Vehicular Ad-Hoc Networks: An Information-Centric Perspective

Abstract:

Emerging Vehicular Ad-Hoc Networks (VANET) have the potential to improve the safety and efficiency of future highways. This paper reviews recent advances in wireless communication technologies with regard to their applications in vehicular environments. Four basic demands of future VANET applications are identified, and the research challenges in different protocol layers are summarized. Information dissemination is one of the most important aspects of VANET research. This paper also discusses the primary issues in information dissemination from an information-centric perspective, and provides two case studies. Finally, future research directions and possible starting points for new solutions are considered.

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1 Introduction

Vehicular Ad-Hoc Networks (VANET) are becoming an integral technology for connecting daily life to computer networks. They could greatly improve the driving experience both in terms of safety and efficiency. As shown in Figure 1, when multi-hop communication is implemented, VANET enables a vehicle to communicate with other vehicles which are out of sight or even out of radio transmission range. It also enables vehicles to communicate with roadside infrastructure. VANET will likely be an essential part of future Intelligent Transportation Systems (ITS).

Currently, ITS relies heavily on infrastructure deployment. Electromagnetic sensors, for example, are embedded into the road surface; traffic cameras are deployed at major intersections; and Radio Frequency Identification (RFID) readers are deployed at highway entrances. A typical procedure for collecting and distributing traffic information is as follows. First, traffic samples are gathered by road surface sensors and uploaded to a municipal transport center. After data processing, traffic reports can then be delivered to a user's cell phone via cellular networks. This is an expensive and inefficient way of disseminating location-based information, especially when the information of interest is only a few hundred meters from the user's physical location. With its short-range communication capabilities, VANET may change this paradigm and make generating and disseminating information more straightforward.

VANET can also serve as a large-scale wireless sensor network for future ITS because every modern vehicle can be regarded as a super sensor node. For example, all new vehicles are usually equipped with exterior and interior thermometers, light sensors, one or more cameras, microphones, ultrasound radar, and other sensory features. Moreover, future vehicles will also be equipped with an on-board computer, wireless radio, and a GPS receiver, which will enable them to communicate with each other and with roadside units. A wireless sensor network of such magnitude is unprecedented, and perceptive computer systems will extend to every corner of the globe. Information can be generated and shared locally in a peer-to-peer manner without the need for restrictive infrastructure.

The capabilities of future vehicles open up a number of potential applications for use in daily life. The main applications of VANET can be categorized as:

Safety applications: pre-collision warning, electronic road signs, traffic light violation warning, online vehicle diagnosis, and road condition detection. This type of application

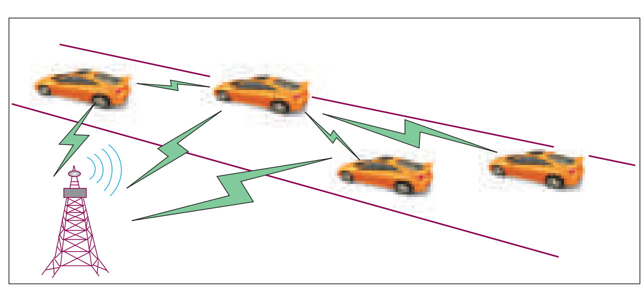


Figure 1. Vehicular ad-hoc networks.

usually takes advantage of short-range communication to perform real-time detection and provide warnings to drivers

Efficiency applications: municipal traffic management, traffic congestion detection, route planning, highway tolling, and public transportation management. This type of application is dedicated to improving both individual and public travel efficiency

Commercial applications: Location-Based Services (LBS) will give rise to a variety of commercial applications such as nearby restaurant specials, cheap gas stations, or even shopping center promotions. Such commercial applications may spur new competition among local businesses.

Infotainment applications: video and music sharing, location-based restaurant or store reviews, carpooling, and social networking. Already, infotainment applications such as Ford Sync[1] and Kia UVO have become attractive add-ons in the vehicle market. The networking of infotainment systems will surely be a trend in the near future.

