A Smart Data Dissemination Protocol for Vehicular Ad-hoc Networks

Sofian Hamad[†] **and Taoufik Yeferny**[2††]

College of Science, Northern Border University, Arar, Saudi Arabia

Summary

Vehicular Ad-hoc Networks (VANETs) have emerged as an interesting way to ensure Intelligent Transportation System (ITS) services. Indeed, various ITS applications related to road safety and transport efficiency are nowadays deployed through VANET. Given the high mobility of moving vehicles as well as the lack of fixed infrastructure, data dissemination has become a central topic in VANET. The thriving challenge would be to notify, in the right time, drivers about dangerous situations that may encounter them and avoiding as far as possible the network broadcast storm problem. In this respect, we introduce in this paper a new geocast data dissemination protocol based on the forward-if-relevant mechanism. In our proposal, a vehicle decides to rebroadcast or ignore the received event according to an estimated event relevance value. To this end, we rely on a data-mining technique to extract some interesting mobility patterns from the past trajectories of the vehicle, which are used latter for computing the relevance of the event for the vehicle. Performed simulations show the efficiency of the proposed protocol in terms of reachability ratio, precision, overhead and latency.

Key words:

VANET; geocast; data dissemination; mobility patterns; data-mining

1. Introduction

Vehicular Ad-hoc Networks (VANETs) have emerged as an interesting way to ensure Intelligent Transportation System (ITS) services. Indeed, various ITS applications related to road safety and transport efficiency are nowadays deployed through VANET. In fact, thanks to embedded sensors, vehicles are able to detect several types of information, for example an accident on the road, an empty place in a parking, bottling, obstacles, weather, road cut, etc. In addition, they can disseminate such data through Vehicle-to-Vehicle (V2V) communications. Given the high mobility of moving vehicles as well as the lack of fixed infrastructure, data dissemination has become a central topic in VANET. The thriving challenge would be to notify, in the right time, drivers about dangerous situations that may encounter them and avoiding as far as possible network saturation as well as conflict and collision issues, commonly known as broadcast storm problem [1], [2]. In the literature, existing data dissemination methods rely on broadcasting or geocasting mechanisms [3], [4], [5], [6], [7], [8], [9], [10], [11]. The former, is mainly used to disseminate non-safety data (e.g., commercial promotions, weather data, etc.) to all vehicles, without exception, using a blind or controlled flooding mechanisms. However, it is unsuitable for disseminating safety data (e.g., accident, emergency warning, etc.), which are of interest to some vehicles near the event location. Indeed, disseminating safety data requires a geocasting mechanism, which broadcasts the event to vehicles driving in certain area called Zone Of Relevance (ZOR). Hence, vehicles receiving the event outside the ZOR are not concerned and therefore they ignore it. Indeed, defining the ZOR of a given event is the most challenging issue in geocast-based approaches. Unfortunately, most existing approaches define the ZOR as a simple geometric shape, for example circle, rectangle or polygon. Such representation of the ZOR is strongly restrictive and does not fit the target region in most cases [12]. Therefore, many interested vehicles will not receive the event if the shape of the ZOR is too small. Whereas, unnecessary extra traffic is generated for informing unconcerned vehicles if the shape is very large. To overcome this drawback, we introduce here a new geocast data dissemination protocol, called BIRE (Broadcast If Relevant Event). This latter, dynamically determines the ZOR of the event based on the forward-if-relevant mechanism. Indeed, within BIRE a vehicle decides to rebroadcast or ignore the received event according to an estimated event relevance value. We assume that the event is relevant enough for the vehicle whenever there is a high probability that it will meet the event. Doing so, only interested vehicles will receive the event. To this end, we rely on a data-mining technique to extract some interesting mobility patterns from the past trajectories of the vehicle, which are used latter for computing the relevance of the event for the vehicle.

The rest of this paper is organized as follows. In Section 2, we review the relevant literature. In Section 3, we thoroughly describe our geocast data dissemination protocol. The performance evaluation of the proposed protocol is presented in Section 4. Section 5 concludes this study and highlights future directions.

