ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization) Vol.2, Special Issue 1, March 2014

Proceedings of International Conference On Global Innovations In Computing Technology (ICGICT'14)

Organized by

Department of CSE, JayShriram Group of Institutions, Tirupur, Tamilnadu, India on 6th & 7th March 2014

Bandwidth Scheduling for Content Delivery in VANET

Babu G [1], Uma Maheswari M [2],

M.Tech, Dept of IT, K.S.R. College of Engineering, Tamilnadu, India[1]

Assistant Professor, Dept of IT, K.S.R. College of Engineering, Tamilnadu, India[2]

ABSTRACT: Vehicular ad hoc network (VANET) technology uses moving vehicles as nodes in a network to create a mobile network. A VANET turns every participating vehicle into a wireless router or node. 100 to 300 meter distance is allowed between vehicles to cover a wide network range. In VANET network topology is rapidly changed due to high mobility of nodes. VANET uses infrastructure support to handle time sensitive data exchange process. Single-hop and multi-hop methods are used for VANET communication. Vehicle to Vehicle (V2V) communication and Vehicle to Infrastructure (V2I) communication methods are used for VANET data transmission. Mobile internet is provided with the consideration of signal range and mobility of vehicle.

Vehicular communication is used to download different contents from the internet. Downloading optimization scheme is used to improve the content downloading throughput. Roadside infrastructure, vehicle-to-vehicle relaying, and penetration rate for communication factors are used in the system. Dynamic Network Topology Graph (DNTG) is constructed and sampling technique is applied to handle the data delivery process.

The content delivery system is improved with historical pattern based vehicle prediction scheme. Data request level based bandwidth scheduling is used in the system. Infrastructure estimation is performed with historical data patterns. Data replication scheme is used to reduce the data delivery delay.

I. INTRODUCTION

A number of interesting and desired applications of Intelligent Transportation Systems (ITS) have been stimulating the development of a new kind of ad hoc network: Vehicular Ad Hoc Networks (VANets). In these networks, vehicles are equipped with communication equipment that allows them to exchange messages with each other in Vehicle-to-Vehicle communication (V2V) and also to exchange messages with a roadside network infrastructure (Vehicle-to-Roadside Communication – V2R). A number of applications are envisioned for these networks, some of which are already possible in some recently designed vehicles (Fig. 1.1):

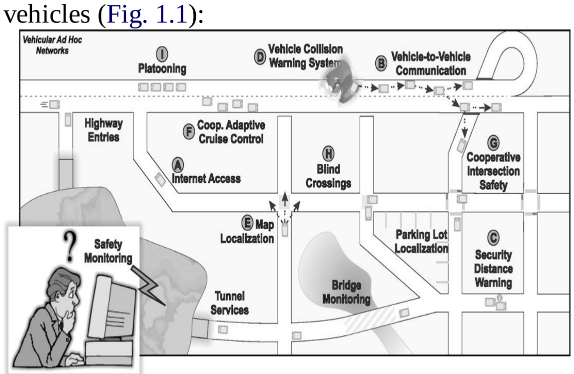

Fig. 1.1 Several VANet applications

- vehicle collision warning
- security distance warning
- driver assistance
- cooperative driving
- cooperative cruise control
- Internet access
- map location
- automatic parking
- driverless vehicles

All of these applications require, or can take advantage of, some sort of localization technique. In the localization problem, the definition of a reference system among nodes is performed by identifying their physical location or their relative spatial distribution in relation to each other. For instance, Map Location is usually done using Global Positioning System (GPS) receivers with a Geographic Information System, while Vehicle Collision Warning Systems can be implemented by comparing distances between nodes' locations combined with geographic information dissemination.

As ITS and VANets technology advances toward more critical applications such as Vehicle Collision Warning Systems (CWS) and Driverless Vehicles, it is likely that a robust and highly available localization system will be required. Unfortunately, GPS receivers are not the best solution in these cases, since their accuracy range from up to 20 or 30 m and since they cannot work in indoor or dense urban areas where there is no direct visibility to satellites. For these reasons and, of course, for security reasons, GPS information is likely to be combined with other localization techniques such as Dead Reckoning, Cellular Localization, and Image/Video Localization, to cite a few. This combination of localization information from different sources can be done using such Data Fusion techniques
as Kalman Filter and Particle Filter.