An abundance of VANET applications will benefit a wide range of parties: from governments and vehicle manufacturers to local retailers and consumers. Although a few Geographic Information Systems (GIS) companies—such as Google, Garmin, and TomTom—have engaged in collecting and distributing traffic information, traditionally, ITS development and deployment has been the domain of governments. In the future, many more participants will be attracted to VANET and will profit from it. Vehicle manufacturers could predict a boost in their sales by selling VANET-enabled vehicles. Fitting vehicles with a variety of electronic controls and devices is a growing trend, especially fitting electronic safety and information systems. Ford Sync is a very successful example of vehicle infotainment. Moreover, local retailers and service providers will also be interested in promoting their sales via VANET. They could broadcast commercials to passing vehicles and even devise hourly pricing strategies. Local businesses may gain a competitive advantage or face greater competition. Undoubtedly, consumers will be the beneficiary of enhanced safety and efficiency, cheaper goods, enriched entertainment, and other advantages.

In this paper, the following section reviews recent advances in wireless communication technologies with regard to their applications in vehicular environments. Section 3 identifies four fundamental demands of future VANET applications. Section 4 discusses existing challenges in different network protocol layers. Section 5 further discusses several research topics in information dissemination from an information-centric perspective. Section 6 concludes.

2 Wireless Technologies and Vehicular Communications

Wireless Personal Area Networks (WPAN) using IEEE 802.15 standards have been largely successful in consumer electronics (including vehicular electronics). Ford Sync is a good example. With Bluetooth technology, a cell phone can be connected to the vehicle's audio system enabling a driver to make calls or play hands-free music using voice commands. 802.11 (a/b/g) WLAN technologies have been widely deployed because of their mass production and relatively low cost. Although 802.11 (a/b/g) was not originally designed for vehicular communications, many studies (in particular References[2-4]) have focused on applying 802.11 to vehicular environments because of the pervasiveness of its technologies. IEEE 802.11p[5] introduces enhancements to 802.11 which are needed to support Wireless Access in Vehicular Environments (WAVE). This includes data exchange between high-speed vehicles and between vehicles and roadside infrastructure in the licensed ITS band of 5.9 GHz.

Another emerging technology is Wireless Metropolitan Area Network (WirelessMAN), also called Worldwide Interoperability for Microwave Access (WiMAX) (IEEE 802.16). It is aimed at providing wireless data over long distances in a variety of ways, from fixed point-to-point links to full mobile cellular type access. Currently, the most common form of automobile connectivity is based on cellular telephony and is known as automotive telematics. Typical examples include GM's OnStar system and Ford's RESCU system. Several GIS companies, including TomTom and Garmin, also use cellular networks to transmit real-time traffic information. Usually, cellular-based telematics is a paid service based on user subscription.

In the near future, it is envisioned that architecture of vehicular networks will be hybrid, as shown in Figure 2. In this architecture, long-distance communication techniques, such as cellular networks and WiMAX, will provide vehicles with instant Internet access, while short-distance communication techniques, such as Dedicated Short-Range Communications (DSRC)[6] and Wireless Fidelity (Wi-Fi), will provide short-range real-time support in an ad hoc manner.