Manuscript received May 5, 2019
Manuscript revised May 20, 2019

2. Literature review

The existing data dissemination protocols rely on broadcasting or geocasting mechanisms. In this respect, Wisitpongphan et al. [13] introduced three broadcasting mechanisms based on different suppression techniques, called Weighted p-persistence, Slotted 1-persistence and Slotted p-persistence. The main aim was to decrease the broadcast redundancy by stopping the spreading of the same messages by many vehicles while ensuring the deliverance of the event to all vehicles. In p-weighted persistence [13], each vehicle receiving an event message rebroadcasts it with a forwarding probability p if it does not receive duplicate copies of the message during a fixed waiting time (e.g., 2 ms). Worth noting that a higher probability is assigned to the vehicles that are located farther away from the broadcaster. Therefore, vehicles near to the broadcaster will discard the message. Slotted 1-persistence [13] assigns different waiting time slots to the neighboring vehicles depending on their locations. A shorter waiting time is assigned to the farthest vehicles from the broadcaster. The receiver of a given message rebroadcasts it with a probability 1 after the assigned time [13] slot if it didn’t receive any duplicates during the waiting time slot. Slotted p-persistence relies on a probability and a slotted waiting time. Indeed, a higher probability and a shorter slotted waiting time are assigned to the farthest vehicles from the broadcaster. Hence, the receiver rebroadcasts the received message with a probability p at the assigned time slot if it didn’t receive any duplicates. Different suppression techniques have been introduced latter to enhance the efficiency of these three basic ones by considering various context features, for example network density, vehicle direction, etc. The proposed broadcasting approaches are suitable for disseminating non-safety events, which are of interest to all vehicles. However, they are inappropriate for disseminating safety events (e.g., accident, emergency warning, etc.), which are of interest to some vehicles near the event location. Indeed, disseminating such safety events requires a geocasting mechanism, which broadcasts the event to vehicles driving in certain area called Zone Of Relevance (ZOR). Indeed, geocasting mechanisms can help overcoming the broadcast storm problem more effectively. In this respect, Ibrahim et al. [14] introduced the p-IVG (probabilistic Inter-Vehicular Geocast) protocol for the highways scenario. They assumed the existence of a ZOR within a rectangular shape near to the event location. In addition they introduced a suppression technique, similar to Slotted p-persistence, to avoid the broadcast storm inside the rectangular ZOR. Indeed, the authors considered that in a dense network, many vehicles inside the ZOR have almost the same broadcasting probability or waiting time, so they will re-broadcast the packet at the same time, which leads to a local spatial broadcast storm. To overcome this shortage, the authors rely on the density of neighboring vehicles to set a dynamic waiting time. However, to estimate the density of the surrounding vehicles, vehicles must exchange beaconing messages. Doing so, will lead to an extra network overhead. Delot et al. [3] introduced a data dissemination protocol based on the forward-if-relevant principle. In the proposed protocol each vehicle receiving the event decides to re-broadcast or discards the received event based on an estimated encounter probability, denoted EP. The latter is an estimation of the likelihood that the vehicle will meet the event. Therefore, whenever the computed EP is greater than or equal to a certain diffusion threshold, then the message will be considered as relevant enough to be re-diffused by the receiving vehicle. Otherwise, the message will be ignored. Hence, within this protocol the ZOR is determined dynamically, since the neighboring vehicles receive the event while it is considered relevant in the area. Allani et al. [11] introduced a data dissemination protocol based on map splitting, called DPMS. The authors assumed the existence of centralized server that offers a storage and processing services. Indeed, its main function is to split the map of a given city into a set of regions, and then to compute the ZOR of each region through the mining of correlations between vehicles’ trajectories and crossed regions. To do so, they relied on the Formal Concept Analysis (FCA), which is a method of extracting interesting clusters from relational data. In DPMS each vehicle downloads the split map and the associated ZORs, via cellular network technology (such as 3G or 4G), whenever it enters in an unvisited city. This split map will be used whenever the vehicle receives an event to check if it is inside the ZOR of the event. In this case, the Slotted 1-Persistence suppression technique is used for disseminating the event to vehicles within the ZOR. Otherwise, the event will be simply stored then ignored. In DPMS the computation of the ZOR is done by a dedicated server. As a downside, vehicles must be equipped by a cellular network technology (such as 3G or 4G) to download the split map from the server. In addition, DPMS relied on a transactional database representing relationships between vehicles trajectories and crossed junctions to compute the ZORs. This representation considers the trajectory of a vehicle as an unordered set of crossed junctions. Therefore, it ignored a key factor which is the order of junctions crossed by the vehicle.

3. Protocol description

In the following, we present the global architecture of our data dissemination protocol BIRE then we thoroughly describe its main components.

