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Enhancement of Vehicular Ad-Hoc Networks Using Vehicle Platoon Aware Data Access

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ABSTRACT:

Vanets(Vehicular Ad hoc Networks) is used for communicating data between vehicles and with roadside infrastructures. Due to high mobility of vehicles the topology changes dynamically which degrades the performance of data access in VANETs. To overcome this problem, we use Vehicle Platoon Aware Data Access solution in Vehicular Ad - Hoc Networks. Here vehicles use a part of their buffer to replicate data for other vehicles in the same platoon to share data with them. If a vehicle leaves a platoon, it prefetches the interested data in advance and transfers it to other vehicles so that they can still access the data. To improve the data access performance in VANETs, a vehicle platooning protocol is configured to recognize platoon formation and to predict platoon splits. Next a data management part is configured to lead platoon members to replicate and prefetch the most interested data so that both data availability and data access performance can be achieved. Simulation results display that vehicle platoon aware data access can efficiently improve the data access performance in vehicular Ad - Hoc networks.

INTRODUCTION:

Innovations in low- cost wireless connectivity together with peer - to - peer co - operative systems is transforming next generation vehicular ad hoc networks. Inside the moving vehicles both drivers and passengers are able to get and share their interested data such as news, video clips, music [1]. But due to high vehicle mobility, the topology of VANETs dynamically changes which results frequent disconnections. Thus,data access performance in vehicular ad hoc networks is lower compared to other conventional wired networks.

To improve the data access performance and to reduce the effect of intermittent connectivity, data replication has been widely used nowadays[2]. With data replication we can increase the data availability and reduce the query delay if there is enough memory space available in the vehicles. To connect vehicles with road side infrastructure easily and quickly and to get the data, the data must strategically placed. Also the contact time of the vehicles may not be long enough to transmit all the data items. For data replication nodes need to transmit data from other nodes and which will result in huge bandwidth and power cost for big volume of data. With these issues we do not expect that nodes in VANET such as vehicles or in - vehicle mobile devices and sensors would be able to replicate all the data items in the network. Thus, we need to design a new fast and convenient data access solutions for VANET.

Our solution is based on vehicle platoon [3] in VANETs, where vehicles form a group while in motion. Vehicles can contribute part of their buffer to replicate and share data for other vehicles, if they move as a relatively stable platoon. Cooperative replication can reduce data redundancy in the same platoon by which more data can be stored in the same platoon reducing the data access delay and improving the data availability. However some vehicles may depart from the platoon and the data replicated by the vehicle will not be available for other nodes in the same platoon. To rectify this problem, the departing vehicle should prefetch its most interested data and transfer it to other platoon members. For this vehicles should be able to detect the split process in advance so that they can prefetch and transfer the data.

Here we use Vehicle Platoon Aware Data Access solution in Vehicular Ad - Hoc Networks. Vehicles use a part of their buffer to replicate data for other vehicles in the same platoon to share data with them. If a vehicle leaves a platoon, it prefetches the interested data in advance and transfers it to other vehicles so that they can still access the data. To improve the data access performance in VANETs, a vehicle platooning protocol is configured to recognize platoon formation and to predict platoon splits. Next a data management part is configured to lead platoon members to replicate and prefetch the most interested data so that both data availability and data access performance can be achieved. We use cost effective data replication algorithms to find the best vehicle to replicate each data in a platoon. We also use data prefetch and transfer heuristics when a split is detected. Simulation results display that vehicle platoon aware data access can efficiently improve the data access performance in vehicular Ad - Hoc networks.

PRELIMINARIES

A. Data Acess In VANET

For vehicles to access data vehicle-to-vehicle approach, which is more flexible and cost effective in VANETs, particularly in rural or highway areas, which lack roadside infrastructure support. The vehicle-to-vehicle approach has been widely used in the literature [1], [5]–[6], [8] and will be used in this paper.