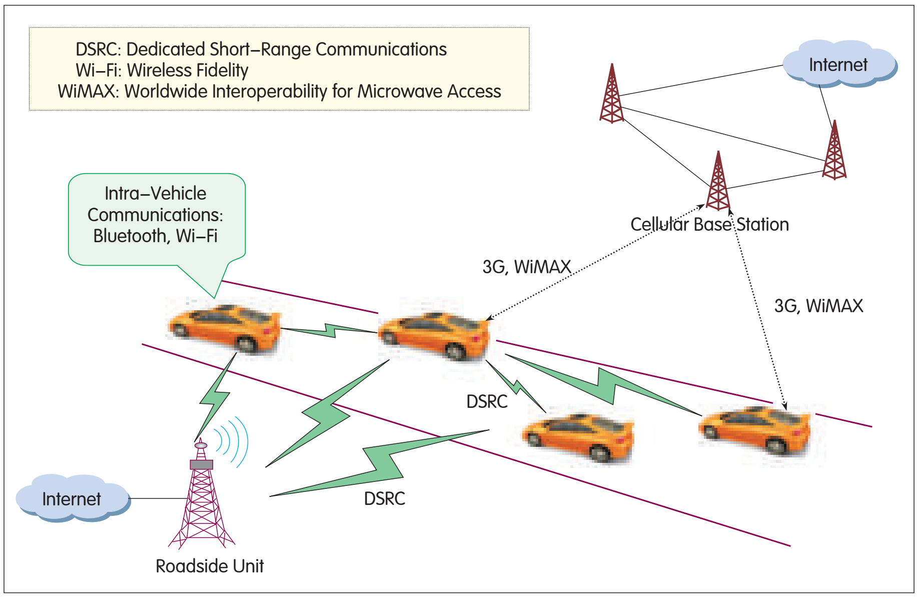
VANET, based on DSRC, Wi-Fi, and other short range communication techniques, will play an important role in future ITS. Compared to infrastructure networks, VANET has two main advantages. It is cheap to deploy and operate, and consumers can enjoy service without subscription. VANET is also essentially a cyber-physical system, which enables communication between two geographically neighboring nodes. This has real-time safety and other applications.

3 Requirements of VANET Applications

Future VANET applications will have four fundamental demands: scalability, availability, context-awareness, and security and privacy.

(1) Scalability

Because of the number of vehicles that could be incorporated into vehicular networks, VANET may



▲Figure 2. Wireless technologies for future vehicular communications.

become the largest ad hoc network in history. Undoubtedly, scalability will be a critical factor. The advantages of hybrid architecture, together with in-network aggregation techniques and P2P technologies, make information exchange more scalable.

(2) Availability

Due to the real-time interaction between vehicular networks and the physical world, availability is an important factor in system design. This may have a major impact on the safety and efficiency of future highway systems. The architecture should be robust enough to withstand unexpected system failures or deliberate attacks.

(3) Context-Awareness

As a cyber-physical system, VANET collects information from the physical world and may conversely impact the physical world. On the one hand, protocols should be adaptable to real-time environmental changes, including vehicle density and movement, traffic flow, and road topology changes. On the other hand, protocol designers should also consider the possible consequences the protocol may have on the physical world.

(4) Security and Privacy

There is a recent trend of making vehicular on-board computer systems inter-connectable to other systems. The Ford Sync, for example, connects the vehicle's entertainment system to the driver's cell phone via blue-tooth technology. In the future, vehicular on-board computers could even be open to software developers. These trends may have serious implications for security and privacy due to the cyber physical nature of VANET. Governments and consumers will have very high expectations of VANET safety and security.

4 Research Challenges

This section discusses research challenges from different network protocol layers. The unique properties of vehicular networks give rise to a number of design challenges. These properties also create new opportunities to solve ITS problems from a different perspective.

4.1 Link Layer

In the link layer, the main challenge lies in adapting link layer protocols to unique vehicular environments and to maximize link layer performance. There are three major design objectives for link layer protocols: responsiveness, reliability, and scalability. Link layer protocols are required to be highly responsive to changes in channel conditions and vehicle mobility, while reliability and scalability are two requirements critical to safety applications. A number of traditional link layer strategies, such as lengthy access point selection, MAC management timeout, and Address Resolution Protocol (ARP) timeout, have been proven inefficient in highly mobile environments. They may lead to increased start-up delays, underutilized bandwidth, or unfair bandwidth allocation. Scalability and reliability are interrelated issues. Reliable broadcasting has been intensively studied for vehicular safety applications. The existing approaches include rebroadcasting, cooperative forwarding, and transmission power adaptation. However, reliability and scalability remain open-ended issues for safety applications because both governments and consumers have extremely high expectations for safety applications.