3.1 Architecture

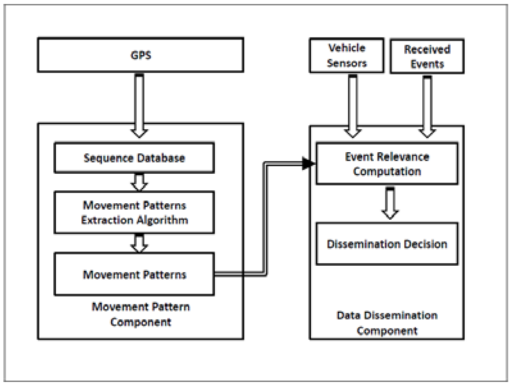


Fig. 1 Protocol Architecture at a Glance

As illustrated in Figure 1, the architecture of the proposed protocol consists of two main components:

- **Movement Pattern Component**: each vehicle periodically runs this component to extract a representative set of its movement patterns from its past movements or trajectories. These patterns will help us to predict the next destination of the vehicle knowing its current position. Such valuable knowledge is of paramount importance for guiding the data dissemination process.
- **Data Dissemination Component**: vehicle runs this component whenever it receives or detects an event (i.e., using its embedded sensors) to decide whether to re-broadcast or ignore the event. This decision is taken with respect to the relevance of the event to the vehicle, which is computed based on the movement patterns of the vehicle extracted by the first component.

In the sequel, we detail the movement pattern and the data dissemination components in Subsection 3.2 and Subsection 3.3, respectively.

3.2 Movement Pattern Component

We assume that vehicles move in a given city according to some pertinent movement patterns. These latter can be extracted from the past trajectories of the vehicle using a data-mining technique. In what follows, we first define the main concepts used in our method of movement pattern extraction before detailing its key steps.

3.2.1 Key notions

Definition 1: (SEQUENCE DATABASE)

A sequence database $\mathcal{D}$ is a pair $\mathcal{D} = (\mathcal{T}, \mathcal{S})$ where $\mathcal{T} = \{t_1 \dots t_n\}$ is a set of a vehicle trajectories and $\mathcal{S} = \{s_1 \dots s_n\}$ is a set of ordered sequences of roads crossed by the vehicle in its trajectories. In the sequel, a sequence of roads $s_i \in \mathcal{S}$ is denoted by $< r_1\ r_2\ \dots\ r_k >$ where each $r_i (1 \leq i \leq k)$ is a road.

Example 1:

Table 1 illustrates a sequence database $\mathcal{D} = (\mathcal{T}, \mathcal{S})$ where $\mathcal{T} = \{t_1, t_2, \dots, t_6\}$ is a set of vehicle trajectories and $\mathcal{S} = \{s_1, s_2, \dots, s_6\}$ represents the sequences set of roads crossed by the vehicle.

Table 1: Sequence Database $\mathcal{D}$

$\mathcal{T}$	$\mathcal{S}$
t_1	$s_1 =< r_1 r_2 r_3 >$
t_2	$s_2 =< r_4 r_5 r_6 r_7 >$
t_3	$s_3 =< r_1 r_2 r_3 r_8 >$
t_4	$s_4 =< r_8 r_4 r_5 r_6 r_7 >$
t_5	$s_5 =< r_1 r_2 r_9 >$
t_6	$s_6 =< r_{10} r_6 r_7 >$

Definition 2: (SEQUENCE SUPPORT)

Let s be a sequence of roads. The support of s, denoted $supp(s)$, is an indication of how frequently the sequence s appears in $\mathcal{D} = (\mathcal{T}, \mathcal{S})$. It is computed as follows :

$$supp(s) = \frac{|\{s_i \in \mathcal{S} \mid s \lesssim s_i\}|}{|\mathcal{T}|}$$

The symbol $\lesssim$ stands for an orderly inclusion (order of items in sequences), e.g., $(r_1 r_2) \lesssim (r_1 r_2 r_3 r_8)$ but $(r_2 r_1) \not\lesssim (r_1 r_2 r_3 r_8)$

Definition 3: (FREQUENT SEQUENCE or MOVEMENT PATTERN)

The sequence s is said to be frequent if its support in $\mathcal{D} = (\mathcal{T}, \mathcal{S})$ is greater than or equal to a (user specified threshold) $minsup$. We consider each frequent sequence as relevant movement pattern.

Example 2:

If we consider a threshold $minsup = 3/6$ and the sequence database $\mathcal{D} = (\mathcal{T}, \mathcal{S})$ of the Example 1, then the

sequence $s =< r_1 r_2 >$ is frequent since its support $supp(s) = 3/6 \geq minsup$.
Consequently, within $minsup = 3/6$ the sequence $s =< r_1 r_2 >$ is considered as a movement pattern.

