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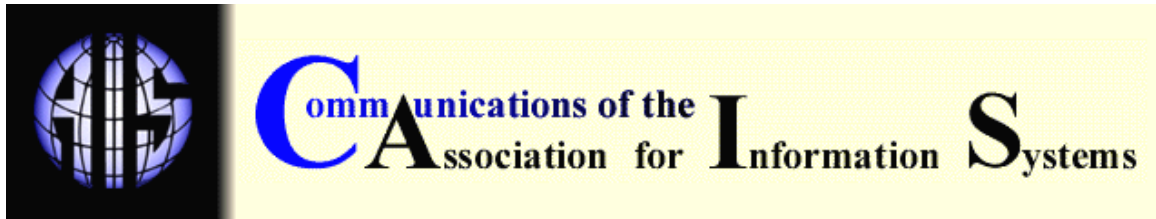
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VEHICULAR MOBILE COMMERCE: APPLICATIONS, CHALLENGES, AND RESEARCH PROBLEMS

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ABSTRACT

With an increasing number of vehicles with significant computing and communication, many applications such as vehicular Internet hot-spots, digital and entertainment content's broadcast, Intelligent Transportation Systems applications, and highway management will become possible. This "vehicular mobile commerce" will actively involve vehicles and users in both extending the existing mobile commerce applications to the vehicular environment and creating many more new and suitable applications. Before vehicular mobile commerce becomes a practical reality, many technical, structural and user issues must be addressed. In this paper, we identify and discuss several vehicular mobile commerce applications as well as wireless and networking challenges. We present possible solutions for vehicular mobile commerce and define several research problems that should be undertaken.

Keywords: vehicular mobile commerce, ad hoc wireless networks, mobile applications

I. INTRODUCTION

In the last several years, mobile commerce attracted significant attention among users, service providers, vendors, content developers, businesses, and researchers [Varshney et al..2000]. As a result, in many new applications were conceived, including location-based services, mobile financial services, multi-party interactive games, and mobile auctions [Varshney et al. 2000; Varshney and Vetter 2002]. The users involved in mobile commerce activities could be fixed or mobile, and the mobile users could be either pedestrians or in vehicles. Nearly all the work on mobile commerce so far assumes that mobile users in vehicles will be accessing regular mobile commerce applications using hand-held devices such as PDAs or cell phones [Varshney and Vetter 2002, Shih and Shim 2002]. In this paper, we look into how vehicles can be used to facilitate existing mobile commerce applications and in creating new and suitable applications in the vehicular environment.

Vehicular mobile commerce will involve vehicles and users inside these vehicles. The term "vehicle" is used broadly to include cars, buses, trucks, trains, ships, planes, and similar entities with sufficient computing and communications ability for supporting vehicular mobile commerce applications. Many features are available in vehicles today to facilitate vehicular m-commerce including short-range wireless networks such as in-car Bluetooth, digital entertainment systems, satellite-based navigation systems, and possibility wireless LAN and other wireless connectivity. Bluetooth connectivity currently exists in at least 30 car models sold in the United States and 15 more will have it soon [Phonecontent, 2004]. The advances in telematics, such as OnStar and other systems, offer access to live customer service, information, and vehicle tracking, and will

facilitate vehicular m-commerce. Many other advances such as airlines and cruise liners installing wireless LANs access points, connected to the rest of the world by using satellite networks, will also create the environment for vehicular mobile commerce.

Vehicular mobile commerce is not the same as the existing mobile commerce while being in a vehicle. For example, if a user conducts a mobile commerce transaction inside a vehicle without using any computing or communications power of the vehicle, then it is plain mobile commerce. However, when the computing and communications functions of a vehicle are employed for mobile commerce, then we consider it to be vehicular mobile commerce. A human does not have to be inside a vehicle for the vehicle to be involved in vehicular mobile commerce applications. For example, a parked car without necessarily having a human inside it could act as a wireless access point for nearby and interested users.

