Collaboration Proposal for

Research, Prototype and Commercialization for Wireless Access in Vehicular Environments (WAVE) Systems

Objectives

We are seeking collaborators and supports for joint development leading to commercialization of WAVE systems for intelligent transportation system (ITS), vehicle infrastructure integration (VII) and Internet access

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Technical Approach

1. PROPOSED TECHNICAL APPROACH

1.1. SUMMARY

Wireless Access in Vehicular Environments (WAVE) is the next generation dedicated short-range communications (DSRC) technology, which provides high-speed vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) data transmission and has major applications in intelligent transportation systems (ITS), vehicle safety services and Internet access. Operating at 5.850-5.925GHz, WAVE systems adopt orthogonal frequency-division multiplexing (OFDM) and achieve data rates of 6-27Mbs/s. In WAVE systems, a roadside unit (RSU) can cover a range of up to 1000 feet. WAVE systems are based on the IEEE 802.11p protocol, which is currently under development.

There is increasing interest in the prototype and commercialization of WAVE systems from both automotive suppliers and government agencies concerned with improving the nation's infrastructure. A variation of the IEEE 802.11 wireless local area networks (wireless LAN) protocols was selected in order to speed implementation and reduce cost. Popularly termed Wi-Fi, the IEEE 802.11 systems are readily available and their chipsets have been driven down the cost curve through large-scale manufacturing. The main issues being addressed by our project team is that the 802.11 protocols were originally designed for indoor environments instead of high mobility applications. When applied to a vehicular environment, the high mobility of vehicles makes receiving signals undergo Doppler shifts, which could seriously degrade the channel capacity. We have developed proprietary algorithms that can correct for time-varying Doppler shifts thereby allowing for full non-degraded channel utilization [14]. Similarly, due to the high mobility of a vehicular environment, the MAC protocol in the 802.11 standards cannot perform equally as that in an indoor environment. We will develop a novel MAC protocol on the basis of 802.11 but hold the following advantages: i) cross-layer optimization with the new physical layer algorithm to combat fast and doubly selective fading; and ii) distributed scheduling for message exchanging in a vehicular network.

The objective of this project is to implement the prototype and further commercialize the WAVE systems invented by us. The project team will first characterize mobile channels, upon which the proprietary baseband algorithms will be developed, validated and implemented. A vehicular network consisting of four onboard units (OBU) and two RSUs will be setup to demonstrate both high-speed data transformation and safety message broadcasting.

Commercialization options include licensing the algorithms for incorporation into 802.11p chipsets to a startup company or an existing chip manufacturer. A consultant experienced in the semi-conductor market will be hired to perform a high level evaluation of the commercialization options.

1.2. WHY COMMERCIALIZE THIS TECHNOLOGY?

The traffic status in the United States is currently in a severe situation. There are about 43,000 deaths on the highways each year, half of which occurred when vehicles left the road and passed through intersections. In a lot of metropolitans, one out of every three vehicles moves in a velocity that is half of its regular speed. Congestion costs 6-billion vehicle-hours nationwide per year. This painstaking situation necessitates the adoption of ITS supported by the DOT for crash prevention and congestion relief. The WAVE system is a major ITS initiative that can enhance the transportation environment in the aspects of safety, management and data services in a fast speed and with less cost when compared to other strategies, such as expensive road infrastructure expansion. In the United States, DOT plans to equip every vehicle with a WAVE system and install a large number of RSUs in the main roads and highways to make the WAVE services available. Through WAVE systems, drivers will be aware of the security and warning messages instantaneously when it is not safe to enter an intersection or the vehicle is close to running off the road. Working as probes, vehicles report timely traffic and road condition information to transportation agencies, which is shared by a large community.

1.3. WHAT IS THE MARKET?

The OnStar system developed and operated by General Motors (GM) is the most successful vehicle information system in United States with 2.5 million customers. However, as the OnStar system is based on low bandwidth cellular channels, it is limited in its ability to provide a comprehensive suite of services based on ITS. The type of functionality envisioned by the WAVE system will require an order of magnitude large communications capacity than is available today.

There are approximately 250M passenger cars currently in use in the U.S. and about 25M (10% of the total) are manufactured every year. In the market segment of U.S. light vehicle navigation systems, 2006 production was 3.4M units and revenues were $1.8B. The CAGR in units was 22.5%.[1] Therefore, the market for inter-vehicle navigation and information systems is clearly large and growing. The OEM market is still larger than the aftermarket segment but the aftermarket is expected to achieve almost equal size within five years.

The communication protocols that are being developed through this project will be incorporated as propriety algorithms in OEM and aftermarket equipment. The revenue model is typically through a license fee of some cents per unit of the millions of units sold.

