

Research on Regional Multicast Algorithms Based on Bus Trajectory and Location Information: Postprint

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Abstract

In vehicular networking applications, geocasting facilitates regional broadcasting for the delivery of location-based commercial information, advertisements, and similar content, as well as for the dissemination of emergency messages to designated areas. Conventional geocasting algorithms have predominantly been deployed in Wireless Sensor Networks (WSNs), without consideration for road network topology and vehicle trajectory information, thereby proving inadequately adapted to the multicast requirements inherent to vehicular networks. Motivated by contemporary commercial demands, this paper incorporates bus trajectory information and proposes a novel geocasting algorithm predicated on bus trajectories. The first phase entails the construction of a trajectory tree and encounter model for bus nodes, followed by the computation of message forwarding capability toward the target region based on the encounter graph, thereby enabling the selection of nodes with superior forwarding capacity to relay messages to the destination area. The second phase employs a stability index to estimate inter-vehicle stability, establishing a vehicle set on each street within the destination region to achieve multicast through the establishment and maintenance of these vehicle sets. Simulation experiments conducted on the integrated SUMO and OMNeT++ platform demonstrate that, as vehicle density increases, the algorithm successfully reduces overall network transmission overhead while maintaining a high packet delivery ratio, thus achieving the anticipated objectives.

Full Text

Preamble

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Research on Geocasting Algorithm Based on Bus Trajectory and Positioning Information

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Abstract: In Internet of Vehicles (IoV) applications, geocasting enables regional broadcasting to deliver location-based commercial information, advertisements, and emergency messages to designated geographic areas. Traditional geocasting algorithms, primarily designed for Wireless Sensor Networks (WSN), fail to consider road network topology and vehicle trajectory information, making them ill-suited for vehicular networking requirements. To address contemporary commercial demands, this paper introduces bus trajectory information and proposes a novel geocasting algorithm based on bus trajectories. The first phase constructs a trajectory tree and encounter model for bus nodes, then calculates each node's message forwarding capability to the target region using an encounter graph, selecting nodes with superior forwarding capability to relay messages. The second phase employs a stability index to estimate link stability between vehicles, establishing vehicle sets on each street within the destination area to achieve geocasting through set construction and maintenance. Simulations conducted on the SUMO and OMNeT++ platform demonstrate that as vehicle density increases, the algorithm maintains high packet delivery ratios while reducing overall network transmission overhead, achieving the desired objectives.

Keywords: Internet of Vehicles; geocasting; bus trajectory; encounter model

0 Introduction

The Internet of Vehicles (IoV) constitutes a large-scale networked system enabling wireless communication and information exchange among vehicle-X entities (where X represents vehicles, roads, pedestrians, and the Internet) based on established communication protocols and data exchange standards. Built upon in-vehicle networks, inter-vehicle networks, and mobile Internet connectivity, IoV integrates intelligent traffic management, dynamic information services, and intelligent vehicle control, representing a quintessential application of IoT technology in transportation systems. As a challenging yet promising technology, IoV supports numerous safety and infotainment applications. Through V2X communication development, IoV enables autonomous driving, traffic information sharing, and various vehicle safety functions. Compared with 5G and other communication technologies, IoV offers significant advantages in hardware deployment and cost efficiency. Furthermore, IoV can leverage Road Side Units (RSUs) as fog nodes for fog computing, alleviating cloud computing burdens and establishing itself as a data exchange platform in smart cities with substantial impact across multiple domains [1].

In urban IoV environments, buses and taxis represent critical vehicle populations. Assuming each vehicle is equipped with On-Board Units (OBUs) capable of collecting dynamic and static information—including vehicle speed, acceleration, and position—for real-time interaction and monitoring, IoV can provide comprehensive services. IoV development creates substantial opportunities for future intelligent transportation systems. For instance, during extreme weather conditions such as storms or snow when road signs become obscured, vehicles can utilize IoV technology to obtain shared traffic, road, and traffic signal information, enabling drivers to anticipate road conditions ahead and prevent accidents or congestion. Additionally, continuous communication between vehicle nodes and RSUs or base stations assists traffic authorities in real-time traffic data collection, facilitating traffic control and scheduling. Furthermore, passengers or users within the IoV can access entertainment services or conduct emergency work tasks in real-time, enhancing both productivity and entertainment value [2].