In many ways, vehicular commerce adds to (and does not replace) the existing mobile commerce by using the ever-increasing computing and communications power of current and emerging vehicles. The role of the vehicle could be as simple as being used whenever necessary to as complex as being fully part of wireless infrastructure. It can also interface to one or more mobile devices from users whenever needed. These capabilities allow the current and emerging wireless devices to be used in exactly the same way as today, but will allow forming ad hoc wireless networks among devices and vehicles and among vehicles and devices in the vehicles. From the users' point of view, it does not matter if the mobile commerce activities were conducted using pure (traditional) wireless networks, a combination of wireless networks involving one or more vehicular wireless networks, or pure vehicular wireless networks. Thus, vehicular mobile commerce can assist and expand the use of traditional mobile commerce activities. The differentiation may cease to exist in the future, as vehicular wireless networks become part of the overall diverse wireless infrastructure.

In addition to many current m-commerce applications, many new applications will become possible because of the increased computing and communications power available in many vehicles. Thus, vehicular mobile commerce can be considered as a near-future set of m-commerce activities where vehicles are involved actively.

Many technical, structural, and user issues must be addressed before this area of work becomes a practical reality. The major challenges include design of protocols, modeling the wireless channels, overcoming short-contact time, message routing, authentication and security, and support for message re-transmission before vehicles move out of range of one another. A possible scenario for inter-vehicular networking is shown in Sidebar 1.

In addition, before vehicular mobile commerce becomes a reality, the following will need to be accomplished:

1. Designing and implementing several possible applications,
2. Addressing limitations of vehicular environment (high-speed, limited attention of the driver, distractions),
3. Using the uniqueness of vehicular environment (satellite connectivity, wireless connectivity, location tracking system, routing information),
4. Defining future possible additions in car (sensors to measure different components, emergency notifications, ad hoc wireless LANs to create communication among nearby vehicles, ability to support and process vehicular credit), and
5. Determining how the emerging Intelligent Transportation Systems can facilitate vehicular m-commerce environment.

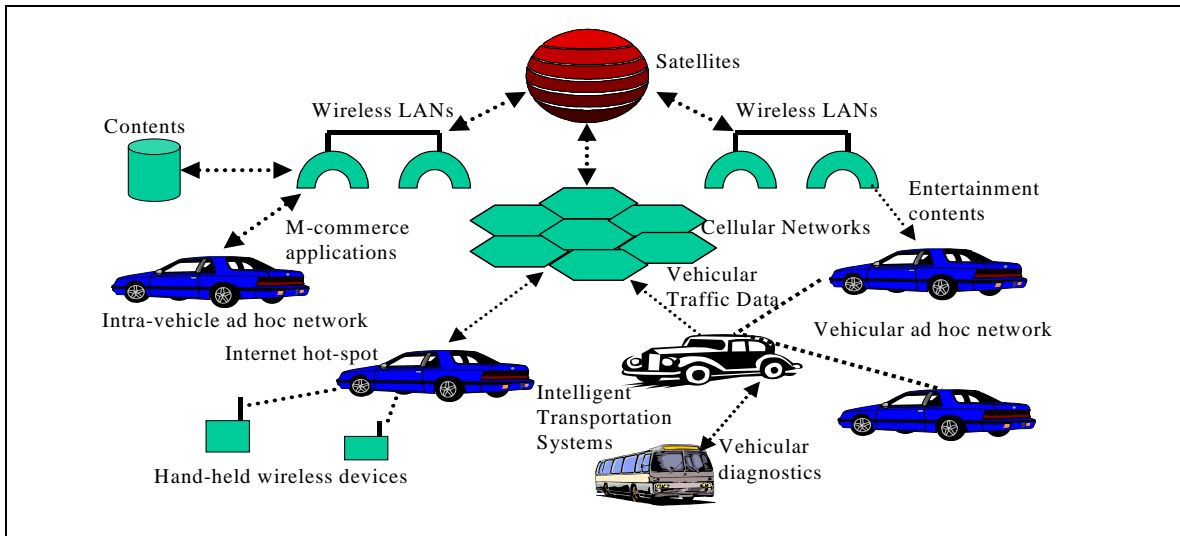This paper presents and discusses many of these challenges. More specifically, the contributions of this paper are:

Figure 1. A Scenario for Vehicular Mobile Commerce and Applications

SIDEBAR I. VEHICULAR MOBILE COMMERCE AND APPLICATIONS

Vehicles traveling at different speeds and a with a diverse set of computing and communications functionalities could exist in the emerging vehicular commerce environment. These vehicles will be supported by using multiple and heterogeneous wireless and mobile networks based on location, time and speed constraints. Some of the vehicles may be supported using existing infrastructure-oriented wireless networks such as cellular wireless networks, wireless LANs, and satellites, while other could form *ad hoc* wireless networks for communications without using fixed infrastructure. Many possible mobile applications can be envisioned including those related to m-commerce, intelligent transportation systems, and entertainment services.

1. identifying several vehicular mobile commerce applications including existing mobile commerce applications extended for vehicular environment and new suitable applications (section II),
2. presenting wireless and networking challenges and possible solutions in vehicular mobile commerce (Section III), and
3. deriving research problems related to vehicular mobile commerce (Section IV).

II. VEHICULAR M-COMMERCE APPLICATIONS

In this section we discuss vehicular mobile commerce applications, for both existing mobile commerce applications extended to vehicular environment and for new and suitable applications for vehicular environment. The existing mobile commerce applications include:

1. using vehicles as business tools,
2. mobile advertising and
3. location-based services.

New and specific vehicular applications include

1. using vehicles for providing wireless Internet services,
2. diagnostic and safety messaging,
3. highway and traffic management, and
4. broadcasting of contents and entertainment services.

VEHICLES AS INTERNET HOT-SPOTS. Vehicles can be used as hot-spots for accessing the Internet wirelessly. To do so will require a base station (of a wireless LAN) in a vehicle. The base station could be connected to a satellite or another base station. This arrangement will allow wireless hot-spot connectivity for in-vehicle passengers and even the users outside the vehicle. The technical challenges and social issues are quite different for moving and stationary vehicles. For example, access quality, bandwidth and signal variation would be much worse when accessing a base station from a moving vehicle than from a stationary vehicle. Some owners may be uncomfortable if someone wants to access their vehicular base station when their vehicles are parked and they are not around. In addition, other users may drain the battery power for parked or stationary vehicles. Security issues must be resolved if hackers could introduce viruses affecting later vehicular operation.

BROADCASTING OF CONTENTS. Vehicles can be used to offer short-range broadcast of entertainment contents, games, and other information to nearby vehicles using the ISM band, which does not require a license for use, or even licensed bands. Since the contact time among vehicles may be short, a wider bandwidth or compression (or both) may be required. Depending on the contents, security and privacy concerns must also be addressed. The payment for the contents broadcast could be made in vehicular credit, which can be used to pay for other vehicular mobile commerce applications (including tolls and diagnostic services).

INTELLIGENT TRANSPORTATION SYSTEMS (ITS) APPLICATIONS. Vehicles can be part of an ITS where, by using wireless networks and vehicular credits, many applications such as paying tolls, locating parking, broadcasting the vehicle's current location in an emergency, uploading and downloading of information, and providing roadside assistance, can be supported. Routing information can be bought wirelessly from other vehicles using vehicular credits. Some incentives/credit can be awarded for good drivers per trip basis, such as a few vehicular credits for driving within the speed limit. All highways can be made toll highways, where drivers can wirelessly pay by using vehicular credits and can also receive some credit for lost time if stuck in traffic jams (poor quality of service for wireless highways).

TOOLS FOR HIGHWAY MANAGEMENT AND IMPROVEMENT. Vehicles with wireless connectivity can be used to collect data on driving habits, highway conditions and traffic speeds, pollution levels, and many other environmental conditions. This information can be transmitted in real-time using wireless networks and can be used for both managing highways as well as designing future "user-centric" and intelligent transportation systems. Trials are being undertaken at the Georgia Institute of Technology on wirelessly monitoring for some of this information. Five hundred "volunteer" vehicles were fitted with $700 GPS systems in Atlanta [IEEE Spectrum, 2004]. The data collected from these vehicles will allow improved prediction of current and future traffic and better planning for future highways.