Definition 4: (MOVEMENT PATTERNS SET)

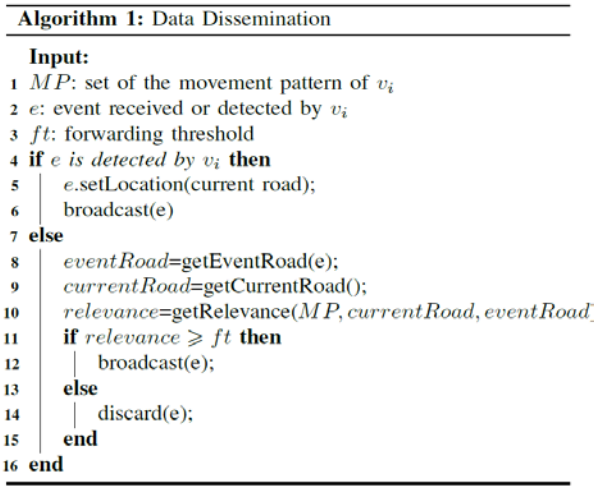
We define the set MP of movement patterns as the frequent sequences of roads crossed by the vehicle extracted from its sequence database $\mathcal{D} = (\mathcal{T}, \mathcal{S})$.
Formally, the set MP is defined as:
$MP = \{s_i \in \mathcal{S} \mid supp(s_i) \geq minsup\}$

3.2.2 Steps of extracting movement patterns

As depicted in Figure 1, the following steps must be followed to extract the relevant patterns of the vehicle:

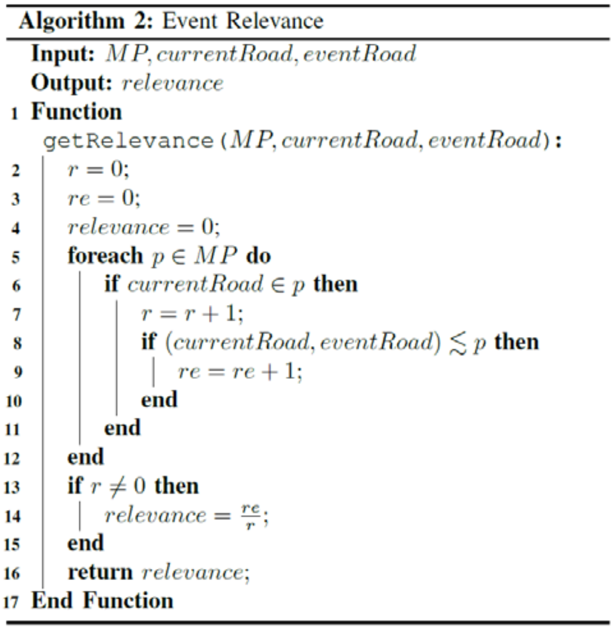
- **Data preparation**: it transforms GPS data points to a sequence database $\mathcal{D} = (\mathcal{T}, \mathcal{S})$ (c.f. Definition 1) representing the vehicle trajectories. It worth noting that this database is updated whenever the vehicle moves in order to add the new trajectories.
- **Mining movement patterns**: it mines the set MP of the vehicle movement patterns (i.e., frequent sequences of roads crossed by the vehicle) from its sequence database $\mathcal{D} = (\mathcal{T}, \mathcal{S})$. To compute the set MP from $\mathcal{D} = (\mathcal{T}, \mathcal{S})$, ,we use the prefixSpan algorithm [15]. In this study, we assume that the set MP of movement patterns is updated every P period (defined manually) to consider the new vehicle trajectories.

3.3 Data Dissemination Component



```
Algorithm 1: Data Dissemination
   Input:
1  $MP$: set of the movement pattern of $v_i$
2  $e$: event received or detected by $v_i$
3  $ft$: forwarding threshold
4  if $e$ is detected by $v_i$ then
5      $e$.setLocation(current road);
6      broadcast(e)
7  else
8      $eventRoad$=getEventRoad(e);
9      $currentRoad$=getCurrentRoad();
10     $relevance$=getRelevance($MP, currentRoad, eventRoad$
11     if $relevance \geqslant ft$ then
12         broadcast(e);
13     else
14         discard(e);
15     end
16 end
```

Algorithm 1 illustrates the behavior of a vehicle v_i upon detecting or receiving a safety event e. Briefly, if v_i is the first vehicle that detects the event e then it broadcasts it to its neighborhood in order to warn them of the dangerous situation (c.f. Lines 5-6 Algorithm 1). If the event e has been received from another vehicle, then the vehicle v_i first computes the relevance of the event e with respect to its current location currentRoad, the event location $eventRoad$ and its movement patterns MP (c.f. Algorithm 2). Thereafter, it broadcasts e if it is considered relevant enough to be disseminated to other vehicles (i.e., the event relevance is greater than a forwarding threshold ft). Otherwise v_i ignores the event (c.f. Lines 11-15 Algorithm 1). Interestingly enough, we assume that the event e is relevant to the vehicle v_i whenever there is a high probability that v_i will moves from its current location $currentRoad$ to the event location $eventRoad$. Hence, we compute the relevance of e to v_i as the ratio between the number of movement patterns that pass through the current location of v_i to the event location and the number of movement patterns that contain the current location of v_i (c.f. Line 5-15 Algorithm 2).



```
Algorithm 2: Event Relevance
   Input: $MP, currentRoad, eventRoad$
   Output: $relevance$
1  Function
   getRelevance($MP, currentRoad, eventRoad$):
2      $r = 0$;
3      $re = 0$;
4      $relevance = 0$;
5      foreach $p \in MP$ do
6          if $currentRoad \in p$ then
7              $r = r + 1$;
8              if $(currentRoad, eventRoad) \lesssim p$ then
9                  $re = re + 1$;
10             end
11         end
12     end
13     if $r \neq 0$ then
14         $relevance = \frac{re}{r}$;
15     end
16     return $relevance$;
17 End Function
```