4.2 Network Layer

In the network layer, the main challenge is to establish a new paradigm for information dissemination in VANET. Ad hoc network routing has been intensively studied in the last decade. In particular, many context-aware routing protocols—such as Mobility-Centric Data Dissemination Algorithm for Vehicular Networks (MDDV)[7] and Vehicle-Assisted Data Delivery (VADD) in Vehicular Ad Hoc Networks[8]—have been proposed for VANET. These protocols significantly improve the packet forwarding performance in vehicular environments by taking advantage of vehicle mobility, GPS position, and road layout. They are essentially all packet-based; a packet travels from a source to a destination untouched throughout the entire process. However, this packet-based paradigm no longer satisfies application requirements in VANET from an information-centric perspective. First, for some applications, there is no definite source and destination, which is necessary for packet-based routing. Second, information is altered (or combined) throughout the forwarding process, and this is not a consideration of packet routing. In a traffic detection application, every vehicle may generate a traffic report that can be combined with other reports as it is disseminated. For all interested vehicles intended to be the recipients of these reports, there is no prior knowledge about how many, when, or where these vehicles might be. Some packet routing approaches such as multicast and geocast can help solve these issues. However, what is needed is a new paradigm for information routing—a replacement for packet routing. The new paradigm will enable information operations such as information generation, aggregation, dissemination, and invalidation.

4.3 Application Layer

In the application layer, the challenge lies in effectively representing, discovering, storing, and updating information throughout the network. Naming and addressing are central problems in vehicular networks. How to index information from the physical world for efficient information storage and dissemination remains an unresolved problem. It is envisioned that the addressing scheme will be a hybrid, multi-level scheme, with context information playing an important role. The naming and addressing policy has a significant impact on other system protocols, such as information discovery and routing. Because vehicles are highly mobile, another challenge is to dynamically map vehicle IDs to position-based addresses. This problem is particularly important for applications across the hybrid network architecture. ARP/Reverse Address Resolution Protocol (RARP)-like mechanisms can be implemented in nodes equipped with both DSRC and infrastructure network interfaces.

Distributed data management is another challenging issue for VANET, impacting data replication, data elimination, and cache replacement. Traditional distributed data management assumes a network is connected with geographically-distributed servers, which is no longer true for VANET. Essentially, VANET can be regarded as a large-scale distributed database in which each vehicle maintains a local part. Vehicles periodically exchange data to update this global database, and inconsistency cannot be avoided. Therefore, maintaining a relaxed consistency model with minimal overhead is a challenge.

▼Table 1. Representatives of information dissemination approaches

Information Dissemination Approaches		Representative Work
Macroscopic	Infrastructure-Based	Reference [9]
	Delay Tolerant Routing	References [10], [11], [12] and [13]
	Data Aggregation, Data Caching	References [15], [18] and [24]
Microscopic	One-Hop	References [2], [3] and [4]
	Data Forwarding	References [7], [8] and [20]
	Resource Management	References [21], [22] and [23]

5 Information Dissemination

In this section, research demands and challenges from an information-centric perspective are discussed. VANET can be regarded as an information-centric system where information is collected and disseminated throughout the network, and it is important to identify the system's demands from this perspective. Information dissemination can be classified into two levels: macroscopic and microscopic. Two case studies are presented for these levels respectively. Table 1 lists the major research topics at these two levels and the representative work on each.

5.1 Macroscopic Information Dissemination

Macroscopic information dissemination deals with disseminating information to one node or a group of nodes in a specified geographical area. The destination of information can be a single specified node in the network, a group of specified nodes, or even a group of unknown nodes. The objective of macroscopic information dissemination is to reduce information delivery delay, reduce delivery overhead (including storage overhead and communication overhead), and increase the future query success rate (if the destination is unknown in advance). General research topics for macroscopic information dissemination include information routing, data caching, and data aggregation.

