characterization as a function of distance.](image)

Particularly, for each vehicle, the contact opportunity is expressed as the fraction of the road section lengths traveled while under coverage of the least one AP. Once the active AP locations in the given road layout are determined according to any one of the above three policies, they are used in the max-flow problem formulation to secure the values of the binary variables y_i,j. Since the system throughput is obtained as the result of the max-flow problem with the preferred AP option, the results show how it represents the preeminent performance can achieve with each deployment strategy. Fig. 3 shows the average content downloader throughput for different deployment strategies, with the function of the number of active APs λ^n.

![Figure 4: Partition of the average downloader throughput with respect to the number of relays between AP and downloader (Max-flow deployment strategy).](image)

In order to demonstrate the absolute result of the throughput figures reported above, we focus on the Max-flow deployment strategy and look at the number of hops that data gets through before reaching its destination. In Fig. 4(a), the hops limit is set to 2, which means the number of relays between APs is 2. The throughput plot of the average per downlink throughput data due to direct data transfers without having to reach the previous hop. As the existence of APs becomes more pervasive, direct transfers paradigm are clearly more frequent. However, it is important to observe that the amount of data downloaded through one relay remains constant, even when 25 APs covering 50% of the route are deployed. The proportion of throughput achieved through direct and multi-hop transfers does not change when the boundary on the number of followed hops is removed, in Fig. 4(b).

Finally, the comparison between Fig. 4(a) and Fig. 4(b) shows the complexity due to the use of more than one relayata time can be eliminated without significant destruction. To summarize, we illustrate the following conclusions:

- Traffic relaying, through either connected forwarding or carry-and-forward, can considerably increase the average per-downloader throughput, even when the road layout is covered by more APs;
- Multi-hop data transfers involving more than one relay are less beneficial to the content downloading process.
VIII. Vehicle Density Based Access Point Data Downloading

In addition, the access point or relay tracks the vehicle capability prior and sends the corresponding low-quality or high-quality file. This achieves the vehicle to receive the proper file resource. Vehicle density is calculated based on previous temporal changes and then the new vehicle density is calculated. The access points capability are adjusted so that it works more in high vehicle density environment and works less in low vehicle density environment.

IX. Security Issues

9.1 Digital signatures as a building block

The message authenticity is necessary to protect VANETs from outsiders. But since safety messages will not contain any sensitive information, confidentiality is not required. In this system, the exchange of safety messages by vehicles in VANET needs authentication of a message but no need for encryption of such messages. Symmetric authentication mechanisms usually encourage less overhead per message than their asymmetric counterparts. In the VANET setting, safety messages are typically standalone and should benefit receivers as quickly as possible. The digital signatures are a better choice. In fact, a preface handshake is not suitable and actually creates more overhead. In addition, with the huge amount of network participants and the irregular connectivity, authentication servers, a PKI (Public Key Infrastructure) mechanism is the most suitable method for implementation of message authentication.

9.2 Estimation of the signature size

As we intend using a PKI for supporting security in VANETs, it is significant to choose a Public Key Cryptosystem (PKCS) with a tolerable implementation overhead in the vehicular network. According to DSRC, safety messages are sent with a periodicity of 100 to 300 ms. This inflict an upper bound on the processing time overhead; this overhead is shown below:

\[ T_{\text{sig}}(M) = T_{\text{sign}}(M) + T_{\text{trans}}(M) + T_{\text{verify}}(M) \]

Where \( T_{\text{sign}}(M) \), \( T_{\text{trans}}(M) \), and \( T_{\text{verify}}(M) \) are the necessary time duration to sign, transmit, and verify a message, respectively; \( \text{Sig}_{\text{PKI}}(M) \) is the size of the signature, and \( \text{M} \) is the message size. The certificate of the sending key is the sending vehicle's certificate. The above expressions show the three factors that affect the choice of a particular PKCS: (1) the execution speed of the signature generation, (2) the verification operation, and (3) the size of the key, signature, and certificate.

Since the actual size of encrypted messages is between 100 and 200 bytes, before being signed, the message is hashed. The overhead is almost constant for a given cryptosystem.

Hence, it is possible to evaluate different options at least relatively to each other. In fact, there are more numbers of candidate PKCS for implementing the PKI in a VANET. To ensure the future security of the PKCS, and taking into account the deployment schedule of DSRC.

<table>
<thead>
<tr>
<th>PKCS</th>
<th>Sig size (Bytes)</th>
<th>Trig (Sig) (Ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RSA</td>
<td>256</td>
<td>0.171</td>
</tr>
<tr>
<td>ECDSA</td>
<td>28</td>
<td>0.019</td>
</tr>
<tr>
<td>NTRU</td>
<td>197</td>
<td>0.131</td>
</tr>
</tbody>
</table>

Table 2: Comparison of signature regeneration and verification time on a memory-constrained Pentium III 400 MHz workstation

<table>
<thead>
<tr>
<th>PKCS</th>
<th>Generation (ms)</th>
<th>Verification (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECDSA</td>
<td>3.255</td>
<td>7.617</td>
</tr>
<tr>
<td>NTRU</td>
<td>1.587</td>
<td>1.488</td>
</tr>
</tbody>
</table>

We list records for public key and signature sizes:
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1. RSASign: the keysizes and signature sizes are large (256 bytes).
2. ECC (Elliptic Curve Cryptography): it is smaller than RSA (28 bytes), slower in verification but faster in signing.
3. NTRUSign: the key size is lies between RSA and ECC (197 bytes), but it is signing and verification it much faster than the RSA and ECC.

In DSRC the least data rate is 6 Mbps (for safety messaging data rate is typically 12 Mbps), the transmission overhead (at 12 Mbps) is acceptable. And the set options are shown in Table 1 and Table 2 give approximately execution time of signature generation and verification for ECD (Elliptic Curve Digital Signature Algorithm) and NTRU. These figures in the table should be taken only as suggestive for the specific platforms such as Pentium 400 MHz with memory constraints.

In conclusion, we can observe that the performance of ECDSA and NTRU outperform RSA. Compared to each other, the advantages of ECDSA is its small and economically designed; whereas NTRU’s speed is more than ECDSA. Therefore, it should depend on case-specific evaluations.

X. Conclusion

We examined the main factors affecting the performance of content downloading in vehicular networks, by formulating and solving an axiomatic flow problem over time extended graph representing a realistic vehicular traffic.

The important results in our system are as follows:

- Our majoride as are the density-based deployment yields performance closed to the optimum result, and that multi-hop traffic delivery is valuable, although the gain is negligible beyond 2 hops from the AP.
- The access points’ capabilities are adjusted so that this work shows one high vehicular density environment and works less in low vehicle density environment.

To our best knowledge, this paper addressing the security of vehicular networks is inefficient and quantified way.

In the future work, we aim to further develop this proposal. In particular, we plan to explore in more detail the respective merits of the key distribution by the manufacturer or by the legislative bodies; we will also go into carrying out additional numerical evaluations of the solutions.

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