B. Platoon-Based Mobility Model

In VANETs, vehicles usually move as a platoon. Although there have been a few group mobility models such as the reference point group mobility (RPGM) [9] and its variations [7], they may not be directly applied to VANETs .We assume that each vehicle platoon has a group motion vector (*GM*) that defines the movement of the entire platoon. The group motion vector follows the road layouts. All vehicles in the same platoon share the same group motion vector and have different random motion vectors (*RM*) due to their mobility deviation The movement of each vehicle in each time slot is decided by the group motion vector and its own random motion vector. Supposing that the velocity of each vehicle follows a normal distribution $N(\mu, \delta 2)$, where μ is the average velocity and δ is the variance, because vehicles in the same platoon have the same average moving velocity and deviation, they share the same normal distribution parameter μ and δ.

When a vehicle meets a platoon, it may join the platoon or stay alone. If the vehicle joins the platoon, it will follow the mobility pattern of the platoon with the corresponding velocity $N(\mu, \delta 2)$; otherwise, it keeps its own mobility pattern. Vehicles may leave the platoon when they 1) choose different routes at the road intersections or highway exits or 2) simply accelerate or decelerate

C. System Model

There are *m* vehicles in the network, which are denoted as *Vi* (*i* = 1. . . *m*), and each vehicle can store several data items in its buffer. There are *n* data items, which are denoted as *Dj* (*j* = 1. . . *n*), and each data item *Dj* has a size *Sj* . Each vehicle requests its interested data from time to time. The request frequency of vehicle *Vi* to data *Dj* is represented by *fij* . Note that the global access frequency of data *Dj* , i.e., _*m i*=1 *fij* , represents the popularity of the data. Fiore and Härri [10] showed that vehicles in the same platoon are relatively well connected. They are able to communicate with each other, either directly or through a small number of vehicle relays. Therefore, we assume that each platoon member knows the data replication arrangement within the platoon. Thus, after receiving a data request, the vehicle can easily locate the nearest platoon member that has the data. Each platoon has a "platoon leader," which can be selected based on different criteria and easily identified with the vehicles' periodic beacons [31], [32]. The main responsibility of the platoon leader is to maintain the data replication cycle (DRC) of the platoon and initiate the data-replicating process. At the beginning of each DRC, the "platoon leader" calculates the best replication arrangement based on some data replication algorithm and informs other platoon members to replicate data according to it. We assume that all vehicles are equipped with communication devices and Global Positioning Systems (GPSs). With the availability of a GPS system, it is practical for the vehicle to locate its position with certain accuracy so that vehicles can estimate not only their distance but the relative positions to each other as well.

PLATOONING PROTOCOL

A. Protocol Overview

The first component of V-PADA is the vehicle-platooning protocol, which is used to quickly identify the platoon and predict the split process. At any given time, each vehicle stays at one of the following states: 1) Initial; 2) Join; 3) Quasi-Split; and 4) Split. When a vehicle enters the network, it is at the Initial state. Later, when it meets other vehicles in the same direction, it may join them as a platoon member. After one vehicle is detected to join the platoon, it enters the Join state and sends out a platoon-join message to all platoon members to announce that a new member has joined the platoon. The message contains the information of vehicle ID, its interest list, data list, and buffer size. As the platoon leader receives this message, it will use the information to determine the best data replication arrangement for the next replication cycle. When one vehicle detects mobility anomaly it switches its state to Quasi-Split, where the anomaly will be further analyzed. If the anomaly comes from the change of road layout (e.g., the platoon is passing a curving road), the anomaly is resolved, and the vehicle returns to the Join state. Otherwise, if the vehicle is detected to split from the platoon, it enters the Split state. It sends out a platoon-split message to inform other platoon members that it is going to leave the platoon. At the same time, it starts to prefetch its interested data and transfer its buffered data to nearby platoon members. It is possible that messages may be lost for some reasons such as channel interference or collisions. Both join and split actions can always be detected by neighboring vehicles through its beacons. Furthermore, existing reliable and efficient broadcasting techniques [4] can be used to provide reliable message delivery.