DIAGNOSTIC TOOLS. Higher-end vehicles with sophisticated computing and communications capabilities can act as diagnostic tools for other stationary and moving vehicles by exchanging information wirelessly. The use of these tools could lead to making the needed or scheduled repair(s) for many vehicles in time and keeping many other people on roads trouble-free.

SAFETY MESSAGING. Vehicles can also be used to send a variety of safety messages to other vehicles. Problems related to the current functioning of a vehicle (such as brake failure or other emergencies) or passengers inside can be sent to other vehicles for their safety and/or for routing to emergency management systems. There are many challenges including authentication, performance, and wireless channel characteristics and its effect on message transmission.

VEHICLES AS ADVERTISING TOOLS. Location and user-sensitive advertising could benefit from inter-vehicle communications. The messages can be sent to all vehicles that are currently in a certain area (identified by advertisers or even by users) or to certain vehicles in all locations. In this application, both context-awareness and driver situation must be considered. For example, if someone is under stress, he/she is not likely to be influenced by any advertisement, no matter

how personalized and interesting. Driver's distraction must also be a major factor in limiting the number and contents in an advertisement.

LOCATION-BASED SERVICES. Applications could use location information to provide specialized contents to vehicles and users. The contents could include information on desired restaurants, devices, users, and products. A user could be interested in knowing the availability and waiting time at one or more of the restaurants close to his current location (pull). Another user would like to be alerted when one of her friends is in the same general area (push). The location information of all fixed entities can be kept in the separate database for each area, while location tracking of mobile and portable entities could be performed on-demand.

BUSINESS TOOLS. Vehicles can be used as business tools for downloading information proactively, as a negotiating tool for mobile business, for locating products and services, and as part of mobile auctions. Such applications could reduce the frustration of people stuck in traffic jams for hours as some useful activities could be conducted.

MEDICAL APPLICATIONS. Physicians and healthcare could provide telemedicine and offer consulting services while stuck in traffic jam. Imagine a physician coming home and telling her husband that, although stuck in traffic jam, she and her vehicle earned $300.

III. WIRELESS CHALLENGES IN VEHICULAR MOBILE COMMERCE

This section discusses some of the technical problems in using vehicle computing and communications abilities. The use of computing and communications facilities for other purposes should not interfere or negatively affect the performance or safety of vehicles. Having said this, the inter-vehicle communications can lead to interference due to use of ISM (Industrial Scientific and Medical) bands, drivers distraction, accidents, and liability. Many of the same driver distraction problems in cell phones and wireless hand-held devices also apply here. In some vehicular mobile commerce applications, the battery power must be left on while the car is turned off and parked. Other problems are un-reliable inter-vehicle communications, potential for network traffic congestion (use of priority-based transmission), and unexpected physical obstacles between and among vehicles (for example, some non-communicating vehicle passing among these vehicles, physical structures on highways, and construction equipment).

THE QUALITY OF INTER-VEHICULAR WIRELESS CHANNEL. In general, wireless channels experience attenuation, slow and fast fading, multi-path interference and other problems. These factors are both time and location dependent, resulting in channel quality that could vary significantly over a short distance or time. In the vehicular environment, the quality of the wireless channel among vehicles could be negatively affected by the motion of vehicles and unexpected obstacles between and among vehicles, thus resulting in potentially un-reliable inter vehicle communications. In addition, vehicles could become a source of scattering and unexpected reflections. Therefore, the effect of multi-path interference, attenuation, and fading must be considered carefully. The communications among vehicles moving in one direction at similar speeds is likely to be quite different from the communications between two vehicles crossing each others path in opposite directions at significant relative speed[1].