4. Performance Evaluation

In this section, we present the performance evaluation of our protocol BIRE versus the Slotted 1-Persistence [13]. We choose the Slotted 1-Persistence as a baseline since it has a high reachability ratio [13][18]. It is worth of mention that for the sake of providing a fair comparison, we defined the ZOR of Slotted 1-persistence as a circle, which is the most efficient shape according to Jochle et al. [16].

4.1 Simulation Setting

The network simulation is carried out by OMNeT++ [17] along with the physical layer modeling toolkit MiXiM. Moreover, urban mobility is simulated with microscopic and continuous road traffic simulation using the SUMO [18] simulator. These two simulators are actually included in the Veins framework [19]. The simulation settings are summarized in Table 2. In the MAC layer, we set the transmission power to 40mW to achieve approximately 300m of interference range. In addition, we vary the amount of vehicles driving on our map from 100 to 1000, ranging from low traffic usually occurring during night times and higher traffic in the afternoon. Furthermore, we select a real-world road map from Menzel Bourguiba city in the north of Tunisia as depicted in Figure 2.

Table 2: Simulation Settings

Frequency band	5.9 GHz
Transmission power	40 mW
Transmission range	300m
Bandwidth	10 MHz
Slot time	13 us
Slot number	5
Average vehicle’s speed	80 km/h
Number of vehicles	100 - 1000
Density of vehicles	20 - 200 vehicles /km2

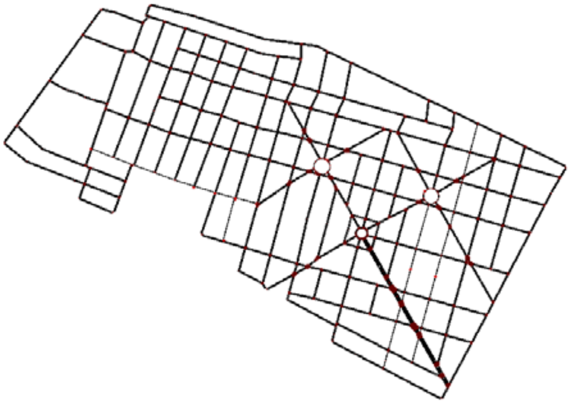


Fig. 2 Menzel Bourguiba road map

4.2 Evaluation Metrics

To assess our protocol we rely on the following metrics:

Reachability: it means the average delivery ratio of disseminated messages [11], where the message must reach all intersected vehicles of such an event e. Formally, the reachability metric is defined as follows:

$$Reachability(e) = \frac{|IIV|}{|IV|}$$

where IIV stands for the set of concerned informed vehicles, i.e., only relevant vehicles for an event e, and IV stands for the set of concerned vehicles in an event e.

Precision: it assesses to what extent the protocol is able to only inform relevant vehicles that are actually concerned by a given event e. Formally, the precision metric is defined as follows [11, 20]:

$$Precision = \frac{|IIV|}{|AIV|}$$

where IIV stands for the set of concerned informed vehicles, i.e. only relevant vehicles for an event e, and AIV stands for the set of all informed vehicles, i.e. relevant as well as irrelevant vehicles for an event e.

F-score: it is defined in [11, 20] as the harmonic mean of precision and reachability:

$$F - score = \frac{2\times(Precision\times Reachability)}{Precision+Reachability}$$

Overhead: The overhead metric stands for the total number of sent packets. Interestingly enough, the ultimate goal of any dissemination protocol is to avoid the overhead problem by looking for minimizing the number of message transmissions in the network [11].

Latency: it refers to the amount of time which is needed to deliver a message to an interested vehicle [11]. The average latency, AL, is defined as follows:

$$AL = \frac{\sum(t_i - T)}{NumberOfInterestedVehicles}$$

where t_i stands for the arrival time of the event message to a vehicle i and T is the time stamp of the occurrence of the event.