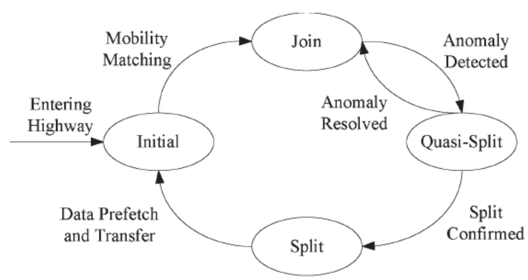


Fig.1. State transition diagram of vehicles in V-PADA

B. Stochastic Time Series Analysis for Platoon Identification

In V-PADA, each vehicle maintains a Cartesian coordinate system, where the moving direction is the X-axis. Each vehicle (called monitoring vehicle) chooses the nearby vehicle as its reference vehicle. The coordinate of the reference vehicle is represented by its shortest distances to the X-axis and the Y -axis, which are denoted by Δy and Δx, respectively. The monitoring vehicle and its reference vehicle periodically exchange their movement profile through beacon messages,1 by which the monitoring vehicle can get a series of relative coordinates of the reference vehicle in terms of Δx and Δy. Then, by analyzing the Δx and Δy series, the monitoring vehicle can estimate the relative motion deviation between two vehicles and determine whether they are in the same platoon or not. If the motion deviation is consistently small, the monitoring vehicle can determine that it may have already joined the platoon. During monitoring, the time interval between any two successive observations of Δx (or

Δy) is equal to the same beacon cycle; thus, the whole monitoring process can be regarded as a discrete and same-spaced process {Xt} (and {Yt} for the Δy series). Therefore, in V-PADA, we can use the stochastic time series analysis on the observed position series to provide precise and automatic platoon identification.

C. Split Prediction

After joining a platoon, the monitoring vehicle keeps monitoring its reference vehicle and its own mobility pattern, so that it can quickly detect the split and have more time to prefetch and transfer data.

1) Anomaly Detection: The most intuitive approach in detecting mobility anomaly is only based on the distance between the monitoring vehicle and its reference vehicle. A mobility anomaly is detected when the distance becomes larger than a predefined threshold. However, it is difficult to find the appropriate threshold. If the threshold is large while the monitoring vehicle and the reference vehicle are close to each other, the anomaly may not be detected, even after a relative large position change . If the distance threshold is small, it may result in high false positives, even if the monitoring vehicle only moves a little bit .

To address the weaknesses of the a fore mentioned approaches, we propose to use the 2-D relative position change between the monitoring vehicle and its reference vehicle to detect mobility anomaly. In this approach, we still use the Cartesian coordination system to determine the relative position of the reference vehicle in terms of Δx and Δy and use time series analysis on the relative position change to detect mobility anomaly. The standard position deviation and the detection confidence interval, the detection boundary can be represented by a rectangle. If the diagonal of the rectangle is 2d, any mobility anomaly that results in a relative position deviation of distance d can be detected. This approach can precisely determine the relative motion between the two vehicles and thus can be used to quickly detect any abnormal position change.

2) Two-Step Split Prediction: In the position-change-based approach, a large position change may come from the following reasons: 1) The vehicle is splitting from the platoon, or 2) the vehicle still stays with the platoon but the platoon changes its moving direction due to road layout such as a curve. Although the vehicle is in the same platoon as its reference vehicle, the observed relative position changes much in two successive observations due to the road curve, resulting in a false alarm of a vehicle split. To mitigate the false alarm issue and quickly detect the split, we design a two-step split prediction method based on the following idea. If a vehicle moves on a straight road, its moving direction is usually stable; otherwise, if it is passing a curve road, its moving direction may continuously change. Furthermore, if a vehicle splits from the platoon, its distance to the reference vehicle increases as they move further apart; if the vehicle is still within the platoon, its distance from the reference vehicle may not change too much, even if they are moving on a curve road. By first analyzing the moving direction (the first step) and then comparing their relative distance deviation (the second step), we can differentiate different splitting scenarios and reduce the false alarm rate due to road curvature

3) Reference Vehicle Selection: We have three rules for selecting the reference vehicle in a platoon. They are given as Rule I: A vehicle always chooses the vehicle in front of it (if any) as its reference vehicle. Rule I guarantees that the reference vehicle will pass the exit before the monitoring vehicle

Rule II: Each vehicle prefers the vehicle that is close to it as its reference vehicle. Rule II considers the communication reliability between the vehicle and its reference

Rule III: Multiple reference vehicles can improve the detection accuracy. By using multiple reference vehicles at the same time, a more accurate split prediction can be achieved.

