THE TRANSPORTER

A Newsletter From The Center For Integrated Transportation Systems Management

Low Profile Wireless Traffic Sensors for Enhanced Vehicle Feature Extraction

Summer 2010

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Low Profile Wireless Traffic Sensors for Enhanced Vehicle Feature Extraction

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According to a report from the National Highway Traffic Safety Administration (NHTSA), motor vehicle accidents account for more than 42,000 fatalities and more than 2.5 million injuries in 2006. Traffic congestion and associated delays such as air pollution and added fuel consumption poses major concerns to the public. Increasing the capacity of the roadways is expensive and in some areas where the land is scarce is not an option. Improving the efficiency of the current transportation system through the implementation of advanced technologies may alleviate the traffic congestion. Real time traffic surveillance is one of the most important components of such approach. The real time travel information has also application in advanced travel advisory systems. Emergency management agencies such as police, fire stations and ambulance dispatchers may also benefit from the real time traffic information in routing their vehicles through the transportation network to save lives. Safety and efficiency of the roads will be significantly enhanced by employing remote sensing and communication technologies that are capable of providing low cost, scalable, and distributed data acquisition of road conditions. Such ITS applications require distributed data acquisitions of different traffic metric's such as traffic speed, volume, and density. In such systems, automated traffic control is possible only through real time traffic information over distributed points of the transportation system. The existing measurement technologies are bending plates, pneumatic road tubes, piezoelectric sensors, inductive loops, infrared, microwave-doppler/radar, passive acoustic, and video image detection. The existing data acquisition technologies in transportation systems suffer from the following drawbacks:

- **Energy efficiency**: most of the existing technologies need to be constantly connected to the main power or battery. Connection to the main power limits deployment of the instrument and using batteries imposes regular maintenance cycles.
- **Cost**: majority of technologies require expensive instruments, which inhibits cost effectiveness of large scale and distributed measurements of the traffic.
- Installation and maintenance: most of existing technologies need high maintenance, calibration and installation costs. Installation costs may include wiring of the instruments to power sources, or the wiring required for communication.
- Scalability: majority of the existing technologies cannot be deployed in large scales due to certain limitations such as installation cost, wiring, availability of energy sources, etc.
- Low speed and offline measurement: lack of low cost real time communication between measurement points and the decision making centers inhibits fast and automated decision making.

The work in our project on wireless sensing technologies is motivated by the above issues, and it encompasses a cost-effective architecture for real time traffic measurement over distributed points of a transportation system. Energy is one of the main challenges of large scale deployment of sensors. A possible solution is to design sensors that harvest the needed energy from ambient light and vibration. We have developed a proof-concept prototype that shows feasibility of wireless sensors with the available energy through ambient environment, therefore no battery is needed in the wireless sensors. **Removing the need for batteries gives a significant deployment advantage to such sensors**. The sensors are capable of performing simple sensing operations such as traffic count measurement and vehicle magnetic signature extraction and by means of low range radio transmissions the devices form a wireless mesh network. Using ultra low power CMOS technologies makes the communication devices extremely energy efficient. Our proposed architecture has the following advantages over the existing methods:

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- **Energy efficiency**: the sensing and measurement architecture uses the minimal level of energy and uses the state-of-the-art low power sensing, amplification, and communication.
- **Broad range of measurement**: with a sensor networking architecture, a larreg class of traffic measurement can be performed. Examples of some measurements include: traffic volume and density, traffic speed, and classification. Furthermore, with a larger density, the sensors can provide an end-to-end communication medium.
- **Easy installation**: compared to existing systems, the system requires minimal installation effort. Per traffic measurement point, the system requires a roadside data collection point and burying a few wireless sensors under the road surface. The form factor of the sensors is comparable to the size of a US quarter coin. Therefore, lane closure time and disturbing the traffic for the installation is minimal and is not labor intensive.
- **Endurance**: since the sensors do not require batteries, calibration, or any other type of maintenance after installation, the system has a very long endurance. We expect the minimum life of each measurement system to be at least 20 years.
- **Low maintenance**: since the measurement devices do not need wiring or batteries, their maintenance demand is minimal.

Figure one: The wireless and batteryless traffic sensor based on GMR. The device is approximately 4x4 inches with thinness of 20mm.

Sensor design: a picture of the initial prototype of the traffic sensor is shown in figure one. This device has been successfully tested for vehicle detection and operation under energy availability constraints. Further optimization of the hardware and embedded software in the microcontroller of the device is in progress.

The work in this project is done under the support of CITSM during 2008-2010, where the project investigators developed a prototype of a low cost energy self sustained sensor network for traffic measurement. Under support of CITSM, the hardware for vehicle detection and low power communication was developed. The sensor was tested for detection of vehicles of different types and various speeds. A short review of the accomplished milestones is provided below.