In this system discuss the localization requirements of a number of VANet applications. We then survey several proposed localization techniques that can be used to estimate the position of a vehicle, and we highlight their advantages and disadvantages when applied to VANets. By concluding that none of these techniques can achieve individually the desired localization requirements of critical
VANet applications, we show how the localization information from multiple sources can be combined to produce a single position that is more accurate and robust by using Data Fusion techniques.

II. RELATED WORK

Our work relates to infrastructure deployment and content delivery in mobile environments, as well as to delay tolerant networks (DTNs). Below, we review the studies that are most relevant to ours, highlighting the novelty of our approach.

Infrastructure deployment. Earlier studies focus on the feasibility of using IEEE 802.11 APs to inject data into vehicular networks, as well as on the connectivity challenges posed by such an environment. The authors show that a random distribution of APs over the street layout can help routing data within urban vehicular ad hoc networks. The impact of several AP deployments on delay-tolerant routing among vehicles is studied. More precisely, each AP is employed as a static cache for content items that have to be transferred between vehicles visiting the AP at different times. Other than in the scope from ours also because they do not provide theoretical justification of the AP placements they propose.

AP deployment is formulated as an optimization problem, where, however, the objective is not content downloading but the dissemination of information to vehicles in the shortest possible time. The study in [14], instead, estimates the minimum number of infrastructure nodes to be deployed along a straight road segment so as to provide delay guarantees to the data traffic that vehicles have to deliver to the infrastructure, possibly with the help of relays. A similar problem is addressed in [15], with the aim to support information dissemination. The different objectives of the above studies lead to completely different formulations, thus to results not comparable with the ones we present.

In [3], [4], infrastructure placement strategies are proposed that maximize the amount of time a vehicle is within radio range of an AP. Although longer periods of time under coverage can undoubtedly favor the download of contents by vehicular users, important differences with our work exist. First, our analysis is not limited to direct transfers from APs to vehicles, but includes traffic relaying. Second, while the problem formulation in [3] guarantees a minimum coverage requirement and the one in [4] maximizes the minimum-contact opportunity, we optimize the actual throughput, accounting for the airtime conflicts deriving from the contemporary presence of an arbitrary number of vehicles. Third, instead of studying a predefined set of paths over a given topology we process complete mobility traces.

An AP deployment strategy designed to favor content download through relaying in vehicular networks is introduced in [5]. The proposed optimization problem, however, aims at maximizing a metric reflecting the amount of vehicular traffic that enables V2V communication, and not the actual throughput. Moreover, such a formulation cannot capture the mutual interference among concurrent traffic transfers.

Content downloading and dissemination. With regard to content downloading in vehicular networks, unlike ours, focuses on the access to web search and presents a system that makes such a service highly efficient by exploiting prefetching. Experimental and analytical results show the contribution of V2V and I2V communications to the system performance. The works in [7], [8] address the benefits of prefetching jointly with traffic scheduling techniques. In particular, the objective of [8] is to maximize the amount of data downloaded by vehicles through APs that form a wireless mesh network, given the AP deployment and an (imprecise) knowledge of the vehicles trajectory and of their connectivity with the APs.

However, no multihop data transfer are investigated. In [7], both I2V and V2V communications are considered and the performance evaluation is carried out through simulation and a testbed on a circular campus bus route. Furthermore, a comparison against the solution to a max-flow problem is presented, but 1) it is limited to a simplified, highway-like scenario featuring one AP and one downloader and 2) it assumes atomic contacts between nodes, hence, neglecting interference and channel contention.

Our study also relates to cooperative downloading in vehicular networks. In this context, the work in [9] introduces a vehicular peer-to-peer file sharing protocol, which allows vehicles to share a content of common interest. Our study on content download, instead, works in the more generic case, where each user is interested in a different file. System assumptions similar to the ones made in [9] are behind the works in [10], [11], about which, as a consequence, the same considerations hold.