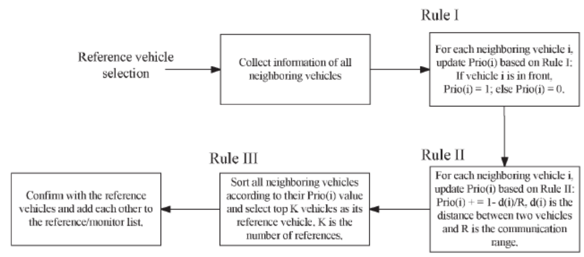


Fig.2. Reference vehicle selection

In V-PADA, each vehicle selects its reference vehicles based on these three rules when it joins the platoon. When a reference vehicle is detected to split from the platoon, it will also apply these rules to find a new reference for its monitoring vehicle.

PLATOON-BASED DATA MANAGEMENT

In V-PADA, we exploit the platooning behavior to optimize the data access. First, we analyze the intraplatoon data replication problem and propose a cost-effective but centralized data replication algorithm called best-location data replication to help vehicles cooperatively access their interested data inside the platoon. The main purpose of the best-location replication algorithm is to optimally place data replicas at their best locations inside the platoon so that the vehicles in the same platoon can hold more interested data to avoid the long delay and low availability of accessing data not in the platoon. Second, we extend the best-location algorithm to a more scalable distributed algorithm called neighboring data replication, where each vehicle cooperatively replicates data with their directly connected neighboring nodes. Finally, we provide heuristics for vehicles to prefetch and transfer data before vehicle splits so that vehicles can still access their interested data after split.

A. Intraplatoon Data Replication

In V-PADA, data replication is periodically executed based on a predefined DRC that is maintained by the platoon leader. At the beginning of each DRC, the platoon leader calculates the best intraplatoon replication for each data item according to the data replication algorithm and then notifies all platoon members, with which each vehicle can buffer the most appropriate data replicas. In the following, we first formulate the intraplatoon data replication problem and then propose a new cost-effective replication algorithm that can remove data redundancy and reduce the data access cost.

1. Best-Location Data Replication Algorithm: The basic idea behind the best-location data replication algorithm is to find the best location (vehicle) to place each data replica so that the overall data redundancy and data access cost within the platoon are minimized

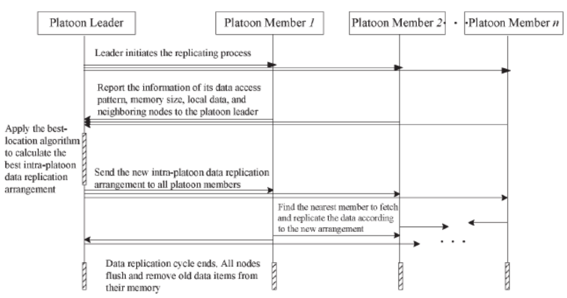


Fig.3. Implementation of the best location data repliction

2. Neighboring Data Replication Algorithm: The best location data replication algorithm can find the best vehicle to allocate each data item inside the vehicle platoon. However, this algorithm requires all platoon members to report their own information to the platoon leader. After the platoon leader collects all information, it calculates the best allocation of all data replications and notifies all platoon members. Obviously, this algorithm is centralized and may have large message overhead. To make the replication algorithm more scalable to large platoons, we propose a distributed data replication algorithm called neighboring data replication. In the neighboring replication algorithm, each vehicle only contacts with its directly connected neighbors, instead of all platoon members, and tries to find the best neighboring vehicle to replicate each data item and eliminate the data redundancy.