Results from CITSM Funding

Different modules of the hardware, namely, energy harvester, super-capacitive energy storage, vehicle detection and communication modules

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Student SPOTLIGHT

Dr. Jason Chou

A recent Ph.D. graduate in Civil and Environmental Engineering, Dr. Jason Chou is no stranger to the University of Maryland. Prior to his May 2010 degree, Chou received his M.S. degree in transportation engineering from the University of Maryland in 2005. Dr. Chou was a police officer in the Criminal Investigation Bureau of Taiwan, where he received his B.S. degree from the Department of Traffic Science at the Central Police University in Taiwan in 1996.

During his doctoral studies, Dr. Chou worked on several important projects, including a benefit-cost analysis for the Highway Emergency Local Patrol (H.E.L.P) program in New York State, a High Occupancy Toll (HOT) lane study for the State of Maryland, and assessment of violation impacts associated with managed lanes on mobility and safety. His dissertation on understanding the impact of incidents and incident management programs on freeway mobility and safety was supervised by Dr. Elise Miller-Hooks.

Dr. Chou's dissertation work was sponsored by the I-95 Corridor Coalition, Maryland State Highway Administration and the Center for Integrated Transportation System Management (CITSM).

Dr. Chou has published several articles in the *ASCE Journal of Transportation Engineering, Transportation Research Record, Advances in Transportation Studies and the Journal of Transportation Research Forum.* After the completion of his doctoral dissertation, he will continue his research at the University of Maryland as a Post-Doctoral Researcher. He is looking forward to a career in industry and hopes to continue his efforts in improving safety and mobility of our world's transportation systems.

were integrated into the hardware of the sensor. A simple road-stud like casing was used to protect the electronic circuits of the sensors and the super-capacitive medium against moisture, humidity, vibration, and mechanical shock.

Different components of the architecture are:

- **Sensing element**: giant magneto-resistive (GMR) device, currently available (e.g. NVE GMR sensors). The device was used to detect presence of a vehicle.
- **Instrumentation**: the amplification, signal conditioning, and different signal processing tasks.
- **Wireless communication**: low power RF-CMOS 2.4 GHz radio transceiver using IEEE802.15.4 as the medium access control layer.
- **Energy harvesting and storage**: a combination of small solar cells and a 15F supercapacitor have been used for energy harvesting and storage.

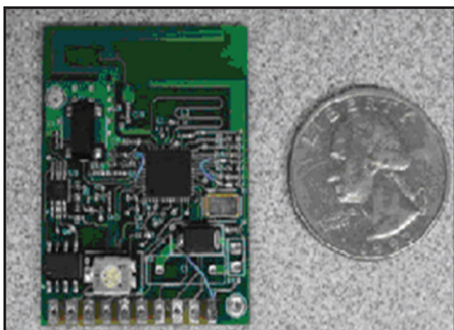


Figure two: The electronic circuit for the sensor fabricated in the current phase of the project.

A picture of the printed circuit board the developed traffic sensor is shown in figure 2.

The initial prototype was evaluated in several field experiments, where vehicles could drive over the device while the data of the traffic sensor was being transmitted wirelessly to coordinator in the proximity. In the current stage of evaluation, different types of vehicles including small passenger type sedan vehicles, medium size vehicles, SUVs, and trucks passed over the sensor. The prototype was able to detect vehicles and find an accurate count in all of the conducted experiments. In certain cases, the device has been able to detect small passing objects such as bikes.

For more information about this and other projects, visit CITSM online at www.citsm.umd.edu

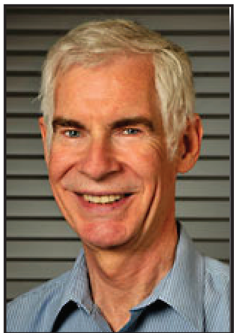
Staff BIOGRAPHY

Nikki Morris

Nikki Morris is currently the Research Coordinator for the Department of Civil and Environmental Engineering. Starting her career, she joined the department as a student worker while pursuing her undergraduate B.A. degree in Economics which she received from the University of Maryland in 2006. After earning her degree she joined the Department as an Account Clerk and later an Account Associate. In 2009, Nikki received her M.S. in Business Management concentrating in Contracts and Procurement from the University of Maryland University College in 2009. Originally from the Caribbean island of Trinidad & Tobago, Nikki left her native country to pursue her academic career.

The most enjoyable part of Nikki's work experience with the department has been the interaction with the students and faculty and learning about their ongoing research projects.

The Role of Information Technology in Improving Transit Systems



Speaker: Dr. Nigel Wilson is a professor in the Department of Civil and Environmental Engineering at the Massachusetts Institute of Technology. He is an internationally renowned expert in public transportation, transportation system design, and new transportation systems.