Geocasting [3] represents a specialized form of geographic multicast that delivers messages from a source to all nodes within a specified target geographic region. This fundamental service supports numerous vehicular network applications. Geocasting enables regional broadcasting of location-based commercial information and advertisements, such as transmitting parking availability information to vehicles approaching a specific area or distributing location-based commercial promotions (e.g., Starbucks sending coupons to nearby vehicles). Emergency message dissemination to designated areas constitutes another critical application, such as broadcasting warning messages to surrounding vehicles following traffic accidents [4].

1.1 Classification of Existing Geocasting Algorithms

Geocasting has been extensively studied in WSNs, where algorithms can be categorized into data transmission-based protocols, route creation-based protocols, and location-based protocols.

1.1.1 Data Transmission-Based Protocols

Data transmission-based protocols include Location-Based Multicast (LBM) [5], where nodes receiving geocast packets forward them to neighbors only if located within the forwarding zone; otherwise, packets are discarded. Consequently, forwarding zone definition becomes critical, typically defined as the minimum rectangle covering both source and geocast regions. Voronoi diagram-based geocasting algorithms aim to improve success rates while reducing LBM's hop count and flooding overhead. Grid-based GeoGRID algorithms partition MANET geographic areas into 2D logical grids of size $d \times d$, selecting a gateway node in each grid with forwarding zones defined by source and geocast region positions [6].

1.1.2 Route Creation-Based Protocols

Route creation-based geocasting algorithms include GeoTORA and mesh-based geographic routing. GeoTORA [7] employs the TORA (Temporally Ordered Routing Algorithm) unicast routing protocol to deliver geocast packets to target regions. TORA is a distributed routing protocol based on “link reversal” algorithms. Mesh-based geographic routing protocols create redundant routes through control packets rather than data packet flooding.

1.1.3 Location-Based Protocols

Several location-based routing algorithms exist for vehicular ad-hoc networks. Greedy Perimeter Stateless Routing (GPSR) represents a typical location-based greedy forwarding algorithm where nodes forward messages to the neighbor closest to the destination within communication range. Algorithms such as GSR and GPCR utilize Dijkstra’s algorithm to determine road intersection sequences connecting sources and destinations. While applicable to geocasting, these location-based routing algorithms exhibit poor performance as they fail to treat target regions holistically. Moreover, most require high vehicle densities. The proposed algorithm leverages geolocation and trajectories to calculate appropriate metrics for vehicular environments [8].

1.2 Trajectory-Based Routing Protocols

Most existing geocasting algorithms target traditional wireless sensor networks without considering complex urban road conditions. Jaehoon Jeong proposed utilizing vehicle trajectory information to enhance routing performance between fixed base stations and mobile vehicles. Y. Wu predicted future trajectories based on current positions and historical data to improve packet delivery. In contrast, this study does not require complete vehicle trajectories; instead, vehicle trajectories gradually propagate throughout the network via inter-vehicle encounters. Reference [8] proposed an improved zone routing protocol based on bus backbone networks, augmenting traditional zone routing protocol link-state update packets with two additional fields storing cluster head and destination node location information. During extra-cluster route discovery, location constraint equations constructed from this information select appropriate peripheral nodes for data forwarding while eliminating redundant communications from other peripheral nodes.

2 Concepts and Definitions

Based on the aforementioned research status of geocasting algorithms in IoV, traditional approaches neglect road topology and vehicle mobility patterns in urban vehicular environments, focusing solely on forwarding zone definitions. Geocasting comprises two phases: first, routing messages from source to destination region; second, continuous information broadcasting within the destination region. This paper’s contributions include: (a) analyzing encounter

patterns among buses—a critical urban vehicle population—by leveraging overlapping routes and temporal encounter probabilities to propose a bus trajectory-based geocasting technique that utilizes trajectory information to reduce mobility uncertainty and improve packet delivery; (b) introducing the concept of node message forwarding capability in the first geocast phase, enabling effective trajectory utilization through local vehicle encounters, where data packets are forwarded to vehicles with higher transmission capability via geographic encounter graphs, with successful delivery defined as at least one message-carrying vehicle traversing any road segment within the target region; and (c) employing a stability index to estimate link stability between vehicle nodes in the second geocast phase, establishing vehicle sets on each street within the destination region to enable single-hop message delivery for vehicles passing through, thereby avoiding multi-hop broadcast overhead while ensuring vehicles missing messages from one vehicle set member can receive them from subsequent members.