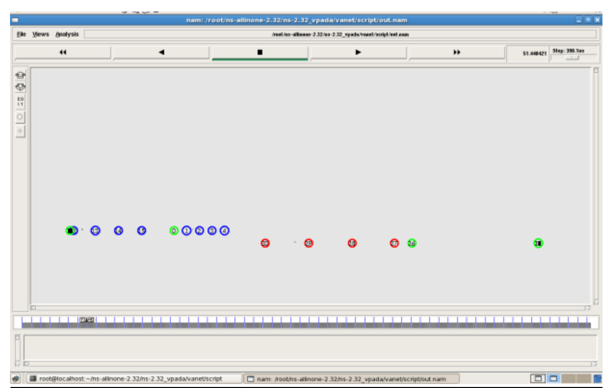
The neighboring data replication algorithm eliminates the replica duplication among neighboring vehicles. Furthermore, it only requires the node to contact its neighboring vehicles to make the replication decision, which saves more communication overhead, compared with the best-location algorithm.

B. Data Prefetch and Transfer on Splitting

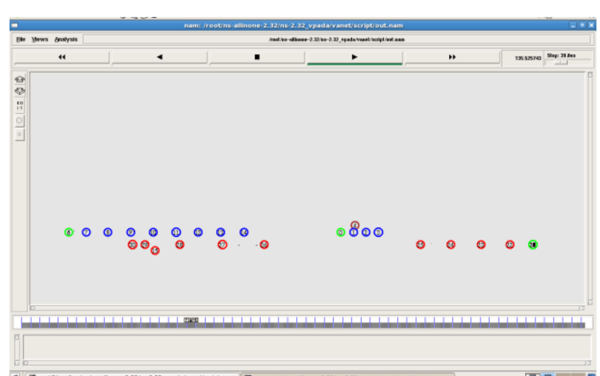
By cooperative replication, the two proposed data replication algorithms can eliminate intraplatoon data redundancy and then reduce the data access cost. However, the advantage of cooperative replication will be affected by platoon splitting. From the splitting vehicle point of view, it may not be able to access the most interested data placed at other platoon members after it is disconnected from the platoon. From the vehicle platoon point of view, if there are some primary data copies buffered at the splitting vehicle, the splitting may also significantly affect the intraplatoon data access. Moreover, if the primary data copy is the only data copy in the platoon, other platoon members will not be able to access the data after splitting. To address this problem, the splitting vehicle should prefetch its most interested data and transfer its buffered primary data copies to other platoon members. More specifically, after a vehicle is confirmed as "split," it begins to immediately prefetch its interested data based on its own data access probability.

Because all vehicles know the arrangement of data replications within the platoon, the splitting vehicle can easily locate the nearest nodes that have the data and prefetch it. To ensure that the split will not affect the data access of other platoon members, the splitting vehicle should transfer as many primary data copies as possible to its nearest neighbor that buffers duplicate copies of other data and replaces them with its primary data copies. With data prefetch and transfer, the splitting vehicle can still locally access its interested data, and the negative effects on other platoon members can be minimized.

RESULTS:



(a)



(b)

(c)

Fig.4. Vehicular Ad-Hoc Networks Using V-PADA

We implement V-PADA in the Ns-2 simulator. In the simulation 30 vehicles move on the highway following the speed limits. The vehicles are divided in two and move in opposite direction as in a bidirectional road. There are seven platoons in the simulation setup and the vehicles enter the highway and move through these platoons. The top row where the nodes move from left to right of the screen is indicated as blue color. The bottom lane where the vehicles move from right to left is indicated as red. In the simulation two nodes deviate from the lanes to simulate anomaly. Node 15 moves from lane 1 to join lane 2 and node 4 leaves the lane 1 and rejoins the same lane afterwards. V-PADA monitor the movement of nodes and switches the nodes between reference nodes and mobile nodes which is also indicated. The messages transferred between the nodes like beacon messages and data are got in a separate trace file from which the results can be depicted.

CONCLUSION:

We have proposed V-PADA, which is a novel vehicle-platoon-aware data access solution for VANETs. V-PADA makes use of the “vehicle platoon” mobility pattern to collaboratively replicate data and optimize data access among vehicles. V-PADA consists of two components. Simulation results have shown that V-PADA outperforms other data access solutions in VANETs. The proposed solution in this paper is not limited to VANETs and can be extended to other mobile ad hoc networks. In the future, we will look into solutions for mobility anomaly detection in more complicated road structures and solutions for cooperative data access with the support of roadside infrastructures. Furthermore we can get the information available from neighboring platoons to decrease the query delay .

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