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Research Article

Disseminating a Large Amount of Data to Vehicular Network in an Urban Area

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The problem of distributing a large amount of data from multiple sources in an urban area is investigated. We explore an opportunistic approach for information collection, in which a vehicle obtains information about resources from encountered vehicles. This protocol could be applied in both dense and sparse vehicular networks. Due to the highly dynamic nature of the underlying vehicular network topology, we depart from architectures requiring centralized coordination, reliable MAC scheduling, or global network state knowledge, and instead adopt a distributed paradigm with simple protocols. In other words, a reliable dissemination is introduced from multiple sources when each node in the network shares a limited amount of its resources for cooperating with others. By using rateless coding at the Road Side Unit (RSU) and using vehicles as data carriers, an efficient way to achieve reliable dissemination to all nodes (even disconnected clusters in the network) is described.

1. Introduction

Recently, many researches have been done to use vehicular ad hoc networks (VANET) for safety and commercial purposes [1–3].

The integration of communication technology in state-of-the-art vehicles has begun years ago: car phones and internet access based on cellular technologies as well as Bluetooth adapters for the integration of mobile devices are popular examples. However, the direct communication between vehicles using an ad hoc network, referred to as intervehicle communication (IVC) or vehicle ad hoc networks (VANETs), is a relatively new approach. Compared to a cellular system, IVC has three key advantages: lower latency due to direct communication, broader coverage, and having no service fee.

Recently, the promises of wireless communications to support vehicular safety applications have led to several research projects around world: the Vehicle Safety Communications Consortium, developing the DSRC Technology (USA), the Internet ITS Consortium (Japan), the PREVENT project (Europe), and the "Network on Wheels" project (Germany) are some samples.

To cater to the emerging wireless communication needs with regard to vehicles, in July 2003, ASTM and IEEE adopted the Dedicated Short Range Communication (DSRC) standard (ASTM E 2213-03) [4]. The aim of this standard is to provide wireless communications capabilities for transportation applications within a 1000 m range at typical highway speeds. It provides seven 10 MHz channels at the 5.9 GHz licensed band for ITS applications, with different channels designated for different applications, including one specifically reserved for vehicle-to-vehicle communications. The specific properties of VANETs allow the development of attractive new services.

Vehicular communications have many different facets. Applications range from safety support [5] (e.g., collision warnings, slow-down warnings), to entertainment for passengers, to local news delivery and advertisement [6] (e.g., electronic toll collection, map download, video download, Internet transactions, Parking Space availability). The key parameter for providing these applications is message dissemination. According to above classification, the messages which are exchanged between vehicles can be categorized into three classes.

(1) Event driven safety messages: which are the results of the detection of an unsafe situation, (e.g., a car crash, the proximity of vehicles at high speed, etc.).

(2) Periodic safety messages: also called beacon messages, are needed to make vehicles aware of their environment and also commercial purposes. Thus, they will be able to avoid emergency or unsafe situations even before they appear. Therefore, beacon messages essentially contain the state of the sending vehicle, that is, position, direction, speed, and so forth, and also aggregated data regarding the state of their neighbors.

(3) Comfort messages: all other types of data packets are included in comfort messages (e.g., data packets include internet access, video conferencing, etc.).

In this paper, a protocol which is able to disseminate a large amount of commercial data to urban areas from roadside units is proposed. This protocol can be used for both dense and sparse networks. Moreover, In previous works, neighbors are assumed to be recognized by beacons which are periodically sent by carriers. In this approach, there is no need to send these beacons.

The protocol should answer to these questions: when and how the act of forwarding should happen; in other words, how does the carrier decide to forward the message? Does it need to keep a copy message for itself?

The remainder of this paper is organized as follows. In Section 2, a brief review of previous works about distributing data in vehicular networks is propounded. In Section 3, we introduce the application of commercial advertisements in VANET. In Section 4, characteristics of vehicular ad hoc networks will be expressed. Section 5 reviews the DMRC method investigated in [7]. Our proposed scheme and simulation tools are described in Section 6. Finally, the paper is concluded in Section 7.