The message forwarding capability of vehicle nodes to the target region is defined as follows: To quantify this capability, vehicle trajectory arrival at destination regions is categorized into direct and indirect arrival. Direct arrival occurs when vehicle trajectories enter the destination region directly, while indirect arrival happens when vehicles reach the target region through encounters with other vehicles. Vehicle v 's message forwarding capability to destination region d is defined as the probability that its extended trajectory coverage overlaps with the destination region.

If v includes only its own arrival, this can be expressed as $PC_{1vvPrpCoverlapsd} = v v 1v1pC = v pC1v1v123, , i 1v(ip pC1, 2, 31(1))piiCP == - - pC|1, 2viiin == i iv i 1v(ip v()), (GvXvEv =)Xv()EvvvIvtvvV1V3V4V5V6\beta1\beta2\beta3V2V1-V7$, where pC represents the vehicle's extended arrival capability. When v further incorporates indirect arrivals, the calculation becomes more complex, depending on encounters with other vehicles.

As shown in [Figure 1: see original paper], vehicle v has three possible extended paths to reach the destination region, denoted by $\beta_1, \beta_2, \beta_3$ representing three paths within the destination region. Whether to include partial β_i in v 's arrival range is probabilistic. Let this probability be $p(\beta_i)$. Then pC can be calculated as $pC = 1 - \prod_{i=1}^3 (1 - p(\beta_i))$. Calculating pC requires obtaining all possible path extension sets $\Omega = \{\eta_i | i = 1, 2, \dots, n\}$ that reach the destination region, where η_i represents each extendable path set. The probability of including η_i in v 's coverage range requires establishing a geographic encounter graph to facilitate computation.

2.1 Geographic Encounter Graph Construction

The geographic encounter graph maintained by v , denoted as $G(v) = \{X(v), E(v)\}$, consists of vertex set $X(v)$ and edge set $E(v)$. It maintains all known trajectories and possible encounters between geographic locations on these trajectories. First, define arrival time: the arrival time of vehicle v at

given position I on its path (denoted as $v_I(t)$) is the absolute moment when vehicle v reaches location I . The graph contains two edge types: unidirectional edges $e \rightarrow$ and bidirectional edges $e \leftrightarrow$. Unidirectional edges represent vehicle a traveling from r_i to r_j along its trajectory, while bidirectional edges represent encounters between two road segments r_i and r_j . As shown in [Figure 2: see original paper], vehicle B belongs to a unidirectional edge, while vertices V_A and V_C share a bidirectional edge. Each edge e in $E(v)$ has weight $P(e) \leq 1$, representing encounter probability between vehicles a and b when on roads r_i and r_j respectively. For unidirectional edges between two road segments on the same trajectory, weight $P(e) = 1$; for bidirectional edges, weight $P(e) < 1$.

2.2 Vehicle Encounter Patterns and Models

Ideally, buses operate on uniform schedules with fixed arrival times at each intersection, simplifying encounter model construction. However, complex traffic conditions and traffic signal impacts cause arrival time fluctuations. Therefore, this paper establishes a bus encounter model with temporal variance. The model considers two temporal phases: weekday and weekend patterns. During weekday rush hours, bus arrival time fluctuations are increased to account for potential delays, incorporating all factors that might cause bus delays.

Assuming each trajectory records intersection IDs and vehicle passage times, and given driver habits and other factors, if vehicle v has three trajectories between 7:00-8:00, they can be recorded as T_2, T_4, T_6 , where $T_2 = \langle (I_1, 7 : 00), (I_2, 7 : 15) \rangle$, $T_4 = \langle (I_2, 7 : 15), (I_3, 7 : 50) \rangle$, and $T_6 = \langle (I_3, 7 : 50), (I_4, 8 : 00) \rangle$, enabling construction of a node' s trajectory tree.

