**Position Statement for 2014 NSF National Workshop on Transportation Cyber-Physical Systems**

# Towards Safe and Efficient Transportation-Based Critical Infrastructure

Wei Yu[1] and Honggang Wang[2]

[1]Assistant Professor
Director of Cyber-Physical Networking System and Security Research Laboratory
Department of Computer and Information Sciences
Towson University, Email: wyu@towson.edu

[2]Assistant Professor
Director of Autonomous Networking and Dependable System Laboratory
Department of Electrical & Computer Engineering
University of Massachusetts Dartmouth, Email: hwang1@umassd.edu

The Intelligent transportation system (ITS) is one type of cyber-physical systems that aims to provide efficient/low latency, effective, reliable, and safe driving experience with minimal congestion and better traffic flow management. To achieve this goal, ITS applications such as inter-vehicle communications (IVC), vehicle-to-vehicle (V2V), and vehicle-to-infrastructure (V2I) should work synergistically and cooperatively. Both safety and efficiency of ITS are important in ITS. In the workshop, to meet the driving safety in ITS, we propose to develop advanced CVT (Connected-Vehicle Technology) for transportation cyber-physical system and accompanying techniques to enable scalable, reliable, and secure communication/control for ambulatory service applications. To provide efficient data service for a large number of users, we propose to leverage cloud computing infrastructure and algorithms (e.g., MapReduce), along with data aggregation techniques in different layers, to boot the efficiency of ITS.

***Connected-Vehicle Technology Enabling Tele-Ambulatory Services for Safety:*** The importance of transportation safety cannot be overstated. In 2008, there were estimated 5,811,000 police-reported traffic crashes in the United States. Tele-ambulatory services enable critical care to victims especially at the events such as road traffic crashes by diagnosing and commencing treatment of patients on route via multimedia (e.g., video conferencing) and vehicle communications. The emergency room doctors can monitor and treat the patients when they are being transferred to the hospital via ambulances, improving the quality of emergency care. However, tele-ambulatory service is still at its initial stage. The on-road ambulance could be congested or crashed due to unpredicted road traffic. An advanced open source wireless technology called Dedicated Short-Range Communications (DSRC), combined with WiFI and WiMax technologies can connect onboard subsystems such as sensors and transponders to various control centers. The DSRC have opened up new opportunities for providing efficient and reliable vehicular communications in intelligent transportation system environment. The recent DSRC-based technology, CVT, allows vehicles of all kinds to communicate with each other, and with stationary roadside equipment and mobile devices. CVT supports local traffic detection in a real-time manner and alerts vehicles nearby to avoid congestion and thus can reduce crashes and vehicle transferring time. This technology also enables the exchange of anonymous wireless data (e.g., position, speed and location) between nearby vehicles to improve transportation safety. For example, the exchanged information helps a vehicle to sense threats and hazards with a full degree awareness of the position of other vehicles and estimate the local traffic nearby.

To this end, we propose to build a CVT enabled tele-ambulatory cyber-physical system involving traffic-aware GPS devices in collaboration with current automobile industry and local transportation agencies. Our proposed system can assist tele-ambulatory drivers in finding an optimized route path that is aware of local traffic information. This novel technology will collect accurate local traffic information for ambulance to avoid traffic congestion by exchanging anonymous position, speed and location information, and alerting nearby vehicles. The current GPS device lacks live and accurate traffic information due to the limitation of real-time traffic collection and satellite communication capability. Each GPS installed in the vehicle suggests the best routing path (e.g., the shortest path) individually from the current vehicle position to the destination. However, the suggested path may not be the best route to the destination due to live traffic congestion. In addition, drivers' independent and individual route choices directed by their GPS for each driver's benefit could lead to more road congestion from a global road traffic point of view. There is a growing interest among diverse sectors of society from automobile manufacturers, to transportation planners and authorities, to safety experts, to environmentalists, to greatly improve safety, efficiency and economy of road transportation. In our proposed approach, CVT shall be integrated into ambulance and ambulance devices including GPS to improve transportation safety and reduce traffic congestion.

***Cloud Computing Based Architecture to Improve Efficiency:*** By constantly monitoring variations in traffic characteristics such as densities, speeds, and queues, high volume data streams (big data) are collected for real-time process and analysis in the transportation cyber-physical systems. Hence, the mounting volume of data stored in central databases and the continuously increasing storage capacity compound to the required high computation power represent significant challenges that can hinder the effectiveness of ITS. To address these challenges, we consider that it is necessary to establish a service-oriented architecture that integrates sensors, communication network, and service and operation layers. In our framework, we will demonstrate how data aggregation techniques, cloud computing infrastructures and algorithms (e.g., MapReduce) can boost the efficiency of ITS.

To develop efficient ITS, a monitoring sensor shall be deployed and installed on vehicles to collect information and transmit the information back to the operation center. With a large number of vehicles dynamically deploying in the transportation network, high volume data streams will be generated by the monitoring sensors over time. With the consideration of moving vehicles, how to efficiently store and process such big data streams is a challenging issue. To overcome this issue, we shall consider data aggregation techniques working on different layers with the consideration of users' needs and traffic context. Particularly, both lossless and lossy data aggregation techniques can be used in sensors to reduce the resources (e.g., energy consumption and bandwidth use) for transmitting information over the communication network while preserving the desired accuracy for ITS operation.