2. Related Work

Advertisements are one of the most important sources of revenue for companies. The advertisement application is a type of data dissemination from an information source to a large number of clients. In this work, we will take some steps to answer questions concerning data dissemination in the context of disseminating information packets from a large array of Road Side Units (RSU) to a bidirectional linear highway vehicular network. Vehicular ad hoc networks (VANETs) can be considered as a category of partitioned ad hoc networks [8]. Since density of vehicles is highly variable with space and time, the network changes from a sparsely disconnected to a densely connected in a short period of time. As a result of these topology variations, traditional routing and forwarding methods do not have a reasonable performance in VANET scenarios. In order to have message dissemination in partitioned ad hoc networks, the idea of Store-Carry-Forward (SCF) was proposed [1]. In SCF, a node carries information while there is not any other node in its vicinity. As soon as another node is detected, the forwarding phase starts. In recent years, several works have been done in using SCF which are more compatible with VANET environment. The most important of these works are SODAD [2], VADD [3], and MDDV [9]. A weak point in SCF is that sometimes the message transfer speed is limited by nodes' velocities. This increases end-to-end delay from a source to a destination. Fortunately, comfort applications of VANET are Delay Tolerant and applying SCF cannot be a major problem. Although SCF seems to be the proper answer for sparse scenarios, designing a routing protocol that can seamlessly handle the two extreme cases: well-connected networks and disconnected networks is still a challenge. In our proposed mechanism, an opportunistic approach of SCF is used. In opportunistic forwarding [10], message dissemination happens when a forwarding opportunity is detected. After forwarding a packet, a copy may be kept in the original node for further forwarding, if needed. For VANETs, opportunity can be defined as a situation where two vehicles meet each other. In [7], disseminating a large amount of data in highways is investigated. The characteristic of highways is that vehicles have approximately constant speed during their moving across the highways.

3. Commercial Advertisement in Vanet

Consider a downtown area with many stores and entertainment centers. Each store has different products and services. Some of products are on sale, some of the entertainment seats are available, and some foods are close to expiration date. Now consider many vehicles which carry many passengers in the downtown area. If store owners advertise their sale or activity information in nearby area, they have the opportunity to find some customers out of these passengers. With this motivation, any store is willing to use a special device to become a Roadside Advertising Unit (RSAU). In a conventional VANET, four primary data transfers can be assumed: (1) vehicle-to-vehicle (v2v) data transfer, (2) vehicle-to-roadside data transfer (v2r), (3) roadside-to-vehicle date transfer (r2v), and (4) roadside-to-roadside date transfer (r2r).

In this work, we continued the DMRC [7] approach for urban area. Therefore, at first the DMRC scheme will be introduced and we develop it for the roads containing vehicles with various speeds and different traffic loads. In our approach, the typical traffic is advertisement data generated by roadside advertising units (RSAU). Each RSAU is equipped with a short range wireless broadcast point which broadcasts the advertisements to the vehicles (r2v). Vehicles are collecting these data when they are moving toward the RSAU and distributing the data when they are moving in opposite direction. In this paper, a new approach that merges the *vehicle-to-vehicle* and *roadside-to-vehicle* communication typologies in order to support reliable data dissemination in an urban area without the need of complex routing protocols is presented. Also our focus in this paper is on sparse networks. In the following, we first reminisce the characteristics of disconnected ad hoc networks.

4. Characteristics of Disconnected Vehicular Ad Hoc Networks

Realizing that a Vehicular Ad hoc Network is prone to network fragmentation, it becomes essential to capture VANET's traffic characteristics for a better understanding of this phenomenon. Based on investigations in [11], it is observed that vehicles tend to move in clusters where two consecutive clusters of vehicles are normally separated by a relatively large distance. Also, it is observed that the probability distribution of the spacing between equipped vehicles in a network with can be approximated as an exponential distribution with parameter λ_s, given by