DTNs. The vehicular cooperation paradigm that we consider relates our work to DTNs. In particular, assesses the benefit to content dissemination of adding varying numbers of base stations, mesh nodes, and relay nodes to a DTN, through both a real testbed and an asymptotic analysis. A DTN time-invariant graph, which is similar to the time-expanded graph used in our study. With respect do not assume the contacts between mobile nodes to be atomic but to have arbitrary duration, and we build the network graph so as to account for the presence of roadside infrastructure and channel contention. The representation of a time-varying network topology as a time-expanded graph can be found in [12], [6], where the former is an earlier version of this work. As for the latter, such a graph is used to identify the nodes whose limited storage may impair the network performance, and to formulate a max-flow problem whose solution leads to an optimal, distributed routing, and storage policy. In our work, we address the performance limits of content downloading and the problem of AP deployment, for which no distributed solution is needed.

III. CONTENT DOWNLOADING IN VEHICULAR NETWORKS

The presence of high-end Internet-connected navigation and infotainment systems is becoming a reality that will easily lead to a dramatic growth in bandwidth demand by in vehicle mobile users. Examples of applications of vehicular communication abound, and range from the updating of road maps to the retrieval of nearby points of interest, from the instant learning of traffic conditions to the download of touristic information and media-rich data files. This will induce vehicular users to resort to resource-intensive applications, to the same extent as today's cellular customers.

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization) Vol.2, Special Issue 1, March 2014

Proceedings of International Conference On Global Innovations In Computing Technology (ICGICT'14)

Organized by

Department of CSE, JayShriram Group of Institutions, Tirupur, Tamilnadu, India on 6th & 7th March 2014

Most observers concur that neither the current nor the upcoming cellular technologies will suffice in the face of such a surge in the utilization of resource-demanding applications. Recent network overload episodes incurred in by cellular infrastructures in presence of smart phone users [1] provide a sobering wake-up call. To wit, a recent analysis on the traffic of a large US-based operator showed that smartphone users represent just 1 percent of the total subscribers, yet drain 60 percent of the network resources [2].

To design a network architecture that will scale to support the mass of vehicular users, one possibility is to offload part of the traffic to Dedicated Short-Range Communication (DSRC), through direct infrastructure-to-vehicle (I2V) transfer, as well as vehicle-to-vehicle (V2V) data relaying. Such an approach is especially attractive in the case of the download of large amounts of delay-tolerant data, a task that is likely to choke 3G/4G operator networks, but that well fits DSRC based I2V and V2V communication paradigms due to its lack of strict time constraints.

Within such a context, previous works on content downloading in vehicular networks have dealt with individual aspects of the process, such as the deployment of roadside Access Points (APs) [3], [4], [5], the performance evaluation of I2V communication, or the exploitation of specific V2V transfer paradigms [7]. None of them, however, has tackled the problem as a whole, trying to quantify the actual potential of an I2V/V2V-based content downloading. In this paper, we identify the downloading performance limits achievable through DSRC-based I2V/ V2V communication.

To this end, we assume ideal conditions from a system engineering viewpoint, i.e., the availability of preemptive knowledge of vehicular trajectories and perfect scheduling of data transmissions, and we cast the downloading process to a mixed integer linear programming (MILP) max-flow problem. The solution of such a problem yields the optimal AP deployment over a given road layout, and the optimal combination of any possible I2V and V2V data transfer paradigm. It, thus, represents the theoretical upper bound to the downloading throughput, under the aforementioned assumptions.

While it is true that the resulting problem is NP complete, we show that, with a careful design of the model, it can be solved in presence of realistic vehicle mobility in a real-world road topology. In addition, we propose a sampling-based technique that efficiently yields a solution even for large-scale instances. Although the problem formulation and the performance figures we derive are interesting per-se, we also exploit our optimal solution to discuss the impact of key factors such as AP deployment, transfer paradigms, and technology penetration rate.

As a final remark, we stress that our model, the first of its type to our knowledge, targets the general case of users interested in best-effort downloading of different data content. As a consequence, the goal is not to study information dissemination or cooperative caching, but to investigate the performance of content downloading.

IV. ISSUES ON CONTENT DELIVERY PROCESS

Vehicular communication is used to download different contents from the internet. Downloading optimization scheme is used to improve the content downloading throughput. Roadside infrastructure, vehicle-to-vehicle relaying, and penetration rate for communication factors are used in the system. Dynamic Network Topology Graph (DNTG) is constructed and sampling technique is applied to handle the data delivery process. The following drawbacks are identified in the existing system.

