NTC Program Progress Performance Report (PPPR) Information Form

For P.I.'s Use

On a semi-annual basis the NTC sponsored P.I. must report Program Progress Performance Report (PPPR) using the format specified in this PPPR Information Form. The form must be submitted electronically to the corresponding NTC Associate Director by 9/15/2015.

Cover Period: 4/1/2015 – 9/30/2015

NTC Funded Project Information (Round/Year 2, 2014-2015)	
University Name	Arizona State University
Project Title	Distributed Traffic Monitoring and Prediction with Vehicle-to-Vehicle Communications
Principal Investigator	Yingyan Lou, Ph.D.
PI Contact Information	Yingyan.lou@asu.edu 480-965-6361

The form includes the following six parts:

- Part I – Accomplishments: What was done? What was learned?
- Part II – Products: What has the program produced?
- Part III – Participants & Collaborating Organizations: Who has been involved?
- Part IV – Impact: What is the impact of the program? How has it contributed to transportation education, research and technology transfer?
- Part V – Changes/Problems

Supplementary documents/materials can be attached to this form with the submission.

Part I – Accomplishments: What was done? What was learned?	
The information provided in this section allows the OST-R grants official to assess whether satisfactory progress has been made during the reporting period.	
Reporting Period	**4/1/2015 – 9/30/2015**
1. What are the major goals of the program?	The National UTC aims to promote strategic transportation policies, investment, and decisions that bring lasting and equitable economic benefits to the U.S. and its citizens. The Center is concerned with the integrated operations and planning of all modes serving the nation's passenger and freight transportation system, including the institutional issues associated with their management and investments. A balanced multi-modal approach will be used that considers freight and passenger travel mobility, reliability, and sustainability, as well as system operations during periods of both recurring and non-recurring incidents, including response to major emergencies. The modes in this theme include highway, transit, rail, and inter-modal interfaces including ports, terminals and airports. In particular, the center focuses on research, education, and technology transfer activities that can lead to (1) Freight efficiency for domestic shipping and for our international land, air, and sea ports; (2) Highway congestion mitigation with multi-modal strategies; and (3) Smart investments in intercity passenger travel facilities such as high speed rail. Major center activities are as following: • **Advanced & Applied Research Promoting Economic Competitiveness:** Our research activities are multimodal/intermodal and multidisciplinary in scope, with the aims of addressing nationally and regionally significant transportation issues pertinent to economic competitiveness and providing practice-ready solutions. • **Education, Workforce Development, Technology Transfer, & Diversity** The consortium is committed to providing high-quality transportation education and workforce development programs for a broad and diverse audience. Center's efforts will support the development of a critical transportation knowledge base and a transportation workforce that is prepared to design, deploy, operate, and maintain the complex transportation systems of the future.

2. What was accomplished under these goals?	***<u>Goal 1:</u> Advanced & Applied Research Promoting Economic Competitiveness*** The overarching goal of this research is congestion mitigation during extreme events (such as major disasters or special events), a subject that directly supports the first research focus area (congestion mitigation) of the National Transportation Center (NTC) @ Maryland. The objective of this project is to develop innovative distributed traffic monitoring protocols as well as localized and area-wide traffic estimation algorithms, sustained by vehicle-to-vehicle (V2V) communications alone, to support coordinated transportation operations. **Scheduled Activities for This Period** 1. Task 1: Distributed Traffic Monitoring and Localized Data Aggregation • Task 1.1: Literature review • Task 1.2: Develop distributed traffic monitoring protocols • Task 1.3: Investigate potential metrics to identify micro-discontinuity in traffic stream • Task 1.4: Implement proposed approaches in a simulation environment • Task 1.5: Validate and evaluate proposed approach via simulation 2. Task 2.1: Literature Review for Localized and Area-wide Traffic Sate Estimation and Prediction 3. Task 3: Report Writing **Work Performed in This Period** ***Task 1: Distributed Traffic Monitoring and Localized Data Aggregation*** <u>All five (5) subtasks for Task 1 were successfully completed</u> in this reporting period. An innovative framework for distributed traffic monitoring and information aggregation using vehicle-to-vehicle (V2V) communications alone was developed. We envision the proposed framework as the foundation to an alternative or supplemental traffic operation and management system particularly helpful under abnormal traffic conditions caused by unforeseen disasters and special events. Each equipped vehicle, through the distributed protocols developed, keeps track of the average traffic density and speed within a certain range, flags itself as micro-discontinuity in traffic if appropriate, and cross-checks its flag status with its immediate up- and down-stream vehicles. The micro-discontinuity flags define vehicle groups with similar traffic states, for initiating and terminating traffic