$$f_s(s) = \lambda_s e^{-\lambda_s s}. \tag{1}$$

4.1. Average Intracluster Spacing ($E[S_{\text{intra}}]$). In this subsection, we are particularly interested in characterizing the intracluster spacing between adjacent vehicles i and $i+1$ which travel in the same cluster. Since the two vehicles belong to the same cluster, the distance between them should be less than the transmission range R. Given that the intervehicle spacing S has an exponential distribution, it follows that the Probability Distribution Function (PDF) of S_{intra} can be expressed as

$$f_{S_{\text{intra}}}(S_{\text{intra}}) = P_r[S \mid S \leq R] = \frac{\lambda_s e^{-\lambda_s S_{\text{intra}}}}{1 - e^{-\lambda_s R}}. \tag{2}$$

4.2. Average Inter-Cluster Spacing ($E[S_{\text{inter}}]$). Obviously, in line with the concept of clusters, the distance between the last vehicle of the leading cluster and the first vehicle of the following cluster should be larger than transmission range R. Given that the interarrival spacing S follows an exponential distribution, PDF of S_{intra} can be expressed as

$$f_{S_{\text{inter}}}(S_{\text{inter}}) = P_r[S \mid S > R] = \lambda_s e^{-\lambda_s (S_{\text{inter}} - R)}. \tag{3}$$

Based on expressed lemmas in [12], the intervehicle spacing is exponentially distributed with the parameter λ_s, then the expected inter-cluster spacing is given by

$$E[S_{\text{inter}}] = \frac{1}{\lambda_s} + R. \tag{4}$$

Also, if the intervehicle spacing is exponentially distributed with parameter λ_s, the expected number of vehicles in a cluster is

$$E[C_N] = e^{\lambda_{sR}}. \tag{5}$$

4.3. Average Cluster Length ($E[C_L]$). The size of a cluster can also be described by its length between the first vehicle and the last vehicle in a cluster.

If the intervehicle spacing is exponentially distributed with parameter λ_s, then the average cluster length is given as

$$E[C_L] = \left(\frac{1}{P_d} - 1\right)\left(\frac{1}{\lambda_s} - \frac{Re^{-\lambda_s R}}{1 - e^{-\lambda_s R}}\right). \tag{6}$$

The proof of (1), (2), (3), and (6) is amplified in [11].

Let V_0 be the average speed of every vehicle on the road and $M_n(L)$ denote the number of clusters a collector vehicle meets during a travel along a road of length L (note that collector and carrier vehicles move in opposite directions, with respect to an RSU). Further, let M_t denote the time duration that a collector vehicle spends in contact with a cluster of carrier vehicles. Given that the intervehicle spacing follows an exponential distribution, $M_n(L)$ and M_t could be achieved by

$$E[M_n(L)] \approx \frac{2L}{(e^{\lambda_s R} - 1)((1/\lambda_s) - (Re^{-\lambda_s R}/(1 - e^{-\lambda_s R}))) + R + (1/\lambda_s)}, \tag{7}$$

$$E[M_t] = \frac{\left(e^{\lambda_s R} - 1\right)\left((1/\lambda_s) - \left(Re^{-\lambda_s R}/\left(1 - e^{-\lambda_s R}\right)\right)\right) + 2R}{2v_0}. \tag{8}$$

The proof of (7) and (8) is mentioned in [16] in detail.

5. Overview of DMRC

DMRC suggests the application of a new class of packet-level coding schemes referred as rateless codes for the reliable and efficient data dissemination in VANETs [14, 15]. Several aspects of rateless codes make them suitable for such applications.

In this strategy, each RSU packetizes its message into smaller data packets of the same size. These packets are then encoded into a set of slightly bigger size using rateless coding. Then the RSU broadcasts the set of encoded packets. Vehicles divided in two groups: collectors and carriers. Collector vehicles are approaching to the specific RSU and try to collect its packets. After receiving the required number of packets, they could decode these packets in order to obtain the message of the RSU. By crossing over each RSU, collector vehicles apply rateless coding on the received message. From this point, they act as Carriers and keep packets in their buffer and broadcast them periodically. In order to the better understanding, Figure 1 shows the difference between collectors and carriers.