Information dissemination can be implemented with or without infrastructure support. Jedrzej et al[9] proposed establishing a P2P overlay network based on cellular network infrastructure. With a reliable connection to internet infrastructure, vehicles can share, discover, and exchange information of non-safety applications in a P2P manner. However, service provided by infrastructure is usually based on paid subscription, which limits the number of consumers. Compared with infrastructure service, ad hoc networks seem to be a more attractive approach. On the other hand, most non-safety applications do not have strict real-time requirements. A recent trend has been to study VANET information dissemination in a delay tolerant manner. Some general purpose DTN routing protocols such as epidemic routing[10] have been proposed and evaluated. Proactive approaches[11-12] take advantage of apriori knowledge of geographical location, connectivity pattern, as well as control over movement. Some existing DTN routing protocols assume a predefined source and destination. For example, in Small and Hass's project[13], a DTN network was established for wild whale monitoring. A sensor node was mounted on the back of a whale, and mobility information was delivered to an infostation hop by hop in a delay-tolerant manner.

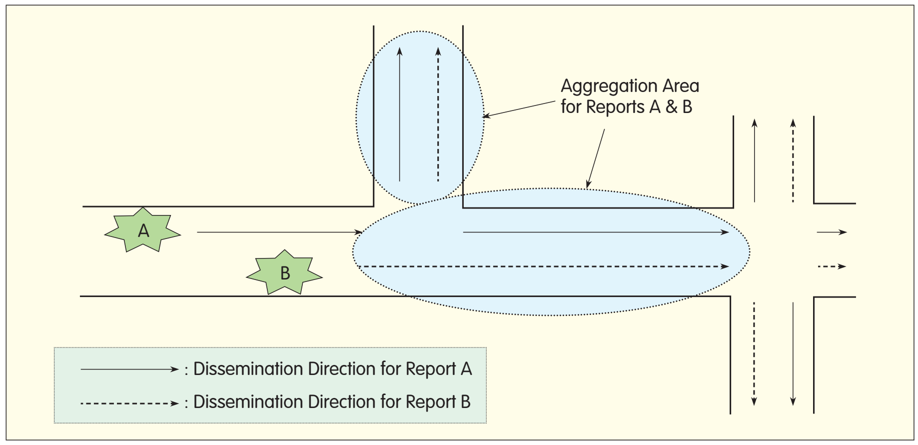
Data caching and aggregation have also been studied in VANET. Zhao et al[14] studied the process of distributing information from a data center into VANETs. Their approach was based on periodical rebroadcasting and buffering. It is a one-way dissemination from a data center to a group of vehicles. Lochert et al[15] proposed a hierarchical aggregation scheme that defines a set of landmarks to calculate travel time. They also proposed a roadside unit placement algorithm to optimize aggregation.

Information dissemination, caching, and aggregation have been individually studied in relation to VANET. However, the delay-tolerant dissemination problem has been fused into data query, data caching, and data aggregation issues because, in VANET, for most types of information, there is no a priori knowledge of the destination vehicles. Any vehicle may generate and send out a query in the hope that a response is returned by a neighboring vehicle as soon as possible.

A new paradigm for information routing needs to be established as an alternative to packet routing. First, the destination of information routing must be defined. The dissemination destination is a virtual concept constrained by time, space, and vehicles. In other words, the destination consists of all vehicles which meet the temporal and spatial conditions. There are two basic dissemination operations: pull and push. For pull, a vehicle periodically broadcasts its interest and pulls data from other neighboring vehicles; for push, vehicles intentionally push data to neighboring vehicles so that other vehicles that may be interested in the data can easily obtain it in the future. Since the pull operation is limited to one hop at the initial stage of market penetration, it is more important to devise push strategies. When devising push strategies, the potential impact to data caching and aggregation must be taken into account. Heuristic neighbor information (such as driving direction, speed, frequently visited places, etc.) or even social networking information can be used to predict and control the dissemination.