1.4. WHAT IS THE COMPETITIVE ADVANTAGE?

As noted, the GM OnStar system is the most widely deployed vehicle information system to date. There are three noteworthy shortcomings for the OnStar system. The first is that it cannot collect and provide real-time local traffic condition information such as accidents, construction, congestion, severe weather related road hazards and AMBER alerts. Secondly, it adopts cellular communications systems and GPS systems. The shadows of the high buildings and hills lead to large path losses and serious fluctuations in the receiving signal. Finally, the OnStar system can only offer data rates up to 9.6Kb/s, which is mainly designed for voice services. Although higher data rates are available through the newer 3G infrastructure, there is still not enough data rate (384kbits/s) for supporting ITS based on V2V and V2I connectivity. In addition, the OnStar system is currently equipped in the GM vehicles and has not been widely accepted and integrated by the automobile community.

On the other hand, WAVE systems offer high-speed data rates of 6-27Mb/s, at least several hundred times faster than that of OnStar systems. WAVE systems have preferable coverage and signal quality since RSUs are mounted at the roadsides directly resulting in reduced power dissipation. WAVE systems are based on the IEEE 802.11p standard and will be a worldwide recognized and adopted standard. The 802.11p standard is scheduled for ratification in April, 2009.

In addition to the IEEE 802.11p standard work group (WG), there are IEEE 802.16e (WiMax) and IEEE 802.20 WGs, aiming at the mobile air interface for high-speed wireless access on the road. However, they are designed for different applications. The former uses 2-6GHz band designed for the pedestrians with a portable computer. The latter adopts a band below 3.5GHz applicable for the high-speed application over a large area. This application is specifically targeted at computer use on high-speed trains. The development of WiMax products is still in processing. WiMax suffers from the same limitations in high-speed mobile applications as current 802.11 protocols. These are the limitations that this project seeks to eliminate. The IEEE 802.20 is intended to address mobile applications but is in the very early stages of development and will not be on the market for some time. Wi-Fi products have a dominant market occupancy rate owing to their low cost and functionality. We conclude that the IEEE 802.11p based WAVE systems will likely hit the market well before other solutions.

1.5. WHAT IS THE TECHNOLOGY?

WAVE systems are an extension of the widely and successfully adopted IEEE 802.11 wireless LAN. The major change lies in the application scenario from indoor fixed environments to outdoor mobile environments, which brings forward considerable challenges for baseband signal processing and medium

[1] Analysis of the North American Automotive Navigation Systems Market, Frost and Sullivan, Aug 2007.

access control (MAC) protocols due to the fast fading channels, Doppler shift and time-varying network topology. The WAVE system development at University of Michigan is several steps ahead of its peers. There are similar prototypes, such as those from UCLA, Ohio State University and Georgia Tech, which are in more rudimentary stages of development.

A risk assessment of the technical portion of the WAVE prototype is listed below.

- Technical difficulties could come from the limitation of field programmable gate array (FPGA) scale and DSP operation capability. In case of this situation, we will tradeoff the performances with decreased coverage or increased RF radiation power level. (Medium)
- Our prototype could turn out to be too expensive for average consumers. In the commercialization step, we will redesign with less expensive components after algorithms are validated. (medium)
- If the ratified WAVE standard differs with our scheme or the DOT modifies the regulations and goals. The highly re-configurable of the prototype allows us to redesign the system quickly. (low)

2. Proposed Plan and Deliverables

2.1. Preliminary Results

WAVE channels were measured and explored by some researchers recently but none has successfully presented a generic channel model and carry out the performance study and optimum design for WAVE systems [1-6]. To this end, in 2006-2007, we established a WAVE testbed to explore the characteristics of 5.9GHz mobile channels, upon which some preliminary results of the performances of WAVE systems are presented [7-9,14]. Figure 1 shows the configuration of the WAVE testbed and the experimental scenarios. Based on the measured data, the capacity of the WAVE testbed for Trace I-III were shown in Fig. 2, which were the first preliminary results for WAVE systems from both academia and industry.

Fig.1 The diagram of a WAVE testbed and the measurement scenario (left). The pictures of an RSU (middle) and an OBU (right)

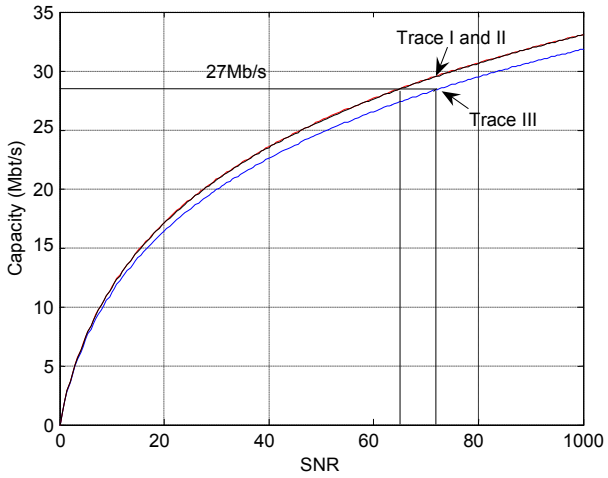

Fig. 2 The capacity of the WAVE testbed for Trace I-III

Seen from the figure, the SNRs needed to reach 27Mbs/s are round 18.1dB for Trace I and Trace III and 18.5db for Trace II. However, Shannon Capacity theorem tells us that a SNR of 7.4dB is enough to reach such a data rate where the bandwidth of the WAVE system is 10MHz. The difference of 10dB in the SNR is mainly caused by the fast-fading and time-varying mobile channels, which will be the main focus of the project.