In this scheme, each carrier node can potentially carry packets from several RSUs simultaneously. Thus, it can act as a carrier and collector for different RSUs at the same time. Every time a collector node listens to a carrier node it receives packets which are innovative (by the rateless encoding property). The number of sufficient packet by which a collector could perform the rateless decoding is limited to ℓ. By this strategy, it is showed that because of the limited buffer in vehicles, they could not carry out infinite packets.

The parameter DD (*Decoding Distance*) is the basic performance metric we consider which can provide insight to the throughput. By collecting sufficient packet, each collector could decode the message of each RSU before entering its communication range (at decoding point). The distance

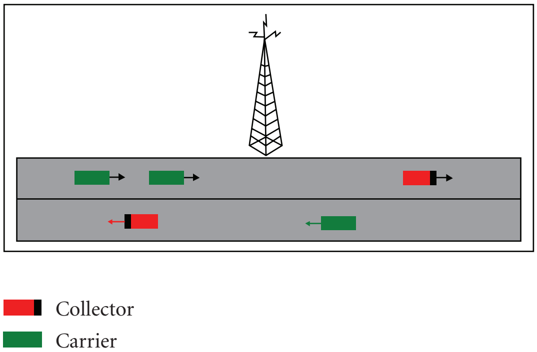

Figure 1: Collector and carrier vehicles.

between each RSU and related decoding point is considered as DD.

To describe DMRC scheme, the basic network model is considered. RSUs are placed uniformly in the road with distance d from each other. The space between two consecutive sources is named as segment. ϕ_i is representing the ith source in the road. If a vehicle is located in jth segment from source ϕ_i, it is in segment ϕ_{ij}.

It can be shown that for any source ϕ_i, DD is directly proportional to the number of packets from the corresponding source ($m_{i,j}$), that carriers posses per each segment ϕ_{ij}. In order to maximize DD, we need to find a solution for $m_{i,j}$'s subject to the buffer limit constraint. Since sources are all the same, we can omit the first index in $m_{i,j}$ and find a generic solution m_j for all sources. We assume that the number of packets carrier posses from ϕ_i cannot be increased. Also, buffer updating for a carrier node occurs when it crosses a new source and enters a new segment (e.g., from ϕ_{ij} to ϕ_{ij+1}). Just after crossing ϕ_i the carrier node has m_0 encoded packets from the source and reduces them gradually as $\cdots \le m_2 \le m_1 \le m_0$ and $m_j = 0$ for $j \ge \Delta$. By considering N_j as the total number of collected packets in segment j, DD can be formally stated as

$$\text{DD} = \min_{m_j} d, \qquad \text{S.t.} \quad \sum_{i=0}^{d} E[N_{\Delta-i}] \ge \mathcal{I}. \tag{9}$$

Since [7] suggests that only the tail behavior of the distribution of m_j's is important and because m_j is nonincreasing with j, one can see that the maximum value of DD is achieved when m_Δ (and hence all the previous segments) has its maximum value [16]. Further, the buffer limit constraint implies that $\sum_{i=0}^{\Delta} m_i \le B$. Therefore, a solution can be formulated as

$$m_0 = m_1 = m_2 = \cdots = m_\Delta = \frac{B}{\Delta+1}. \tag{10}$$

This solution is only applied for a single road with a fixed velocity. To find the maximum distribution for m_j's in an urban area, we set the desired value for DD (DD*) and calculate the value of m_0 for all sources.

6. Proposed Approach for Data Dissemination

6.1. Proposed Scheme. As mentioned previously, we are interested in solving the problem of distributing large amount of data from multiple sources in an urban area. A network in which roads are separated by junctions is considered. Each road has its own characters. Characters of each road are defined as the average speed of vehicles and the rate of vehicle entering in the road. These two parameters determine the traffic load in each road. RSUs in such a network are uniformly distributed along the roads. Upon crossing an RSU, every node that has been successful in decoding the RSU's message acts as a carrier for that source. Then, every carrier node generates some encoded packets from the RSU's information packets and stores them. The number of stored packets is determined for maximum performance, given that the storage buffer is limited to B.