5.1.1 In-Network Data Aggregation

This sub-section examines the details of macroscopic information dissemination through an example of in-network data aggregation. As previously mentioned, in the near future, every vehicle will be a super sensor, capable of monitoring its surrounding environment. Each vehicle may generate a traffic report when the vehicle speed is well below the speed limit. However, it is inefficient for every vehicle to generate a report and then broadcast it to the entire network. It is unnecessary to broadcast the speed of individual vehicles on a road which is a few miles away; drivers expect to know general congestion information ahead. Actually, traffic reports can be combined as they are propagating, and the overhead for dissemination can be effectively reduced.



▲Figure 3. Dissemination tree.

Figure 3 illustrates an example of report dissemination. Two vehicles A and B, which are geographically close to each other, generate two traffic reports. These two reports are intended to be delivered to all vehicles following behind so that those vehicles can take a detour before encountering a traffic jam. A report will be duplicated at an intersection, each copy going in one direction. In this way, a dissemination tree is formed. Since vehicles A and B may not be within each other's signal range, one may not know that a similar report was generated by the other. Instead of being disseminated across the entire network, these two reports can be merged as they propagate. In Figure 3, the dotted circle shows the possible aggregation area for these two reports.

In order to aggregate the two reports, they must be delivered to the same vehicle at the same time. For traditional wireless sensor networks, researchers have proposed a number of structural or semi-structural-based aggregation schemes involving the creation of a transmission schedule to ensure reports meet each other at the fork of a routing tree. However, a fixed routing structure is infeasable in VANETs. Several VANET projects, such as Self-Organizing Traffic Information System (SOTIS)[16] and TrafficView[17], use periodic rebroadcasting to collect and redistribute traffic information. Rebroadcasting is a feasible solution for local information exchange and dissemination, but it is difficult to scale it to city-wide dissemination.

Essentially, in-network data aggregation schemes trade off increased delay for reduced redundancy. When a node receives a report, it introduces a delay before forwarding it to the next hop so that it may receive another report for this duration. Structure-based schemes use a transmission schedule to determine this delay. Rebroadcasting schemes use a fixed delay for rebroadcasting. If the delay is more adaptive, however, a packet is more likely to meet other reports. In our previous work[18], intelligent delay control policies based on local observations were investigated. For example, suppose a node observes that a report has recently passed by; if the node receives another report in a

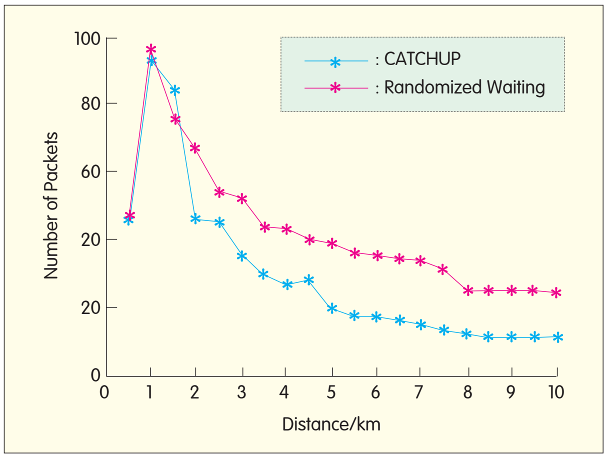


Figure 4. Performance of in-network data aggregation.

short period, it can simply forward it to the next hop immediately in the hope that it can catch up with a previous one. If no report has recently passed, a long delay can be applied in the hope that more reports can be later received by this node. A future reward model is designed to define the benefits of different delay-control policies, and then to establish a decision tree to help a vehicle choose an optimal policy from the perspective of long-term reward. Figure 4 shows the performance of such an aggregation scheme. Our scheme (CATCHUP) is compared with Randomized Waiting[19]; the results show that the number of packets can be significantly reduced as the distance to the report source increases.