	information aggregation. The framework is validated using a microscopic traffic simulation platform VISSIM and its built-in component object model. The impact of market penetration rate (MPR) is also investigated with a new methodology for performance evaluation under multiple traffic scenarios. Our simulation results show that the average coverage ratio linearly increases with MPR. A decreasing relationship is also observed between the average relative error in either density or speed and MPR. Given a MPR, free flow speed and traffic demand level both affect the performance of the proposed framework. The patterns are further analyzed and summarized. ***Task 2: Localized and Area-wide Traffic State Estimation and Prediction*** Task 2.1: Literature Review: The team has started the literature review for Task 2 Localized and Area-wide Traffic Sate Estimation and Prediction Descriptive. A comprehensive list of relevant past research has been complied and studied. The team is in the process of summarizing the findings from this literature review. ***Task 3 Report Writing*** Draft report: A technical paper has been produced during this reporting period, which will become the basis of the first part of the final report. ***Goal 2: Education, Workforce Development, Technology Transfer, & Diversity*** This project has supported one PhD student, Peiheng Li, at ASU. Mr. Li will graduate in December 2016. Additionally, this research topic helped Dr. Lou recruit a new PhD student, Joshua Frisby, to pursue his research in the ITS area. Mr. Frisby earned his Master's degree in Computer Science in August 2015. This supports the diversity goal of the center.
3. How have the results been disseminated?	• A presentation was made at the 2015 ITE/IMSA conference in Phoenix, AZ in February 2015 • An abstract was submitted to the 14th WCTR in March 2015 • A presentation was made at the 64th Roads and Streets Conference in Mesa, AZ in April 2015 • An invited presentation was made at the 2015 CICTP International Conference in Beijing, China in July 2015 • A full paper was submitted to 2016 TRB Annual Meeting in August 2015
4. What do you plan to do during the next reporting period to accomplish the goals?	**Scheduled Activities for This Period** 1. Task 2: Localized and Area-wide Traffic State Estimation and Prediction

(10/1/2014 – 3/10/2015)	• Task 2.1: Literature review • Task 2.2: Develop localized cooperative platoon evolution estimation algorithm • Task 2.3: Develop area-wide traffic state estimation / prediction algorithm • Task 2.4: Validate and evaluate proposed approach via simulation 2. Task 3: Report writing **Relation to the Goals** ***Advanced & Applied Research Promoting Economic Competitiveness:*** The overarching goal of this research is congestion mitigation during extreme events (such as major disasters or special events), a subject that directly supports the first research focus area (congestion mitigation) of the National Transportation Center (NTC) @ Maryland. Traffic congestion adversely affects the economy due to time wasted, additional fuel consumption, and opportunity cost. While the frequency is not as high as recurrent congestion, the magnitude of congestion during extreme events is too significant to ignore. Reducing traffic congestion during extreme events promotes economic competitiveness. The proposed vision also aligns well with Department of Transportation's Intelligent Strategic Research Plan[1], and is a likely future scenario made possible by advanced communication technologies. The proposed approaches could also open up new possibilities for a variety of transportation applications such as real-time traffic-responsive route guiding system and instant user feedback platform for dynamic value-added road pricing systems. It could enable a new paradigm of a safer, more efficient and cost-effective transportation infrastructure. ***Education, Workforce Development, Technology Transfer, & Diversity*** The PI plans to continually support and involve both graduate and undergraduate students in this project, supporting the education and workforce development goals. The PIs plan to write one refereed journal paper on the proposed study. Target journals include Transportation Research Part C: Emerging Technologies. The results will also be presented at

[1] Department of Transportation (2010) *Transforming Transportation through Connectivity: ITS Strategic Research Plan*, 20102014. http://www.its.dot.gov/strategic_plan2010_2014/index.htm

	national venues such as Transportation Research Board annual meeting. Several follow-up studies are planned, such as transportation network models and tools to support optimal research allocation and coordinated operation through V2V alone or with limited existing infrastructure. The PI plans to seek external support for the follow-up studies from National Science Foundation and Federal Highway Administration Exploratory Advanced Research programs.