Upon crossing the ith source, every carrier node generates some encoded packets and puts $m_{i,j}$ packets in their buffer in jth segment from source ϕ_i. In the basic model, segments have the same length of d. The number of stored packets is determined for maximum performance, given that the storage buffer is limited to B. Each collector could gather packets from the vehicle clusters. Consider a collector vehicle meets a cluster of vehicles in ϕ_{ij}. The number of broadcast packets during the meet time M_t follows the Poisson distribution with the mean ρ, because carriers send encoded packets randomly and without coordination. Thus, based on [13], the maximum throughput occurs when ρ is equal to 1/2 of packet transfer time and is equal to $1/2e$. By using (6) and (7) and considering that a received packet is of collector's interest (i.e., the packet is from ϕ_i) with the probability of $m_{i,j}/B$, the maximum expected number of collected packets from a cluster (N_j^C) and total number of collected packets N_j^T, that could be obtained from the segment ϕ_{ij}, are given by ψ

$$\begin{aligned} E\left[N_j^c\right] &= \rho_{\max} \times E[M_t] \times \frac{m_{ij}}{B}, \\ E\left[N_j^T\right] &= E\left[N_j^c\right] \times M_n(d). \end{aligned} \tag{11}$$

To find the maximum distribution for m_j's in an urban area, the desired value for DD (DD*) is set and the value of m_0 for all sources would be calculated.

A network in which the velocity of vehicles is V_1 is considered. We are interested in achieving the message of RSUs at DD* from each source. The goal is to find the value of m_{i0} for the ith source. N is considered as the number of RSUs that a carrier node keeps their packets in its buffer. Based on DMRC scheme, $N = B/m_{i0}$. The value of m_{i0} for all sources could be obtained as follows:

$$\rho_{\max} \times E[M_t] \times \frac{m_{i0}}{B} \times M_n(N \times d - d^*) = \mathcal{I}. \tag{12}$$

Using (7) and (8) in (12), the value of m_{i0} for each source would be calculated. Now, in order to find a suitable distribution for an urban area, a large road consisting of segments with different traffic loads is considered. In each segment, the average speed of vehicles and the rate of vehicle entering the segment are different. By considering the specific value for DD* and based on vehicle velocity and intervehicle spacing in each segment of the road, we can calculate the required number of stored packets in the collector buffer corresponding to each RSU. The value of DD* determines the segment (or segments) in which collector could collect the required number of packets. We assume that the nature of information is commercial advertisement and it is only useful in a nearby geographical area. By this assumption, we could consider the end for our simulated road. Based on the parameters of jth segment, $E[N_j^c]$ would be determined. The assumption is that messages from sources located in the last segment are collected by the collectors in that segment. Therefore, the value of m_{i0} for these sources will be calculated using (12). For these sources, $m_{0i} = \Delta$ is assumed.

Using the value of m_{i0} for sources located in the last segment (Δ), the value of m_{i0} corresponding to the other sources should be calculated one by one. Therefore, the value of m_0 for the last source in the last segment but one (m_{0j}) is calculated. The number of sources located in the range of DD* from the above source is defined as k. As a result, $((B - m_{0j} - K\Delta)/\Delta) \times d$ determines the distance in which the collector collects packets for the jth source. Consequently, the value of m_{0j} is calculated using the following equation:

$$\rho_{\max} \times E[M_t] \times \frac{m_{0j}}{B} \times M_n\left(\frac{\left(B - m_{0j} - K\Delta\right)}{\Delta} \times d\right) = \mathcal{I}. \tag{13}$$

It should be notified that the value of $E[M_t]$ is varied for each segment. In (13), $E[M_t]$ is calculated based on the parameters of the last segment. Based on the above algorithm, the value of m_0 for other sources could be calculated, too. The point is that, for each source, the parameters of segments in which the collector collects packets should be determined. Regarding these values, (13) would be altered for each source. For example, for some sources, the last segment may not be included in the distance in which the packets are collected. Accordingly, instead of using Δ and k for calculating their m_0, the m_0 and k values should be determined corresponding to the source of the other segments.