SHORT CONTACT TIME BETWEEN VEHICLES. A major issue in inter-vehicular communications is the short-term contact time between vehicles, especially for those ones traveling at high speeds (Figure 2). Short contact time leads to restraints on the design of networking protocols, as some of the richer contents will require very large bandwidths (or spectrum) because the available transmission time is significantly lower than what is available in most other wireless networks. The limited time will also reduces the possibility of re-transmitting signals among vehicles because they may no longer be in each other's signal coverage. If re-

[1] For example, if two cars are each traveling at 50mph in opposite directions on the same road, their relative speed is 100mph

transmission is required, then a much longer path involving multiple hops may have to discovered and used for re-transmission. Effectively, re-transmissions are particularly expensive in the vehicular environment. Techniques such as forward error control, which allows receiver to overcome transmission errors at the expense of required redundancy in the original packet, may need to be considered. In some cases, prediction can be used to prepare contents before certain vehicles come in contact.
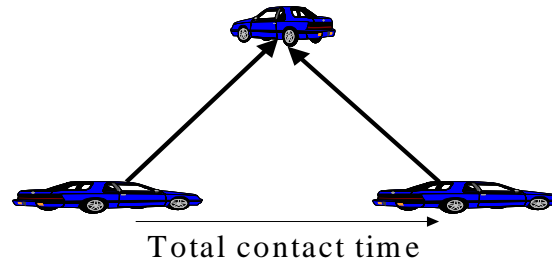

Total contact time

Figure 2. Short Contact Time in Inter-Vehicular Communications

DIFFICULTY IN OBTAINING WIDER SPECTRUM. One way to address short contact time between vehicles is to allow a wider spectrum for inter-vehicle communications. The use of existing ISM bands is becoming quite difficult due to crowding of systems, such as multiple wireless LANs, in these bands. A dedicated band can be allocated for inter-vehicle communications. One possibility is to use parts of Dedicated Short Range Communications (DSRC) band allocated for Intelligent Transportation Systems (ITS) and vehicular applications. The DSRC band is 75 MHz wide and exists in 5.9 GHz. One major issue here would be the use of radio vs. microwave frequencies. Radio may offer increased range at same power due to lower frequencies, while microwave will require point-to-point (line of sight) communications among vehicles.

DIFFICULTY IN USING INFRASTRUCTURE-BASED WIRELESS NETWORKS. Although some of the infrastructure-oriented wireless networks can be used to support inter vehicle communications at low (0-40 miles) and medium vehicular speeds (40-100 miles), many smaller cells of infrastructure-oriented networks will be overwhelmed (significant number of handoffs and processing) with fast moving vehicles (100+ miles). A grid of wireless LANs could be used but rapidly moving vehicles may not be easily supported due to association and disassociation processes required when moving from one wireless LAN to another. Due to the motion of vehicles and required wireless coverage, infrastructure-based wireless networks are likely to be unsuitable for inter-vehicle communications. Also, the use of satellites for inter-vehicular communications will be difficult due to large bandwidth requirement and need for two-way communications in real-time. Due to the motion of vehicles, keeping track of exact locations will be difficult for many infrastructure-oriented wireless networks. Formation of mesh-network among users in four different vehicles on a major highway has been tested, where link distances of several hundred feet were achieved among vehicles moving in the same direction (Verma and Beckman, 2003).

SUITABILITY AND FORMATION OF AD HOC WIRELESS NETWORKS AMONG VEHICLES. In some cases, it may be desirable to create an ad hoc network among nearby vehicles. However, forming vehicular ad hoc networks is a difficult task due to very small contact-time, quality of wireless channel at high speeds and role of obstacles. The formation of ad hoc wireless networks will also be influenced by the number of vehicles in close-by locations, the amount of transmission power generated, and the willingness of vehicles to act as routers for supporting communications among other vehicles. It may be easier to form ad hoc network among vehicles going in one direction at closer speeds. Then communications among multiple ad hoc networks can also be achieved when these networks cross one another.

PROCESSING AND MEMBERSHIP OVERHEAD. Rapidly joining and leaving members of ad hoc wireless networks create processing and membership overhead. Depending on the number of vehicles, network size, and membership changes, the overhead could become significant. The overhead can be equally divided among vehicles involved in ad hoc networks, or based on the processing abilities of different vehicles.