- Infrastructure estimation accuracy is low
- Vehicle prediction is not optimized
- Content delivery latency is high

V. DYNAMIC NETWORK TOPOLOGY GRAPH (DNTG) FOR CONTENT DELIVERY

We envision a network composed of fixed roadside APs and vehicular users, where some of the latter (hereinafter, named downloaders) are interested in downloading best effort traffic from the Internet through the APs. We consider the general case in which every downloader is interested in different content: downloaders can either exploit direct connectivity

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization) Vol.2, Special Issue 1, March 2014

Proceedings of International Conference On Global Innovations In Computing Technology (ICGICT'14)

Organized by

Department of CSE, JayShriram Group of Institutions, Tirupur, Tamilnadu, India on 6th & 7th March 2014

with the APs, if available, or be assisted by other vehicles acting as intermediate relays. Specifically, we account for all possible data transfer paradigms that can be implemented through I2V/V2V communication:

Direct transfer, resulting from a direct communication between an AP and a downloader. This represents the typical way mobile users interact with the infrastructure in today's wireless networks;

Connected forwarding, i.e., traffic relaying through one or more vehicles that create a multihop path between an AP and a downloader, where all the links of the connected path exist at the time of the transfer. This is the traditional approach to traffic delivery in ad hoc networks;

Carry-and-forward, i.e., traffic relaying through one or more vehicles that store and carry the data, eventually delivering them either to the target downloader or to another relay deemed to meet the downloader sooner.

We stress that connected forwarding and carry-and forward are inherently multihop paradigms. We assume that vehicular users are rational; hence, they can be engaged in relaying traffic for others only if they are not currently retrieving the content for themselves. Furthermore, because our goal is to derive an upper bound to the system performance, we assume the availability of preemptive knowledge of vehicular trajectories and perfect scheduling of data transmissions.

From the viewpoint of the network system, we consider that each node (a vehicle or an AP) has one radio interface only. This is a common assumption for vehicular nodes, while the extension to the case, where APs have more than one interface is straightforward. Any two nodes in the network can communicate at a given time instant, i.e., they are neighbors, if their distance is below or equal to their maximum radio range. Also, we assume that the maximum radio range is common to all network nodes and is equal to the node interference range. We consider that V2V communications occur on the same frequency channel, which is different from the channels used for I2V communication; APs with overlapping coverage areas operate on separate channels. When under AP coverage, a vehicle can always choose either I2V or V2V communication. The nodes share the channel bandwidth allocated for service applications using an IEEE 802.11-based MAC protocol.

Our objective is to design the content downloading system so as to maximize the aggregate throughput. To this aim, we have to jointly solve two problems: 1) given a set of candidate locations and a number of APs to be activated, we need to identify the deployment yielding the maximum throughput; 2) given the availability of different data transfer paradigms, possibly involving relays, we have to determine how to use them to maximize the data flow from the infrastructure to the downloaders. Our approach consists in processing a road layout and an associated vehicular mobility trace, so as to build a graph that represents the temporal network evolution (Section 4). By using this graph, we formulate a max-flow problem whose solution matches our goals (Section 5).

We generate a time-expanded graph, hereinafter DNTG, from a vehicular mobility trace. To build the graph, we consider that on the road layout corresponding to the mobility trace there are: 1) a set of A candidate locations (a_i, i = 1, . . .,A) where APs could be placed, 2) a set of V vehicles (v_i, i = 1, . . . , V) transiting over the road layout and participating in the network, and 3) a subset of D vehicles that wish to download data from the infrastructure.

The aim of the DNTG is to model all possible opportunities through which data can flow from the APs to the downloaders, possibly via relays. Given the mobility trace, we therefore identify the contact events between any pair of nodes (i.e., two vehicles, or an AP and a vehicle). Each contact event is characterized by:

1. The quality level of the link between the two nodes. Several metrics could be considered; here, we specifically take as link quality metric the data rate achievable at the network layer;
2. the contact starting time, i.e., the time instant at which the link between the two nodes is established or the quality level of an already established link takes on a new value;
3. The contact ending time, i.e., the time instant at which the link is removed, or its quality level has changed.

VI. INFRASTRUCTURE AND REPLICA MANAGEMENT SCHEME

The content delivery system is improved with historical pattern based vehicle prediction scheme. Data request level based bandwidth scheduling is used in the system. Infrastructure estimation is performed with historical data patterns.