4.3 Results

Figures 3-5 depict the reachability, the precision and the F-score of Slotted 1-Persistence and BIRE protocols when varying the number of vehicles in the network. We observe that the different metrics decrease as far as the vehicle density goes up for both protocols. Indeed, increasing the number of vehicles in the network undoubtedly decreases the probability to reach the interested vehicles. In addition, Figure 3 shows that the reachability of Slotted 1-persistence protocol is slightly sharper than that of BIRE. This can simply be explained by the fact that within Slotted 1-persistence all vehicles (i.e., inside or outside the ZOR) are notified increasing consequently the reachability. Nonetheless, Figure 4 depicts that BIRE has a high precision than Slotted 1-persistence under different vehicle densities. As also shown in Figure 6, BIRE increases the overall precision of Slotted 1-persistence by around 500%. Indeed, by adopting the forward-if-relevant principle, BIRE dynamically determines the ZOR of the event and therefore only a small number of uninterested vehicles, outside the ZOR, are notified leading to a higher precision. Furthermore, Figure 5 shows that BIRE has a high F-score whenever compared to Slotted 1-persistence. In fact, our protocol achieves a better trade-off between reachability and precision under different vehicle densities. Figure 6 also demonstrates that our protocol increases the overall F-score of Slotted 1-persistence by around 430%. Figures 7-8 depict the evolution of the overhead and the latency of BIRE and Slotted 1-persistence protocols under different vehicle densities. As expected, the performance of both protocols decreases as far as the number of vehicles in the network goes up. Indeed, in a dense network, vehicles exchange more messages leading to an increase in the overhead and latency.

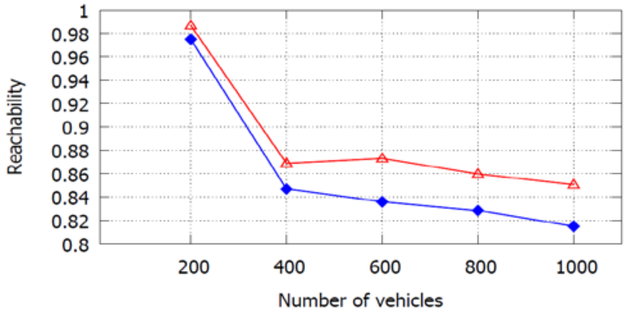


Fig. 3 Reachability w.r.t. the variation of the number of vehicles

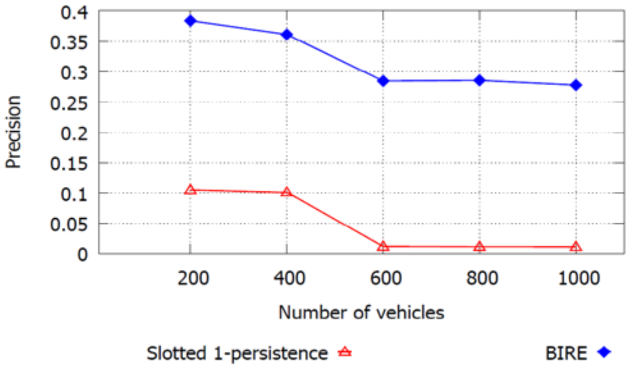


Fig. 4 Precision w.r.t. the variation of the number of vehicles

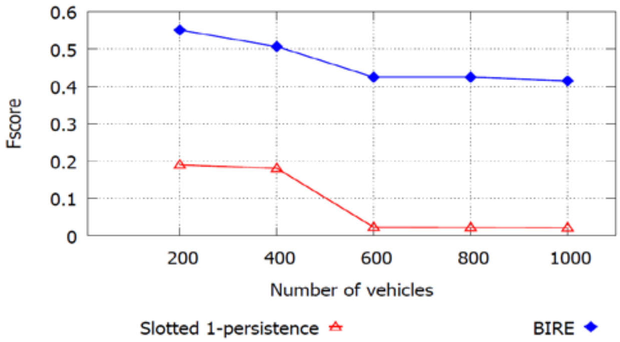


Fig. 5 F-score w.r.t. the variation of the number of vehicles

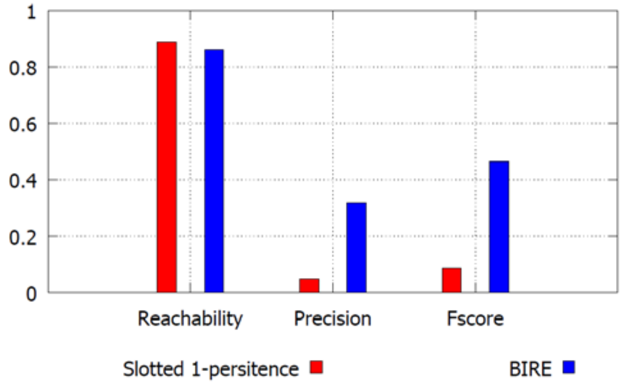


Fig. 6 Average Reachability, Precision and F-score

In addition, we note that our protocol achieves less overhead (around 26 %) and latency (around 7%) whenever compared to Slotted-1 persistence. These encouraging performance are owed to the fact that within BIRE only a small number of vehicles inside the ZOR disseminate the messages, which undoubtedly leads to decrease the overhead and therefore the latency.