THE NUMBER OF VEHICLES NEEDED. When using vehicles as routers in ad hoc wireless network, there is a challenge of how many vehicles are needed to create a reliable inter-vehicular wireless network. Even if a reliable inter-vehicular ad hoc network can be built, there are still issues of meaningful services that can be provided to the members of vehicular wireless network. It may be possible to keep an ad hoc network "alive" when a certain number of users/services exists in the network. Once the number of members drops below a certain threshold, vehicles can be given choice of whether to maintain inter-vehicular communication at a low enrichment level or to dissolve the ad hoc network.

DESIGN TECHNIQUES. Network design techniques that can be used to support inter-vehicular wireless networks include:

1. Formation of ad hoc wireless networks among vehicles going in one direction, or use of current speed in deciding on a common network
2. Use of speed, location or time-out based methods for deciding on changes in mobile routers
3. Support for both expansion and compaction of vehicular wireless networks by supporting merging/breaking up of multiple ad hoc networks
4. Use of additional wireless networks to enhance both connectivity for and usefulness of vehicular mobile commerce

Certainly, the inter-vehicular networks should be ubiquitous and available anywhere any time to millions of users in and close to moving and parked vehicles. Due to the non-centralized nature of vehicular networks, these will be autonomous (self configuring, self maintaining). The proposed vehicular networks should also be evolvable and scalable and will support changes in number of users without sacrificing performance. More work is necessary in designing of actual wireless networking protocols for vehicular environment by considering short-contact time and channel quality among vehicles. Then modeling and simulation of proposed networking protocols should also be considered. The designed protocol could also support

- Reliable communications among vehicles moving at different speeds (by adding fault-tolerance at multiple layers)
- Resource registration and discovery (such as finding information on a vehicle with certain entertainment contents)
- Dependable quality of service

Reliable communications can not use "simple" retransmission as the contact time between vehicles is very small (especially fast moving vehicles), but by "on-the-fly" creation of ad hoc wireless networks, the information can be sent to a destination vehicle using multiple hops.

Ways to facilitate inter-vehicle communications include:

- Perform resource discovery
- Locate the desired vehicle
- Build an ad hoc network involving the desired and many other vehicles
- Communicate with the desired vehicle

RESOURCE DISCOVERY. Resource discovery involves capability and content registration, capability update, and vehicle search (both local and non-local). The routing protocols must be simple due to the little time for processing available and the unreliable channel between fast moving vehicles. The routing efficiency can be sacrificed to allow quick and simple routing. There

will be multiple ad hoc networks operating at any time. Each ad hoc network can have a group leader (who can be chosen as the one moving at the average of all vehicles speed in a certain direction). The number of vehicles needed in an ad hoc network to sustain communications and the physical size of ad hoc network must also be determined. The group leaders may also have other ways (via cellular or satellites) to communicate with other group leaders of ad hoc vehicular networks. The protocols should also support communications among ad hoc networks (Figure 3) that are moving away from one another (expanding universe of ad hoc networks) as well as the ones that are moving into each another (collapsing universe of *ad hoc* networks).
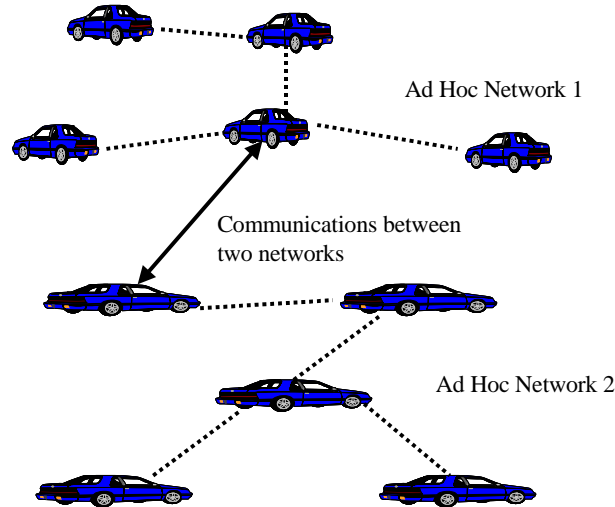
Figure 3. The Communications between Ad Hoc Networks

IV. RESEARCH PROBLEMS IN VEHICULAR M-COMMERCE

Major challenges that must be overcome for vehicular m-commerce include

1. identifying suitable applications and services,
2. addressing security and privacy concerns,
3. providing mobile payments,
4. using the capabilities of the underlying wireless infrastructure and
5. implementing business models.