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization) Vol.2, Special Issue 1, March 2014

Proceedings of International Conference On Global Innovations In Computing Technology (ICGICT'14)

Organized by

Department of CSE, JayShriram Group of Institutions, Tirupur, Tamilnadu, India on 6th & 7th March 2014

Data replication scheme is used to reduce the data delivery delay. Pattern extraction algorithm, density and request level based bandwidth scheduling algorithm, infrastructure estimation algorithm and replica assignment algorithms are used for the pattern analysis and scheduling process.

6.1. Pattern Extraction Algorithm

Apriori algorithm is adapted to extract the patterns. Historical vehicle movement information is used for pattern extraction process. Vehicle entry and exit information are used in the analysis. Vehicle locations and moving details are used in the pattern analysis.

6.2. Density and Request Level Based Bandwidth Scheduling Algorithm

Vehicle density in the road is used for the bandwidth allocation process. Request load and content size is used for the bandwidth assignment process. Request priority and mobility factors are used in the bandwidth allocation process. Scheduling is dynamically updated with infrastructure details.

6.3. Infrastructure Estimation Algorithm

Vehicle count and data access details are used to estimate the infrastructures. Time intervals are used in the infrastructure estimation process. Dynamic Network Topology Graph (DNTG) is used for infrastructure estimation process. Historical data and current status are used in the system.

6.4. Replica Assignment Algorithm

Replicas are used to maintain frequently requested contents. Shared content and request frequency are used for replica assignment process. Most frequently requested files are updated in replica systems. Contents are delivered from the replicas and servers.

VII. REPLICA ALLOCATION AND BANDWIDTH SCHEDULING IN VANET

The content delivery system is improved with historical pattern based vehicle prediction scheme. Data request level based bandwidth scheduling is used in the system. Infrastructure estimation is performed with historical data patterns. Data replication scheme is used to reduce the data delivery delay. The VANET content delivery system is designed to manage bandwidth and replica. Historical data analysis is carried out to predict content and vehicle density. RSU requirements are identified with network load information. The system is divided into five major modules. They are vehicle and infrastructure management, pattern analysis, bandwidth scheduling, replica management and content delivery process.

OBU and RSU are managed in the infrastructure management module. Historical data analysis is performed under pattern analysis module. Data transmission bandwidth is allocated under bandwidth scheduling module. Data replication process is carried out under replica management module. Content request and response transmission are managed under content delivery process module.

7.1. Vehicle and Infrastructure Management

Road network, vehicles and infrastructure properties are collected for the current status. The vehicle communication is carried out with the On Board Unit (OBU) environment. Data server and replica are provided in the Road Side Infrastructure (RSI). OBU and RSI are used for the data transmission process over the network.

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization) Vol.2, Special Issue 1, March 2014

Proceedings of International Conference On Global Innovations In Computing Technology (ICGICT'14)

Organized by

Department of CSE, JayShriram Group of Institutions, Tirupur, Tamilnadu, India on 6th & 7th March 2014

7.2. Pattern Analysis

Pattern extraction is performed using the historical vehicle movement details. Apriori algorithm is tuned for the vehicle pattern analysis process. Vehicle flow is analyzed with different time slots. Vehicle location and moving status details are also analyzed in the pattern extraction process.

7.3. Bandwidth Scheduling

Bandwidth scheduling is used to allocate bandwidth for the vehicles. Density and request level based bandwidth scheduling algorithm is used for the bandwidth allocation process. Request frequency and load level are used in the bandwidth scheduling process. Vehicle traffic level is used for bandwidth assignment process.

7.4. Replica Management

Replica management handles the data distribution process for the replicas. Replica assignment algorithm is used to assign replica contents. Most frequently requested data values are updated to the replicas. Shared data are delivered from the data servers and replicas.

7.5. Content Delivery Process

User requests are processed under the content delivery process. Infrastructure estimation algorithm is used to improve the content delivery process. Dynamic Network Topology Graph (DNTG) is used for the content delivery process. Content delivery is carried out with the support of data servers, replicas and vehicles.