To address bus schedule deviations, this paper assumes bus arrival times at intersections fluctuate within a range following a normal distribution. Assuming bus arrival time at intersection I is $t \sim N(\mu, \sigma^2)$ with lower and upper bounds $[t_l, t_h]$, the probability density function is $f(x) = \frac{1}{\sqrt{2\pi}\sigma} \exp(-\frac{(x-\mu)^2}{2\sigma^2})$. For two vehicles with intersecting trajectories, encounter probability depends on the proximity of their arrival times at trajectory intersection points. This paper categorizes bus encounters into three scenarios:

First scenario: Two vehicles travel in the same direction on the same road segment, such as buses A and C meeting on road segment r_2 . Assuming A' s arrival at intersection follows $t_A \sim N(\mu_A, \sigma_A^2)$ and C' s arrival follows $t_C \sim N(\mu_C, \sigma_C^2)$, the encounter probability is $P_{AC} = P\{|t_A - t_C| < \delta\} = \int_{-\infty}^{+\infty} \int_{t_C - \delta}^{t_C + \delta} f_A(t_A) f_C(t_C) dt_A dt_C$.

Second scenario: Two vehicles travel in opposite directions on the same road segment, such as buses A and B meeting on road segment r_4 .

Third scenario: Two vehicles traveling in different directions meet at an intersection, such as buses B and C meeting at intersection I_2 .

2.3 Stability Index Definition

The vehicle node stability index measures link stability between two vehicles by considering link duration. Assuming vehicle j is neighbor k of vehicle i and they are on the same street, the stability estimation index between vehicles j and k is calculated as follows, where R is vehicle communication range. For vehicles approaching each other (either moving toward each other or moving in the same direction with the rear vehicle faster), the link breakage distance is $D_{ij} = R - d_{ij}$. For vehicles moving apart (either separating from each other or moving in the same direction with the front vehicle faster), the link breakage distance is $D_{ij} = R + d_{ij}$.

3.1 Node Message Forwarding Capability-Based Vehicle Routing Algorithm

The proposed geocasting algorithm comprises two phases. The first phase forwards messages to the destination region through bus node encounters, as illustrated in [Figure 4: see original paper]. This phase involves: (a) initializing maps and vehicle trajectories using Xi'an's road network with 5,736 road segments and 2,722 intersections; (b) checking whether bus nodes exist among source node neighbors—if present, constructing a geographic encounter graph and calculating each node's message forwarding capability, otherwise relying on ordinary vehicles and selecting the neighbor closest to the destination region center; (c) calculating node message forwarding capability and selecting the node with maximum forwarding capability; and (d) checking whether any node has reached the destination region, terminating if true or repeating step (b) otherwise.

3.2 Stability Index-Based Geocasting Algorithm

The second geocasting phase employs stability indices to estimate vehicle stability, establishing vehicle sets on each street within the destination region. These sets enable single-hop message delivery for vehicles passing through the region, avoiding significant overhead from multi-hop broadcasting. Vehicles failing to receive messages from one vehicle set member can still obtain them from subsequent members, thereby improving message reception rates.

3.2.1 Vehicle Set Configuration

In vehicular networks, broadcasting requires selecting only one neighbor node as the next relay along the broadcast direction due to street width constraints. Assuming v_i is the first vehicle successfully receiving broadcast messages on a street segment, it calculates stability estimation indices for each neighbor vehicle and selects the neighbor with the highest stability index as the next vehicle set member. v_i then forwards a message containing the selected neighbor's ID and broadcast content while setting a waiting timer. If the selected neighbor

successfully receives the message, it repeats the selection process and forwards to the next vehicle set member. If v_i does not receive acknowledgment from its selected neighbor, indicating unsuccessful forwarding, its waiting timer expiration triggers recalculation of stability indices and selection of an alternative vehicle set member. [Figure 5: see original paper] illustrates the vehicle set configuration flowchart.

3.2.2 Vehicle Set Maintenance

Due to high vehicle mobility, vehicle positions within sets continuously change. As vehicles move, links between set members may break, necessitating new vehicle inclusion. Typically, vehicles in a set maintain two neighbor nodes in different directions. If a vehicle node detects via beacon messages that a neighbor has left its communication range, it reselects the most stable vehicle node in that direction to join the set and notifies the newly added vehicle. As shown in [Figure 6: see original paper], initially v_i and v_j belong to the same vehicle set, but over time v_j moves beyond v_i 's communication range, breaking their link. v_i then recalculates neighbor stability indices and selects a new vehicle v_k as a set member.

4.1 Environment and Parameter Configuration

This paper evaluates the proposed method through OMNeT++ and SUMO simulations. SUMO's open-source nature facilitates road network import. The experiments utilize Xi'an's map with 5,736 road segments and 2,722 intersections, supporting up to 1,200 vehicle nodes. Additional simulation parameters are listed in .