Based on these extracted values for all sources, the trend of dropping packets from the buffer of carriers could not follow the expressed algorithm in DMRC scheme.

The algorithm of the proposed scheme for urban area changes as follows: upon crossing new source in the road i, the value of m_{0i} packets from corresponding source would be stored in the buffer. In order to fix the number of B (buffer size) packets in the buffer, by reaching a new source, collector vehicle should drop a number of old packets which are equal to a number of added packets from the new RSU. Based on this scheme, we find an adaptive solution with the traffic load diversity in an urban area.

6.2. Siimulations. Evaluating the performance of a proposed scheme will be done by developing NS-2 [17] simulator in this section. Implementing the realistic traffic models is performed by SUMO [12]. Vehicles enter the road from one end with interarrival times drawn using instances of exponential distribution with parameter λ_s. In order to compare our scheme with DMRC, we also considered 50 points as the positions of RSUs along the road. We use the transmission range R as the unit of distance in our simulations. We focus on a collector vehicle that departs from one end of the road and travels along it until it reaches the other end. The number of vehicles in each road is determined by (6) and (7). Table 1 shows the parameters used in simulations.

Table 1: Simulation parameters.

Parameters	Value
Simulation time	1600 seconds
Communication range (R)	200 m
Distance between consecutive RSUs (d)	400 m
Simulation road length	24000 m
Broadcast interval	100/second
Buffer size	300
Required number of packet for decoding the message ($\mathcal{I}$)	800 packets

Table 2: The values of m_0.

Vehicle velocity	m_0
20 (m/s)	11
30 (m/s)	8
40 (m/s)	4

As the first step, we investigate the influence of vehicle velocity and interarrival time on determining the number of stored packets in the buffer of carrier corresponding to each RSU (m_0). Primarily, we fix the value of 0.2 vehicle/sec for interarrival time and 2800 m for DD*. By setting the vehicle velocity and using (12), we can find the values of m_0 corresponding to each source. These values related to each velocity are presented in Table 2.

We perform simulations with value determined in Table 2. At this point, we consider another performance metric to compare the result. P_{success} is the probability that a random message is generated at a (random) source ϕ_i is available at node v before it enters the communication range of ϕ_i. We measure P_{success} as a function of distance to the source. The presented graphs are the average of P_{success} over all active sources.

Figure 2 presents P_{success} for various vehicle velocities in the road.

Now, in order to see the influence of interarrival time of vehicles, we change it based on the presented values in Table 3 and calculate the value of m_0 for sources.

Figure 3 shows the changes in P_{success} for different values of λ_t.

In order to implement our scheme, we consider a 24000 meters road with 2 intersections. The first segment is regarded as the first 6000 meters distance of the road. The second segment is set from 6000 meters till 12000 meters of the road and after 12000 meters is the last segment. Each

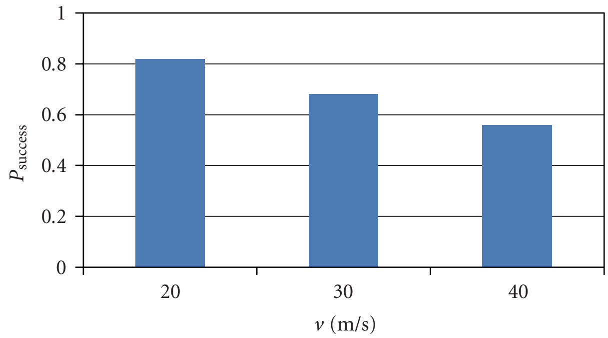

Figure 2: P_{success} for different velocity.