1. Identifying suitable applications and services: The vehicular environment, in terms of bandwidth, channel characteristics, and spectrum availability, is quite different from the regular wireless environment. These conditions combined with increased fading (fluctuation in signal power) and potentially short-contact time among vehicles will offer many additional restrictions that did not exist before. An increased level of interference in the spectrum available for inter-vehicular communications could also limit the speed of transmission.

Two sets of challenges need to be resolved in services and applications:

1. what is desirable for users and
2. how to deliver services to the users.

The types of services and applications must be identified (e.g., entertainment contents, games, and informational items, suitable for vehicular environment). The transmission range, speed of vehicles, and other factors can be used in deciding what applications and services are currently

available for vehicular users. Ways to deliver these applications to users in vehicles could include complete download from another vehicle (short contents) or partial downloads from multiple vehicles. Also, because re-transmission from the same vehicles is difficult due to mobility and short contact time, additional sources of information/contents must be identified. Related issues include digital rights management and paying for contents and services. All these issues must be addressed before vehicular mobile commerce becomes a reality. It is possible that future highways and roads may reserve a lane for vehicular contents and services as opposed to providing comprehensive coverage to all lanes. As opposed to HOV lanes, these lanes may allow vehicles to move slowly, thus making it easier to download or manage contents.

2. Addressing security and privacy challenges: In the vehicular commerce environment, some applications with financial value may require strong security, while applications such as traffic routing or highway safety applications may not need such support. For some users, location information may be sensitive and thus must be protected even if the application does not require or use encryption. The security and privacy issues take a new dimension in vehicular mobile commerce because inter-vehicle communications is both subject to hackers-on-the-road and the law enforcement. Even existing wireless networks have struggled with providing strong end-to-end security and these challenges become even more difficult in vehicular environment. Fortunately, the processing power of many vehicles could become substantial, thus allowing the use of strong encryption to provide both security and privacy. As the contact time among vehicles may be small, there may not be any time to negotiate or select one of several different encryption/security protocols. Thus, it may be preferable to use a common and simple scheme that will be used universally in the vehicular environment. Also due to the lack of a central server, two way or multi-way authentication will have to be deployed to allow all sides to trust one-another. Some of the vehicular mobile commerce applications can use anonymous credentials where both sides do not have to know each other even if the messages are encrypted. Certainly, a significant amount of work is needed to design and implement secure communications among vehicles and multi-way authorization without adding significant overhead in the limited bandwidth vehicular environment.

3. Support for mobile payments: In the vehicular environment, many mobile commerce applications may require making payment for services. Although it is possible to use traditional payment methods, it may be easier to implement a vehicular credit system for payments. For example, a car collected certain number of credits for providing Internet access or routing information to other vehicles. Later on the driver can use the credits for toll on a major highway. A more extreme case is to use vehicular money, a kind of virtual cash, which can be transmitted among vehicles and can also be used for non-vehicular commerce purposes. The support for payments among vehicles will be a difficult challenge especially when combined with security and privacy problems (discussed above). For security purposes, this concept may be short-lived because hackers may want to attack vehicles with considerable amount of vehicular credits. It is also possible that multiple payment providers may be involved in creating, offering, managing, and using vehicular credits and may even allow conversions back to real money. The situation can be extrapolated to involve one or more payment aggregators and national/international vehicular payment providers. On an extreme thought, payments could even lead to a vehicular economy!

4. Design and use of wireless infrastructure: The wireless infrastructure will play a major role in realizing vehicular mobile commerce. Problems such as short contact time, unsuitability of infrastructure-oriented wireless networks, formation of ad hoc wireless networks, lack of wider spectrum, and varying quality of channels need to be resolved. These issues were introduced in Section III. In this section we discuss the specific networking requirements of vehicular mobile commerce. These requirements include

- the need to locate vehicles for communications,
- management of group applications among multiple vehicles and
- support for mobile commerce transactions.