Table 1. Parameters of Bus Node Trajectories

Parameter	Value
Simulation area	4000m \times 4000m
Scenario update time	43200s
Vehicle types	Car, Bus
Vehicle speed	0-30 m/s

In these simulations, each vehicle generates messages with randomly selected square target regions across the road network. Each parameter configuration is executed 100 times with averaged results. The first phase compares against Epidemic routing (which blindly forwards messages upon encountering uninformed vehicles, suffering from high transmission overhead), NTR algorithm [22] (which builds trajectory trees to predict future positions and contact probabilities), and IPBB algorithm [8]. The second phase compares against LINGER [23], which minimizes protocol overhead for message dissemination in vehicular networks.

4.2 Simulation Results

The first phase evaluation uses two metrics: (1) Delivery ratio—the proportion of packets received by destination nodes to those sent by source nodes; and (2) Transmission overhead—network energy consumed during data exchange and packet forwarding.

[Figure 7: see original paper] illustrates packet delivery ratio versus vehicle count (200–1200). The proposed BTGR algorithm maintains high delivery ratios as vehicle density increases, while Epidemic routing shows decreasing performance due to network congestion from blind forwarding and fixed 300 MB vehicle caches. With fewer than 400 nodes, BTGR’s delivery ratio is slightly lower than NTR and IPBB due to insufficient bus nodes reducing encounter opportunities. The ratio of ordinary to bus vehicles is 3:1 with a message generation rate of 2 messages per minute.

[Figure 8: see original paper] shows total routing overhead versus vehicle count. Epidemic routing’s infection-style forwarding causes explosive overhead growth, while BTGR effectively reduces transmission overhead by broadcasting only within target regions.

[Figure 9: see original paper] demonstrates the impact of message generation rates (1–6 messages/minute) on delivery ratio with 800 vehicles. BTGR outperforms other methods when the rate exceeds 2 messages/minute. At lower traffic rates (<2 messages/minute), Epidemic routing performs best due to aggressive message replication maximizing network capacity utilization, but its efficiency degrades sharply as traffic increases due to limited network capacity.

[Figure 10: see original paper] depicts transmission overhead versus message generation rate. BTGR consistently maintains lower overhead than other algorithms, with all algorithms showing decreased overhead as generation rates increase. This occurs because with stable vehicle counts, total contact nodes remain constant while increased message generation creates resource contention, reducing unnecessary transmissions.

[Figure 11: see original paper] shows average end-to-end latency versus vehicle count (200–1200). BTGR exhibits higher latency initially (<800 vehicles) due to insufficient bus nodes in the large simulation area, but latency decreases with more vehicles (>800). Epidemic routing shows minimal latency variation due to its blind flooding approach. IGBB also underperforms at low vehicle densities, while NTR’s trajectory-based link establishment reduces latency as vehicle density increases.

[Figure 12: see original paper] illustrates latency versus message generation rate (800 vehicles). BTGR outperforms others when rates exceed 2 messages/minute, though all algorithms experience increased latency with higher generation rates due to resource contention among stable vehicle populations.

The second phase evaluation uses packet transmission ratio—defined as the pro-

portion of vehicles receiving messages to those passing through the target region during a time period.

[Figure 13: see original paper] shows the impact of vehicle count on packet transmission ratio in the second phase. Even if the first vehicle set member fails to transmit, other members can deliver messages as vehicles traverse the street, improving transmission ratios.

5 Conclusion

This study proposes a geocasting algorithm based on bus trajectory and positioning information, building upon traditional geocasting algorithms while incorporating urban road networks and bus trajectory data. The algorithm selects highest-capability nodes at each hop to transmit messages from source to target region, then establishes and maintains vehicle sets enabling single-hop broadcast delivery. Consequently, the algorithm achieves higher packet delivery ratios with lower transmission overhead.