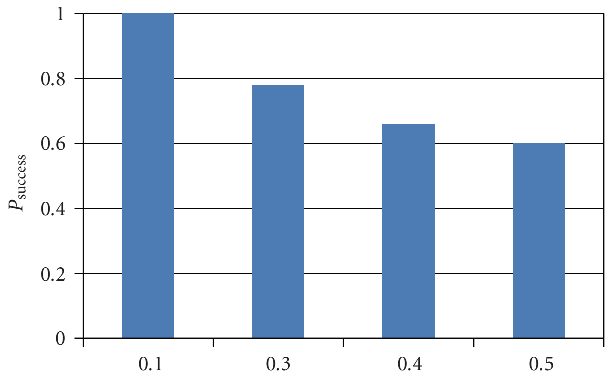

Figure 3: P_{success} for different λ_t.

Table 3: The values of m_0.

Interarrival time	m_0
0.1 (vehicle/sec)	9
0.3 (vehicle/sec)	11
0.4 (vehicle/sec)	10
0.5 (vehicle/sec)	9

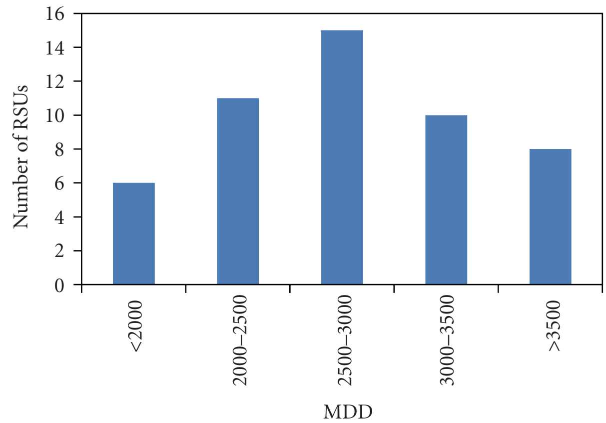

Figure 4: Dispersal of MDD around 2800 m for scheme B.

Table 4: Road parameters.

Segment	Road parameters	Value
0–6000 m	Interarrival of vehicles (λ_1)	0.2 veh/sec
	Average velocity (V_1)	38 m/s
6000–12000 m	Interarrival of vehicles (λ_2)	0.6 veh/sec
	Average velocity (V_2)	28 m/s
12000–24000 m	Interarrival of vehicles (λ_3)	0.4 veh/sec
	Average velocity (V_3)	35 m/s

Table 5: The vaiues of m_0 for all sources.

$m_{050} - m_{030}$	18
$m_{029} - m_{027}$	20
$m_{026} - m_{023}$	19
$m_{022} - m_{020}$	21
$m_{019} - m_{016}$	16
$m_{015} - m_{013}$	17
$m_{012} - m_{010}$	18
$m_{09} - m_{08}$	16
$m_{07} - m_{01}$	10

segment is characterized with interarrival of vehicles and the average velocity of vehicles in that segment. Parameters related to each segment are presented in Table 4.

In order to meet the optimal distribution of m_{0i}, the value of DD* is set to 2800 m. the value of m_{0i} corresponding to the sources of the last segment of the road would be calculated by using $N = B/m_{0i}$ in the (12). Therefore, The value of m_{0i} for the last 20 sources is equal. Then, we used (13) to adjust the value for 29th source. Considering the value of DD*, we can find the segments in which the collector should collect the packets of specific RSU. The value of m_{0i} corresponding to each source is presented in Table 5.

By considering the value of $N = 10$ in DMRC scheme, the value of MDD for vehicle velocity between 20–40 (m/s) is between 3500–2000 m. Therefore, we approximately could mention the average of 2800 m as decoding distance for these velocities. We compare our scheme (scheme A) with two other schemes. The first is DMRC scheme with $N = 10$. The second one is the scheme which uses the average velocity of V_i as the velocity and average λ_i in these three segments as the intervehicle spacing and set these values in (12) to obtain equal value for m_{0i} corresponding to all sources (scheme B). Based on the determined parameters in Table 2, we have $\overline{v} = 33.66$ $\overline{\lambda} = 0.4$. By using (13) and $N = B/m_{0i}$, we obtain 18 packets as the number of stored packets from every RSU in the road. We first perform the simulation for our proposed scheme.

Figure 4 shows the dispersal of MDD for all sources in the entire road.