To make ITS efficiently processed and analyzed the big data in scalable and cost-effective manners, we shall also consider leveraging the cloud computing infrastructure and algorithms. To this end, a streaming-based storage model needs to be developed in order to reduce the storage processing time. The cloud infrastructure consists of a number of cloud servers distributed across multiple locations to accommodate data collection on dispersed vehicles in the transportation network. The distributed cloud storage server in ITS shall provide bidirectional data synchronization capability to vehicles monitoring sensor, reducing the time needed for storage, and avoiding a potential bottleneck of a centralized system. The collected data shall be normalized, indexed and stored in cloud storage server. A more complex relational structure with index tables shall be established to be more efficient in processing any data query requests. In addition, the streaming-based storage model shall consider the locality of vehicles and the tradeoff between transmission delay incurred by the available bandwidth and the propagation delay incurred by the distance between vehicles and the storage servers. To efficiently process the large data stream from vehicles, we shall leverage the stream processing algorithm such as MapReduce-based data processing. For example, to generate and display the temporal graph associated with a traffic situation, the distributed and parallel computing mechanisms can be implemented in the cloud computing environment. Given a large amount of data, deriving the spatial and temporal traffic graph to support system operation and a larger number of users, requires intensive computation time. By using MapReduced-based data processing, the time taken for such meaningful information can be significantly reduced.

In ITS, sensors are connected through a communication network to measure physical characteristics of a transportation system. The deployment of some sensors such as road sensors in unattended or even harsh environments and the lack of tamper-resistance hardware will increase the possibility of sensors to be compromised by cyber adversaries. Once sensors are compromised, the adversary may manipulate information, posing serious threats to ITS operation. As an example, the false data injected by compromised sensors can lead to false events and affect the correct decision made at the ITS. Hence, it becomes critical to systematically investigate the cyber attacks' impact on the system operation and develop effective countermeasures to secure the transportation infrastructure.

**Author Bios:**

**Wei Yu** is an assistant professor in Towson University and the Director of Cyber-Physical Networking System and Security Research Laboratory. Before joining Towson, he worked for Cisco System Inc. for nine years. His research areas include cyber security, cyber-physical systems, networking and distributed systems. His research been actively supported by the US government agencies, including National Science Foundation (NSF), Army Research Laboratory (ARL), National Institute of Standards and Technology (NIST), Department of Defense (DoD), Air Force Research Laboratory (ARRL), and Air Force Office of Scientific Research (AFOSR). He published over 110 papers, including publications in premier security and system journals such as the IEEE Transactions on Networking (ToN), IEEE Transactions on Parallel & Distributed Systems (TPDS), IEEE Transactions on Dependable and Secure Computing (TDSC), IEEE Transactions on Computers (TC), IEEE Transactions on Mobile Computing (TMC), and IEEE Transactions on Transactions on Vehicular Technology (TVT), and conferences such as IEEE Security and Privacy (Oakland), ACM Computer Communication Security (CCS), IEEE International Conference on Computer Communications (INFOCOM), and IEEE International Conference on Distributed Computing Systems (ICDCS). He received 2012 Excellence in Scholarship Award, Fisher College of Science and Mathematics at Towson University and the Best Paper Award at 2013 and 2008 IEEE International Conference on Communication (ICC), respectively.

**Honggang Wang** is an assistant professor at UMass Dartmouth and is an affiliated faculty member of Advanced Telecommunications Engineering Laboratory at University of Nebraska-Lincoln. His research interests include Wireless Healthcare, Body Area Networks (BAN), Multimedia Sensor Networks, Cyber Security, Wireless Networks and Cyber-physical System. He has published more than 90 papers in his research areas, including more than 30 publications in prestigious IEEE journals such as IEEE TWC, IEEE TM, IEEE TVT, IEEE JSAC, IEEE TITB, IEEE TIFS, IEEE TSG, IEEE CM, IEEE NM, IEEE WCM, IEEE TNSM, IEEE TETC, IEEE System Journal and Pattern Recognition. He also published papers in prestigious conferences such as INFOCOM, ICDCS, ICC, Globecom and ICME. He is the winner of the Best Paper Award of the 2008 IEEE Wireless Communications and Networking Conference (WCNC). He serves as a Lead Guest Editor of IEEE Journal of Biomedical and Health Informatics (J-BHI) (previous IEEE Transactions on Information Technology in Biomedicine (TITB)) special issue on "Emerging Wireless Body Area Networks (WBANs) for Ubiquitous Healthcare" in 2013, an Associate Editor of IEEE IoT (Interne of Things) Journal, a Guest Editor of IEEE Sensors Journal, an Associate Editor of Wiley's Security and Communication Networks (SCN) Journal and Transactions on Emerging Telecommunications Technologies. He also serves as TPC Chair or Co-Chair for several conferences such as TPC Chair of 8th ICST/ACM International Conference on Body Area Networks (BODYNETS 2013) and TPC symposium Co-Chair of IEEE conference on communications 2015 (ICC 2015, Mobile and Wireless Networking symposium). He is the TPC member for IEEE INFOCOM 2013-2014, IEEE BSN 2014, IEEE ICC 2011-2013, IEEE Globecom 2010-2013, and IEEE ICME 2013. He serves on NSF panel 2012-2013. He currently serves as a Board Co-Director of IEEE MMTC (Technical Committee on Multimedia Communications) Services and Publicity.