2.2. Technical Path

The deliverables or milestones for WAVE prototype are as follows:

- Channel Measurement and Modeling (Mar. 2008-April 2008)
- Baseband Algorithm Development and Implementation (May 2008-June 2008)
- Road Experiments (July 2008-August 2008)

2.3. COMMERCIAL PATH

The commercialization steps for WAVE systems are listed below:

- Select and engage commercial partner.
- Demonstrate WAVE prototype and a vehicular network in live field test.
- Push adoption through standards forums and publications.

It is anticipated that the WAVE prototype and a vehicular networks will be completed in August, 2008. The business development consulting portion of the project will commence in September, 2008.

Proposal Team Experience

Dr. Weidong Xiang, Team leader, is currently an Assistant Professor of the ECE department of University of Michigan, Dearborn (UMD), will serve as the primary technical resource for this effort. His research interests include WAVE and vehicular networks, high-speed wireless LAN prototype integrating MIMO, OFDM, software radio, and smart antenna, ultra wide band (UWB), and real-time wireless control networks [10-13].

References

1. Acosta, G. and Ingram, M.A., "WAVE Motion-Related Channel Model Development," doc.: IEEE 802.11-06/1017r1, San Diego, CA, July 18, 2006.
2. I. Z. Kov´acs, P. C. F. Eggers, K. Olesen, and L. G. Patersen, "Investigations of outdoor-to-indoor mobile-to-mobile radio communication channels," *Proc. IEEE Veh. Tech. Conf.*, vol. 1, Vancouver, Canada, pp. 430–434, Sept. 2002.
3. J. Maurer, T. F¨ugen, and W. Wiesbeck, "Narrow-band measurement and analysis of the inter-vehicle transmission channel at 5.2 GHz," *Proc. IEEE Veh. Technol. Conf.*, vol. 3, pp. 1274–1278, Birmingham, AL, May 2002.
4. R. Wang and D. Cox, "Channel modeling for ad hoc mobile wireless networks," *Proc. IEEE Veh. Tech. Conf.*, vol. 1, pp. 21–25, Birmingham, AL, May 2002. A. S. Akki and F. Haber, "A statistical model of mobile-to-mobile land communications channel," *IEEE Trans. Vehicular Technology*, vol.35, no.1, pp.2-7, Feb. 1986
5. A. S. Akki, "Statistical properties of mobile-to-mobile land communication channels," *IEEE Trans. on Veh. Tech.*, vol. 43, pp. 826–831, Nov. 1994.
6. F. Vatalaro and A. Forcella, "Doppler spectrum in mobile-to-mobile communications in the presence of three-dimensional multipath scattering," in *IEEE Trans. on Veh. Tech.*, vol. 46, pp. 213–219, Feb. 1997.
7. Xiang, W., Richardson, P., and Guo, J., 2006, "*An invited paper:* Introduction and preliminary research on wireless access for vehicular environments technology," *MOBIQ,* 2006, pp.1-8, San Jose, California, July
8. Xiang, W., Richardson, P., and Guo, J., "An overview of wireless access for vehicular environments technology" submitted for publication on the *IEEE Transactions on Vehicle Technology*
9. Xiang, W., "Mobile channel modeling for wireless access in vehicular environments (WAVE) Systems," in preparation for submitting to the *IEEE Transaction on Communications.*
10. W. Xiang, T. Pratt and X. Wang, "A software radio testbed for two-transmitter two-receiver space-time coding OFDM wireless LAN," *IEEE Communication Magazine*, Vol. 42, pp.S20-S28, June 2004.
11. W. Xiang, D. Waters, T. Pratt, J. Barry and B. Walkenhorst, "Implementation and experimental results of a three transmitter three-receiver OFDM/BLAST testbed," *IEEE Communication Magazine*, Vol. 42, pp.88-95, December 2004
12. W. Xiang, P. Richardson, B. Walkenhorst, X. Wang and T. Pratt, "A high-speed four-transmitter four-receiver MIMO OFDM testbed: experiment results and analyses," *EURASIP Journal of Applied Signal Processing,* April, 2006
13. X. Wang and W. Xiang, "An OFDM-TDMA/SA MAC Protocol with QoS Constraints for Broadband Wireless LANs," ACM/Kluwer Journal of Wireless Networks, 2005.
14. **A patent, W. Xiang, "Enhanced Carrier Frequency Estimator," No. 60/995.491**