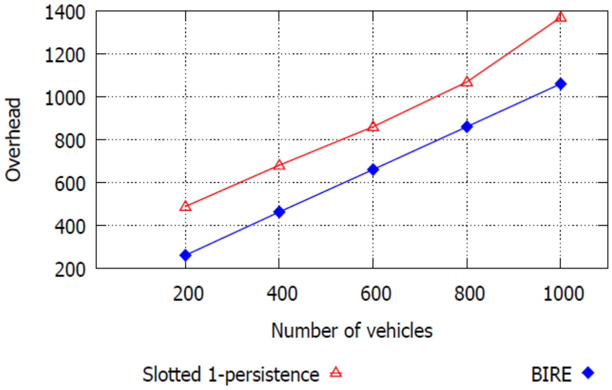


Fig. 7 Overhead w.r.t. the variation of the number of vehicles

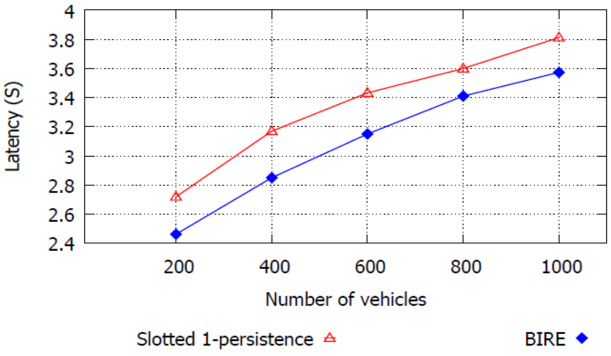


Fig.8 Latency w.r.t. the variation of the number of vehicles

5. Conclusion

In this paper, we have introduced BIRE as a geocast protocol for safety event dissemination in VANET. BIRE relies on the forward-if-relevant principle to dynamically determine the ZOR. Indeed, it decides to rebroadcast or discard a given event according to its relevance for the receiving vehicle. To this end, we have relied on a data-mining technique to extract some interesting mobility patterns from past vehicle trajectories, which were used for computing the relevance of the event for the receiving vehicle. Simulation results have shown that BIRE has outperformed the baseline approach. Avenues of future work are as follows:

1. Considering complex VANET scenarios, for example in rural and sparse areas, which are characterized by high mobility and low vehicle density;
2. Considering other features for computing the relevance of the event to the vehicle;
3. Integrating BIRE with a data aggregation protocol to enhance its performance.

Acknowledgments

The authors gratefully acknowledge the approval and the support of this research study by the Deanship of Scientific Research at Northern Border University, Arar, K.S.A.

References

[1] S. Allani, T. Yeferny, R. Chbeir, and S. B. Yahia, “Dpms: A swift data dissemination protocol based on map splitting,” in Computer Software and Applications Conference (COMPSAC), vol. 1, 2016, pp. 817–822.

[2] T. Yeferny and S. Allani, “MPC: A rsus deployment strategy for vanet,” Int. J. Communication Systems, vol. 31, no. 12, 2018.

[3] T. Delot, S. Ilarri, N. Cenerario, and T. Hien, “Event sharing in vehicular networks using geographic vectors and maps,” Mob. Inf. Syst., vol. 7, pp. 21–44, 2011.

[4] C. Celes, R. B. Braga, C. T. D. Oliveira, Andrade, R. M. de Castro Andrade, and A. A. F. Loureiro, “Geospin: An approach for geocast routing based on spatial information in vanets,” in Proc. of the Inl. Vehicular Technology Conference (VTC), Las Vegas, September 2013, pp. 1–6.

[5] H. Rahbar, K. Naik, and A. Nayak, “Dtsg: Dynamic time-stable geocast routing in vehicular ad hoc networks,” in Proc. of the Inl. 9th IFIP Annual Mediterranean Ad Hoc Networking (Med-Hoc-Net), June 2010, pp. 1–7.

[6] R. S. Schwartz, H. Scholten, and P. Havinga, “A scalable data dissemination protocol for both highway and urban vehicular environments, ”EURASIP Journal on Wireless Communications and Networking, vol. 2013, pp. 1–19, 2013.