Data aggregation in VANETs has attracted much research attention. However, issues involving scalability, data representation and processing, and delay tolerant routing remain unresolved. Among these, scalability is the most pressing issue. Although a number of data aggregation schemes have been proposed for VANETs, it is still not clear how scalable these schemes are in terms of city-wide communication.

5.2 Microscopic Information Dissemination

Microscopic information dissemination deals with information delivery in one hop or in a few hops. In the initial market penetration stage, a vehicle may rarely encounter another vehicle or roadside unit. Therefore, increasing the efficiency of each encounter between vehicles is important.

A few recent research projects have paid close attention to one-hop communication in a vehicular environment. Bychkovsky et al studied the techniques to increase one-hop throughput via open WiFi links. They conducted a number of field tests to investigate the performance loss in MAC association, IP address acquiring, and IP route establishing. Hadaller et al conducted a 802.11-based one-hop communication experiment and furnished a detailed experimental analysis. From their experiments, the researchers identified the underlying causes of throughput loss in existing wireless access mechanisms. In sum, these works attempt to analyze and improve the link throughput from the perspective of lower layer protocols (phy, MAC, routing).

Microscopic information dissemination also deals with local multi-hop communication. Usually, the main task of local multi-hop communication is to coordinate local vehicles to disseminate information in a predefined direction. VADD is a forwarding protocol which takes advantage of traffic pattern and road topology to source the best road for delivering a packet. MDDV exploits vehicle mobility for information dissemination, and makes neighboring vehicles collaborate in packet forwarding in order to increase reliability. Zhao et al[20] studied throughput improvement gained through cooperative relaying to a roadside unit.

Because of the short session duration of a mobile-encounter scenario, efficient management of channel resources is also a practical issue. Chang et al[21] proposed a scheduling algorithm for downlinks—from a roadside unit to passing vehicles. Zhang et al[22] proposed another scheduling algorithm which considers both upload requests and download requests. Yu et al[23] studied the admission control problem when a roadside unit is experiencing (or close to experiencing) overloaded conditions. These studies improve the efficiency of roadside unit access from different resource allocation perspectives.

In general, the main challenge in microscopic information dissemination is how to bind lower layer conditions (mobility, channel, position) and upper layer application requirements together. From the upper layer perspective, DTN applications can tolerate information delays and information inaccuracy; from the lower layer perspective, mobility, channel, and location may change dramatically in a short period of time. Existing work has studied the one-hop communication problem with different network protocols. However, there is still no effective bond between the upper and lower layers. The bond may allow us to take advantage of the lower harsh conditions, rather than being constrained by them.

Three aspects are considered when designing microscopic information dissemination protocols.

(1) Application Requirement

DTN applications do not assume a reliable link, but do prioritize data for transmission. They may specify the information loss tolerance level during the dissemination process.

(2) Resource Management

Problems include how to schedule lower layer resources (such as transmission channel and transmission rate); how to schedule upper layer tasks; and how to allocate resources to ensure fairness.

(3) Cooperation

Here, focus is on cooperation between vehicles within signal range. Potential techniques include multi-task scheduling, relaying, multi-party

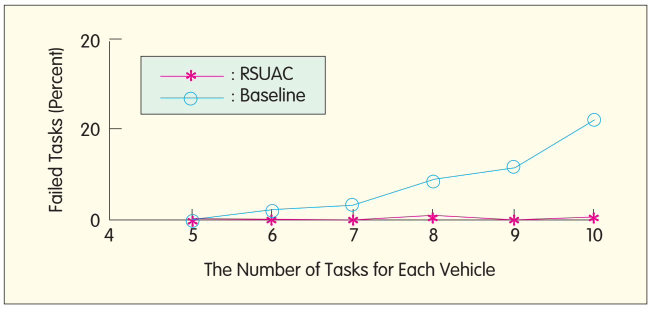


Figure 5. Performance of admission control.

network coding, and others.