VIII. CONCLUSION

Vehicular Ad hoc networks (VANET) constructed to manage communication under road networks. Content delivery is managed with vehicles and road side infrastructure. Bandwidth scheduling is performed with vehicle load prediction model. The data replica is used to improve the data delivery rate. The system reduces the infrastructure requirement. Data delivery delay is minimized by the replicas. Pattern based density prediction process is used for the infrastructure estimation process. Reliable data delivery process is supported by the content delivery scheme.

REFERENCES

[1] B.S. Arnaud, "iPhone Slowing Down the Internet - Desperate Need for 5G R&E Networks," http://billstarnaud.blogspot.com/2010/04/iphone-slowing-down-internet-desperate.html, May 2010.
[2] U. Paul, A.P. Subramanian, M.M. Buddhikot, and S.R. Das, "Understanding Traffic Dynamics in Cellular Data Networks," Proc. IEEE INFOCOM, Apr. 2011.
[3] Z. Zheng, P. Sinha, and S. Kumar, "Alpha Coverage: Bounding the Interconnection Gap for Vehicular Internet Access," Proc. IEEE INFOCOM, Apr. 2009.
[4] Z. Zheng, Z. Lu, P. Sinha, and S. Kumar, "Maximizing the Contact Opportunity for Vehicular Internet Access," Proc. IEEE INFOCOM, Mar. 2010.
[5] M. Fiore and J.M. Barcelo-Ordinas, "Cooperative Download in Urban Vehicular Networks," Proc. IEEE Sixth Int'l Conf. Mobile Ad Hoc and Sensor Systems (MASS), Oct. 2009.
[6] G. Iosifidis, I. Koutsopoulos, and G. Smaragdakis, "The Impact of Storage Capacity on End-to-End Delay in Time Varying Networks," Proc. IEEE INFOCOM, Apr. 2011.
[7] B.B. Chen and M.C. Chan, "MobTorrent: A Framework for Mobile Internet Access from Vehicles," Proc. IEEE INFOCOM, Apr. 2009.
[8] S. Yoon, D.T. Ha, H.Q. Ngo, and C. Qiao, "MoPADS: A Mobility Profile Aided File Downloading Service in Vehicular Networks," IEEE Trans. Vehicular Technology, vol. 58, no. 9, pp. 5235-5246, Nov. 2009.

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization) Vol.2, Special Issue 1, March 2014

Proceedings of International Conference On Global Innovations In Computing Technology (ICGICT'14)

Organized by

Department of CSE, JayShriram Group of Institutions, Tirupur, Tamilnadu, India on 6th & 7th March 2014

[9] M. Gerla and M. Gruteser, "Vehicular Networks: Applications, Protocols, and Testbeds," Emerging Wireless Technologies and the Future Mobile Internet, D. Raychaudhuri, M. Gerla, eds., Cambridge Univ., May 2011.
[10] M. Sardari, F. Hendessi, and F. Fekri, "Infocast: A New Paradigm for Collaborative Content Distribution from Roadside Units to Vehicular Networks," Proc. IEEE Sixth Ann. Comm. Soc. Conf. Sensor, Mesh and Ad Hoc Comm. and Networks (SECON), June 2009.
[11] O. Trullols-Cruces, J. Morillo, J.M. Barcelo-Ordinas, and J. Garcia-Vidal, "A Cooperative Vehicular Network Framework," Proc. IEEE Int'l Conf. Comm. (ICC), June 2009.
[12] F. Malandrino, C. Casetti, C.-F. Chiasserini, and M. Fiore, "Content Downloading in Vehicular Networks: What Really Matters," Proc. IEEE INFOCOM Mini-Conf., Apr. 2011.
[13] Francesco Malandrino, Claudio Casetti, Carla-Fabiana Chiasserini and Marco Fiore, "Optimal Content Downloading in Vehicular Networks", IEEE Transactions On Mobile Computing, Vol. 12, No. 7, July 2013.
[14] A. Abdrabou and W. Zhuang, "Probabilistic Delay Control and Road Side Unit Placement for Vehicular Ad Hoc Networks with Disrupted Connectivity," IEEE J. Selected Areas in Comm., vol. 29, no. 1, pp. 129-139, Jan. 2011.
[15] V. Kone, H. Zheng, A. Rowstron, and B.Y. Zhao, "On Infostation Density of Vehicular Networks," Proc. Fifth Ann. Int'l Wireless Internet Conf. (WICON), Mar. 2010.