One of the requirements of vehicular m-commerce is the ability to locate another vehicle with the information you need. This information could be requested or even a small payment can be made to another vehicle by using a vehicular credit system. One or more types of location management schemes can be used for these purposes. Both the accuracy and response time of location tracking is important as is minimal overhead among vehicles. Some vehicular m-commerce applications such as interactive mobile games would require continued group connectivity, which will be difficult to achieve as fast moving vehicles may alter the group memberships rapidly. The groups can be formed among vehicles moving in the same general direction at similar speeds to allow longer contact time. In vehicular wireless networks, transaction should be completed before a vehicle moves out of range. One solution is to divide a transaction into multiple steps where one or more steps can be executed by an individual vehicle. It may also be possible to designate some vehicles as transaction support vehicles because they contain considerable processing and transaction processing abilities.

5. Suitable business models: A major issue in vehicular mobile commerce involves the additional cost of adding functions and/or making modifications in the vehicles. Some users might be interested in paying for these changes if sophisticated entertainment contents and services can be used. Options for pricing vehicular m-commerce services are flat rate pricing, per transaction pricing, content-based pricing, pricing based on number of hops used, and subscriptions. The pricing scheme must also be clear to every user.

If multiple providers are involved, the rules for revenue division among them need to be established. The number of users and services, and thus the total revenue, could fluctuate significantly. More work is needed in estimating cost and return on investment in vehicular mobile commerce environment including the potential services, pricing, and estimates of the number of users.

V. CONCLUSIONS

With increasing number of vehicles with computing and communications capabilities, vehicular mobile commerce could become an important part of the emerging m-commerce environment. Vehicular mobile commerce includes both existing mobile commerce applications extended to the vehicular environment and new applications suitable for the vehicular environment. However, major challenges before vehicular commerce becomes a reality relate to the design of network and communications protocols, message routing in vehicular ad hoc networks, authentication and security, and message transmission before vehicles move out of range. These challenges are significant due to the time- and location- dependent quality of wireless channels, potentially short-contact time among vehicles, and power management issues. Additional challenges include how to reduce drivers' distractions, how to maintain the safety and primary purpose of vehicles, and the technical enhancements required in vehicles for supporting vehicular mobile commerce. In this paper, many of these challenges are identified, discussed and possible solutions are offered. Also, research problems are identified, including security and privacy in vehicular environment, design of suitable applications, use of ad hoc wireless networks, support for mobile payments, and necessity of business models. These challenges must be addressed by the research and development community, network designers, wireless service providers, content developers, wireless spectrum regulators, vehicle designers and manufacturers, and, certainly users of vehicular applications.

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REFERENCES

EDITOR'S NOTE: The following reference list contains the address of World Wide Web pages. Readers who have the ability to access the Web directly from their computer or are

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IEEE Spectrurm (2004) "Network of Traffic Spies Built into Cars in Atlanta", http://www.spectrum.ieee.org/WEBONLY/wonews/apr04/0404 cars. html

Phonecontent (2004) Promise of Bluetooth in Cars Kept at Last http://www.phonecontent.com/bm/news/gnews/351.shtml

Shih, G. and S. Shim (2002), "A Service Management Framework for M-commerce Applications", ACM/Kluwer Journal on Mobile Networks and Applications (MONET), (7)3, June, pp. 199-212.

Varshney, U., R. Vetter, and R. Kalakota, (2000) "M-commerce: A New Frontier", *IEEE Computer*, October, pp. 32-38.

Varshney, U., and R. Vetter (2002) "Framework, Applications, and Networking Support for M-commerce", *ACM/Kluwer Journal on Mobile Networks and Applications (MONET)*, (7)3, June, pp. 185-198.

Verma, S. and P. Beckman (2003) "Use of Mobile Mesh Networks for Inter-Vehicular Communication", *Proceedings of IEEE Vehicular Technology Conference*, October 4-9, Orlando, FL.

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