Part II – Products: What has the program produced?	
Publications are the characteristic product of research projects funded by the UTC Program. OST-R may evaluate what the publications demonstrate about the excellence and significance of the research and the efficacy with which the results are being communicated to colleagues, potential users, and the public, not the number of publications. Many research projects (though not all) develop significant products other than publications. OST-R may assess and report both publications and other products to Congress, communities of interest, and the public.	
Reporting Period	**4/1/2015 – 9/30/2015**
1. Journal publications:	Lou and Li (2015) A Distributed Framework for Network-wide Traffic Monitoring and Platoon Information Aggregation Using V2V Communications, *Transportation Research, Part C* (Submitted)
2. Books or other non-periodical, one-time publications	Lou and Li (2015) A Distributed Framework for Network-wide Traffic Monitoring and Platoon Information Aggregation Using V2V Communications, *2016 Transportation Research Board Annual Meeting,* Washington, D.C. (Submitted)
3. Other publications, conference papers and presentations	**Conference Presentations** Li (2015) Improving Traffic Mobility using Connected Vehicle Technology: A New Algorithm for Distributed Traffic Detection and Information Aggregation, *2015 ITE/IMSA Spring Conference*, Phoenix, AZ, February 2015. Lou (2015) Distributed Traffic Monitoring with Vehicle to Vehicle Communications. *64th Roads and Streets Conference*, Mesa, AZ, April 2105 Lou (2015) Distributed Traffic Monitoring with Vehicle to Vehicle Communications. *CICTP 2015*, Beijing, China, July 2105 (*Invited*) Li (2015) Distributed Traffic Monitoring with Vehicle to Vehicle Communications. *2015 ITSAZ Conference*, Mesa, AZ, September 2015 (*Student paper award finalist*)
4. Website(s) or other Internet site(s)	None
5. Technologies or techniques	An innovative framework of protocols for distributed traffic monitoring and information aggregation using vehicle-to-vehicle (V2V) communications alone was developed. Each equipped vehicle, through the distributed protocols developed, keeps track of the average traffic density and speed within a certain range, flags itself as micro-discontinuity

	in traffic if appropriate, and cross-checks its flag status with its immediate up- and down-stream vehicles. The micro-discontinuity flags define vehicle groups with similar traffic states, for initiating and terminating traffic information aggregation. The framework is validated using a microscopic traffic simulation platform VISSIM and its built-in component object model.
6. Outreach activities	None
7. Courses and workshops	None
8. Inventions, patent applications, and/or licenses	None
9. Other products	None

Part III – Participants & Collaborating Organizations: Who has been involved?	
OST-R needs to know who has worked on the project to gauge and report performance in promoting partnerships and collaborations.	
Reporting Period	**4/1/2015 – 9/30/2015**
1. What organizations have been involved as partners?	None.
2. Have other collaborators or contacts been involved?	Dr. Xiaoyan Hong from the Computer Science department at The University of Alabama has been involved in several discussions and has provided valuable inputs. The PI has made contacts with some vendors of DSRC equipment and is working to acquire some devices for field testing purposes.

Part IV – Impact: What is the impact of the program? How has it contributed to transportation education, research and technology transfer?	
DOT uses this information to assess how the research and education programs: • **increase the body of knowledge and techniques;** • **enlarge the pool of people trained to develop that knowledge and techniques or** • **put it to use; and,** • **improve the physical, institutional, and information resources that enable those people to get their training and perform their functions.**	
Reporting Period	**4/1/2015 – 9/30/2015**
1. What is the impact on the development of the principal discipline(s) of the program?	The project is the first step towards the envisioned transportation operation system that relies on V2V communications to support coordinated traffic operation algorithms and does not require any fixed infrastructure. The envisioned system is particularly suitable for mobility applications in situations where the capability of existing fixed infrastructure is limited due to damage, power outage, or work overload, such as during the immediate or extended aftermath of major disasters or special events. The envisioned system is self-sustained through V2V communications alone, and thus will provide desired redundancy when existing infrastructure and standard capabilities suffer damage. It could also open up new possibilities for a variety of transportation applications and could enable a new paradigm of a safer and more efficient transportation infrastructure.
2. What is the impact on other disciplines?	The data elements identified as necessary to support the envisioned vehicle-to-vehicle communication system as well as the new protocols developed from this research may have an impact on vehicle communication technologies.
3. What is the impact on the development of transportation workforce development?	This project has supported one PhD student at ASU. It has provided research opportunity as well as an enhanced education experience to the student. The student will gain more knowledge in intelligent transportation systems, and improve research, programming, and technical writing skills.
4. What is the impact on physical, institutional,	None.

and information resources at the university or other partner institutions?	
5. What is the impact on technology transfer?	None at the moment, but the team is excited about potential future work to transfer the framework and protocols developed in this study into products.
6. What is the impact on society beyond science and technology?	The proposed approaches could also open up new possibilities for a variety of transportation applications such as real-time traffic-responsive route guiding system and instant user feedback platform for dynamic value-added road pricing systems. It could enable a new paradigm of a safer, more efficient and cost-effective transportation infrastructure.
7. Additional impacts	None.

Part V – Changes/Problems	
If not previously reported in writing to OST-R through other mechanisms, provide the following additional information or state, "Nothing to Report, if applicable:	
Reporting Period	**4/1/2015 – 9/30/2015**
1. Changes in approach and reasons for change	Nothing to report.
2. Actual or anticipated problems or delays and actions or plans to resolve them	Nothing to report.
3. Changes that have a significant impact on expenditures	Nothing to report.
4. Significant changes in use or care of human subjects, vertebrate animals, and/or biohazards	Nothing to report.
5. Change of primary performance site location from that originally proposed	Nothing to report.