[7] Q. Yu and G. Heijenk, “Abiding geocast for warning message dissemination in vehicular ad hoc networks,” in Proc. of the Intl. Communications Workshops (ICC Workshops), May 2008, pp. 400–404.

[8] C. Sommer and F. Dressler, “Information Dissemination in Vehicular Networks,” in Vehicular Communications and Networks: Architectures, Protocols, Operation and Deployment. Woodhead, March 2015, pp. 75–93.

[9] T.-H. Hsu, D.-H. Chen, and Y.-H. Tung, “A geocasting forwarding scheme for mobile nodes in vanets,” in Proc. of the Intl. conference on Biometrics and Security Technologies (ISBAST), July 2013, pp. 77–81.

[10] B. Alsubaihi and A. Boukerche, “Semantic and self-decision geocast protocol for data dissemination over vanet (sas-gp),” in Wireless Communications and Networking Conference (WCNC), March 2015, pp. 1948–1953.

[11] S. Allani, T. Yeferny, and R. Chbeir, “A scalable data dissemination protocol based on vehicles trajectories analysis,” Ad Hoc Networks, vol. 71, pp. 31 – 44, 2018.

[12] S. Allani, T. Yeferny, R. Chbeir, and S. B. Yahia, “A novel VANET data dissemination approach based on geospatial data,” in The 7th international Conference on Emerging Ubiquitous Systems and Pervasive Networks (EUSPN 2016)/The 6th International Conference on Current and Future Trends of Information and Communication Technologies in Healthcare (ICTH-2016)/Affiliated Workshops, September 19-22, 2016, London, United Kingdom, 2016, pp. 572–577.

[13] N. Wisitpongphan, O. Tonguz, J. Parikh, P. Mudalige, F. Bai, and V. Sadekar, “Broadcast storm mitigation techniques in vehicular ad hoc networks,” Wireless Communications, IEEE, vol. 14, no. 6, pp. 84–94, 2007.

[14] K. Ibrahim, M. Weigle, and M. Abuelela, “p-ivg: Probabilistic intervehicle geocast for dense vehicular networks,” in Vehicular Technology Conference (VTC), April 2009, pp. 1–5.

[15] J. Pei, J. Han, B. Mortazavi-Asl, J. Wang, H. Pinto, Q. Chen, U. Dayal, and M.-C. Hsu, “Mining sequential patterns by pattern-growth: the prefixspan approach,” IEEE Transactions on Knowledge and Data Engineering, vol. 16, no. 11, pp. 1424–1440, 2004.

[16] T. Jochle, B. Wiedersheim, F. Schaub, and M. Weber, “Efficiency analysis of geocast target region specifications

for vanet applications,”in Proc. of the Intl. Vehicular Networking Conference (VNC), November 2012, pp. 250–257.
[17] V. Andras, “Omnet++,” in Modeling and Tools for Network Simulation, Wehrle, Klaus, Gunes, Mesut, Gross, and James, Eds., 2010, pp. 35–59.
[18] F. Kaisser, C. Gransart, and M. Berbineau, “Simulations of vanet scenarios with opnet and sumo,” in Communication Technologies for Vehicles, ser. Lecture Notes in Computer Science. Springer Berlin Heidelberg, 2012, vol. 7266, pp. 103–112.
[19] C. Sommer, R. German, and F. Dressler, “Bidirectionally Coupled Network and Road Traffic Simulation for Improved IVC Analysis,” IEEE Transactions on Mobile Computing, vol. 10, no. 1, pp. 3–15, 2011.
[20] K. Arour and T. Yeferny, “Learning model for efficient query routing in P2P information retrieval systems, ” Peer-to-Peer Netw. Appl., vol. 8, no. 5, pp. 741-757, 2015.

SOFIAN HAMAD received the B.Sc. degree (Hons.) in computer science from Future University, Khartoum, Sudan, in 2003, the M.Sc. degree in management business administration (MBA) from the Sudan Academy of Science, in 2007 and the Ph.D. degree in electrical engineering from Brunel University, London, U.K., in 2013. He is currently an Assistant Professor with the Department of Computer Science, Northern Border University. His current research interests include ad-hoc and mesh wireless networks, vehicular technology, and the Internet of Things.

TAOUFIK YEFERNY received the M.C.S. and Ph.D. degrees in computer sciences from the University of Tunis El Manar, Tunisia, in 2009 and 2014, respectively. From 2013 to 2016, he was an Assistant Professor with the High Institute of Applied Languages and Computer Science of Beja, Tunisia. Since 2016, he has been an Assistant Professor with Northern Border University, Saudi Arabia. His current research interests include mobile P2P systems, vehicle ad-hoc networks, and intelligent transportation systems.