References

- [1] Wang Xiaojing. Information distribution based on the game in VANET [D]. Dalian: Dalian University of Technology, 2013.
- [2] Javadi M S, Habib S, Hannan M A. Survey on Inter-Vehicle Communication Applications: Current Trends and Challenges [J]. Information Technology Journal, 2013, 12(2).
- [3] S. Allal and S. Boudjit. Geocast routing protocols for VANETs: Survey and guidelines. in Proc. IEEE IMIS, Palermo, Italy, 2012, pp. 323-328.
- [4] Das S, Lobiyal D K. Intersection Area Based Geocasting Protocol (IBGP) for Vehicular Ad Hoc Networks [M], Advances in Computer Science and Information Technology. Computer Science and Information Technology.
- [5] M. Jerbi, S. Senouci, T. Rasheed, et al. Towards Efficient Geographic Routing in Urban Vehicular Networks. IEEE Trans. Vehicular Technology, vol. 58, no. 9, pp. 5048-5059, Nov. 2009.
- [6] Ko Y B, Vaidya N H. GeoGRID: a protocol for geocasting in mobile ad hoc networks [C], International Conference on Network Protocols. IEEE, 2000.
- [7] Ko Y B, Vaidya N H. Flooding-Based Geocasting Protocols for Mobile Ad Hoc Networks [J]. Mobile Networks and Applications, 2002, 7(6).
- [8] Wan Hang, Wang Xuecheng. Improved zone routing protocol based on bus backbone networks [J]. Application of Electronic Technique, 2018, 44(6): 108-112, 119.
- [9] Meriem Houmer, Moulay Lahcen Hasnaoui. An Enhancement of Greedy Perimeter Stateless Routing Protocol in VANET [J]. Procedia Computer Sci-

ence, 2019, 160.

[10] Peng Yali, Xu Hong, Yi Hong. Routing protocol for bus vehicle network with cyclical movement [J]. *Journal of Computer Applications*, 2015, 35(2): 313-316, 334.

[11] Das S, Lobiyal D K. Intersection Area Based Geocasting Protocol (IBGP) for Vehicular Ad Hoc Networks [M], *Advances in Computer Science and Information Technology*. Computer Science and Information Technology.

[12] Lian Rui. Research on geographic routing algorithm based on node mobility prediction in Ad Hoc networks [D]. 2017.

[13] Li L, Liu Y, Li Z, et al. R2R: Data forwarding in large-scale bus-based delay tolerant sensor networks [C], *International Conference on Wireless Sensor Network*. IET, 2010.

[14] Gao Xing. The Research about Geocast Routing Algorithm in VANET [D]. 2015.

[15] Li P, Zhang T, Huang C, et al. RSU-Assisted Geocast in Vehicular Ad Hoc Networks [J]. *IEEE Wireless Communications*, 2017, 24(1): 53-59.

[16] Zhang Y, Wang H M, Ding Z, et al. Non-Orthogonal Multiple Access Assisted Multi-Region Geocast [J]. *IEEE Access*, 2018, 6: 2340-2355.

[17] Byungseok Kang and Hyunseung Choo. An energy-efficient routing scheme by using gps information for wireless sensor networks. *International Journal of Sensor Networks*, 26(2): 136-143, 2018.

[18] Ramin Yarinezhad. Reducing delay and prolonging the lifetime of wireless sensor network using efficient routing protocol based on mobile sink and virtual infrastructure. *Ad Hoc Networks*, 84: 42-55, 2019.

[19] X. Cao and S. Madria. An Efficient Trajectory-Based Routing Using Virtual Coordinates for Low-Power WSNs with Mobile Sinks, 2019 15th International Conference on Distributed Computing in Sensor Systems (DCOSS), Santorini Island, Greece, 2019, pp. 170-172.

[20] S. Perkin, C. Hamon, R. Kristjansson, et al. Framework for trajectory-based probabilistic security assessment of power systems. in *IET Generation, Transmission & Distribution*, vol. 13, no. 7, pp. 1088-1094, 2019.

[21] F. Liu, W. Zeng, C. Yuan, Q. Wang, et al. Trajectory-Based Hand Gesture Recognition Using Kinect via Deterministic Learning. 2018 37th Chinese Control Conference (CCC), Wuhan, 2018, pp. 9273-9278.

[22] I. Chang, M. Hung, C. Chang, et al. NTR: An efficient trajectory-based routing protocol for the vehicular delay tolerant networks. 2017 IEEE International Conference on Systems, Man, and Cybernetics (SMC), Banff, AB, 2017, pp. 389-394.

[23] M. Fiore, C. Casetti, C. Chiasserini and D. Borsetti, “Persistent Localized Broadcasting in VANETs,” in *IEEE Journal on Selected Areas in Communications*, vol. 31, no. 9, pp. 480-490, September 2013.

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