5.2.1 Roadside Unit Admission Control

This subsection provides a case study for microscopic information dissemination. Roadside Units (RSU) play an important role in future ITS. They are usually deployed at highway ramps or road intersections, and can communicate with passing vehicles with DSRC technologies. RSUs can provide these vehicles with a variety of potential services. For example, a passing vehicle may download digital maps, commercials, and traffic reports from an RSU. However, an RSU is a sparse resource. In the initial phase of market penetration, only a limited number of RSUs can be deployed at highway ramps or major intersections. Even when a vehicle encounters a unit, it may take less than half a minute to move out of signal range. Moreover, multiple vehicles may concurrently compete for services from the RSU. Therefore, it is important to efficiently manage RSU access.

Transmission integrity is also important for RSU access, since the services provided may be time or location sensitive. If downloading a task like a digital map or traffic report cannot be completed before the vehicle moves out of signal range, the downloaded part would be meaningless, not to mention a waste of bandwidth. Admission control is a potential approach to guaranteeing transmission integrity. The task of admission control is to determine whether to admit a new upload or download task. Once a task has been admitted, a transmission schedule is calculated to guarantee completion of the task.

Admission control has been the subject of intensive study. Traditional admission control schemes mainly focus on long-term sessions; for example, VoIP and multimedia services. Some real-time systems simply characterize transmission tasks by average rate, peak rate, or burst size. However, roadside unit access is mainly focused on short sessions, and the transmission rate for a moving vehicle may vary dramatically. A dedicated admission control scheme is therefore desirable for roadside unit access.

In our previous work, an admission control scheme was proposed for roadside unit access. The scheme calculates a transmission schedule for all tasks (including current and new tasks) based on a channel prediction model and a vehicle mobility model. If a feasible schedule is found, new tasks will be admitted; otherwise, new tasks will be rejected to guarantee the success of current tasks. The problem was treated as a linear-programming optimization problem and a set of algorithms were designed to calculate the bandwidth allocation schedule. All concurrent transmission tasks share the bandwidth according to the schedule, thereby maximizing the success rate of these tasks. In a NS2-based simulation, our scheme was compared with a baseline admission control method. The baseline method allocated bandwidth based on a minimum required rate. Figure 5 demonstrates that the RSUAC scheme effectively reduced the percentage of failed tasks even when the workload (number of tasks per vehicle) increased.

6 Conclusions

VANET is a promising area for future ITS, and has the potential to become the largest ad hoc network in history. In the past few years, it has attracted much attention from academia, industry, and government. However, there are fundamental issues that remain unresolved. Better paradigms are needed for information dissemination and distributed data management. Undoubtedly, the number of research contributions will continue to increase in the near future.

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Roundup

ZTE and Three Release Android Éclair Handset in the UK

ZTE Corporation and Three have launched the ZTE Racer, a low cost Android 2.1 (Éclair) powered handset.

The Racer is the first Android handset in the UK from ZTE and is Three's first Android handset to break the 100 barrier, selling at 99.99.

Android could account for the second highest market share of mobile operating systems by 2012, according to a recent report from Gartner. However, it can take over a year to develop a new smartphone which means that device manufacturers are struggling to keep up with developing Operating Systems (OS) and new devices are often launched with older versions of the OS.

The Racer is a ZTE and Three co-branded handset that combines a 2.8" QVGA touchscreen, 3.2 megapixel camera, 256 MB of internal memory, Bluetooth and 7.2 Mbit/s HSDPA capabilities.

The handset is aimed at consumers who require access to a wide range of applications. The Android OS allows users to download thousands of apps from the Android market with quicklink access to services including Facebook, Spotify, YouTube, Google Maps and Google Talk.

ZTE expects to increase its share of the UK carrier handset market from three percent in 2009 to eight percent in 2010. In Q2 this year alone, ZTE mobile devices sales in the UK passed the million unit mark for the first time. (ZTE Corporation)