Figure 5 shows the dispersal of MDD for all sources in the entire road for the scheme using the average of values in Table 2.

As presented in Figure 4, messages of 15 RSUs are decoded approximately in 2800 m but in Figure 5, this value is 9. Also the average decoding distance for all RSUs in scheme A is equal to 2814 m with standard deviation of 770, but in the scheme B, MDD is equal to 3011 with standard deviation of 1181. Although the larger MDD is the better

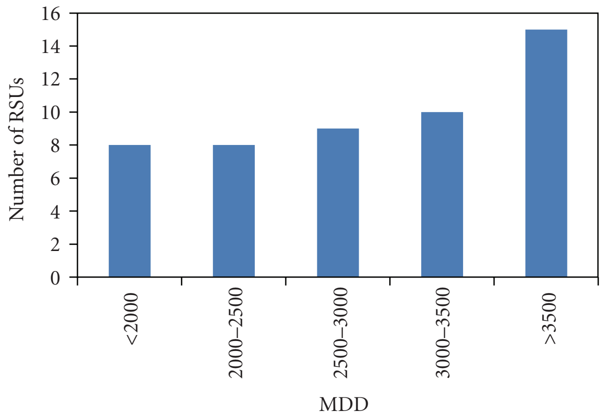

Figure 5: Dispersal of MDD around 2800 m for scheme B.

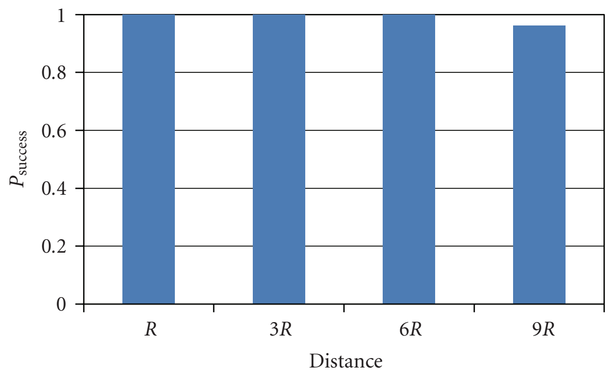

Figure 6: $P_{success}$ for variouse distances (in multiple of R) in scheme A.

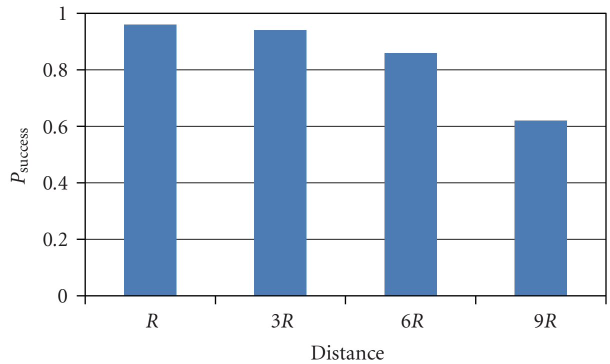

Figure 7: $P_{success}$ for variouse distances (in multiple of R) in DMRC ($N = 10$).

result, it was expected to find the value of 2800 for MDD. Therefore, our scheme is working better.

In order to evaluate scheme A and DMRC, The value of $P_{success}$ is compared for both schemes and $P_{success}$ versus distance is plotted for scheme A and DMRC with $N = 10$ in Figures 6 and 7, respectively.

As presented in Figures 6 and 7, $P_{success}$ in the scheme A has the better results.

7. Conclusion

In this work, a new scheme based on rateless codes for collaborative content distribution from road side units to vehicular networks in an urban area is presented. Using the advantage of DMRC, an adaptive model which is compatible with the characteristics of the road was introduced. The proposed scheme can seamlessly handle both sparse and dense scenarios. Our simulations are performed in an urban area without any traffic lights, and by considering some sideways streets, the traffic loads in the road would be changed. The future researches are to introduce more realistic traffic models for urban areas with traffic lights where the exponential assumptions for interarrival time are not valid. Further, adapting the analysis for such scenarios and finding the optimal distribution for buffer allocation are our immediate goals.

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