Seminar Abstract: Presented on April 9, this seminar discussed improving performance of computers and communications technologies are now starting to have a significant impact on the urban public transport industry. Automatic data collection systems including automatic vehicle location systems, automatic passenger counting systems, advanced passenger information systems and electronic fare payment and ticketing systems are becoming ubiquitous in large systems and are having an impact on the quality and availability of information for service and operations planning, controlling the service and measuring the resultant service quality delivered to passengers. While the impacts of these advances are already apparent in many systems, there is the potential for much deeper impact in the future. Technology continues to improve across the board and will offer opportunities to develop and apply more ambitious models to assist in many facets of the performance of public transport systems. Traditional models of the inter-relationships between service planning, operations control and passenger information, for example, have been based largely on the independence of these functions one from another. So the service plan has largely driven both the operations control and passenger information functions in most operating agencies, simplifying these aspects of the system. In the future, public transport systems may be able to take advantage of improved information and better communication between operating personnel, agency managers and passengers which will enable a rethinking of these inter-relationships. This seminar will examine current public transport industry practice in this arena and discuss the potential for future enhancement of these individual public transport agency functions as well as their inter-relationships.

Unexpected Events and Intelligent Transportation Systems

Speaker: Dr. Asad J. Khattak is Frank Batten endowed chair Professor of Civil Engineering at Old Dominion University, where he teaches and conducts research in transportation. Since Fall 2006, he has developed and directed ODU's Transportation Research Institute and educational programs. Dr. Khattak's research focuses on various types of innovations related to (a) intelligent transportation systems (their planning/operation and behavioral impacts), (b) transportation safety, and (c) sustainable transportation. Dr. Khattak has more than 16 years of research experience and 13 years of teaching experience in the transportation field, after completing his Ph.D in Civil Engineering from Northwestern University in 1991. He has authored 75 scholarly journal articles and 46 technical reports to research sponsors. As a principal- or co-investigator, he has successfully completed 32 sponsored research and educational projects totaling $4.5 million.

Dr. Khattak is Editor for the SCI-indexed Journal of Intelligent Transportation Systems. He is also Associate Editor of SCI-indexed International Journal of Sustainable Transportation. His service to professional organizations is further reflected in active participation in the Council of University Transportation Centers (CUTC) and as a member of the Committee on Intelligent Transportation Systems, Transportation Research Board, National Academies. He co-chairs the TRB Advanced Traveler Information Systems sub-committee.

Seminar Abstract: Presented on April 16, this presentation aimed to answer a few fundamental questions: How can cities operate transportation systems to better handle uncertainty created by unexpected events? What is the role of technological innovations, specifically, intelligent transportation systems? We will discuss the performance of transportation system under different situations, ranging from relatively normal weather conditions to mandatory evacuations under hurricane conditions. Further, the performance of the system will be examined when one relatively small traffic incident occurs to the occurrence of complex cascading (secondary) incidents. The role of traveler information systems and freeway service patrols in reducing incident-induced congestion will be examined. The presentation will go into the development of various tools that can 1) encourage the diffusion of innovative intelligent transportation systems strategies, and 2) predict incident durations, the chances of secondary incidents, and associated delays. These tools aid in planning and proactively identifying operational strategies to deal with unexpected events.

ABOUT CITSM

The Center for Integrated Transportation Systems Management (CITSM) at the University of Maryland College Park was established as a tier I university transportation center in 2008. The goal of the center is the Development of Advanced Technology, Improved Processes, and Enhanced Organizational Structures for the Integrated Management and Operation of Transportation Facilities and Corridors.

The CITSM focuses on the development of tools, processes and institutional relations that foster seamless management and operations of today's transportation infrastructure. Such seamless operations will be derived from concentrating on the overall mission of transportation agencies rather than the narrower objectives of individual institutions and facilities. Integrated operation of the transportation infrastructure as a system rather than a collection of individual resources, offers the potential for significant improvements in system efficiency as measured by reductions in travel time and congestion along with improvements in travel reliability. Integrated system operation will have a positive impact on the nation's economy, safety, air quality and energy consumption.

The theme of the Center is "Integrated Transportation Systems Management." The Center conducts research and provides education and technology transfer related to this theme. The objective of this research is to provide improved mobility and reduced congestion for travelers and shippers using the nation's transportation infrastructure. The emphasis of this work is on the integrated management of the transportation systems at all levels including planning, engineering, and operations. The University of Maryland has selected this theme because of its potential for significantly improving transportation system mobility and reliability, as demonstrated by numerous prior research projects conducted by its faculty and staff. A second, but equally important, objective of the Center is to educate the next generation of transportation engineers and planners with the tools needed for seamless management and operations of today's transportation infrastructure and the deep understanding of the benefits of such a fully integrated system.

CITSM

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