# Participatory Sensing for Pervasive Transportation Services

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## 1 Background and Experience of the Participant

Dr. Wang-Chien Lee is an Associate Professor in the Dept. of Computer Science and Engineering at Penn State University. Dr. Lee performs cross-area research in data management, pervasive/mobile computing, and networking, with a particular interest in the aspects of location-awareness. He has developed various data management techniques and network sevices/protocols for supporting advanced applications (e.g., location-based services and transportation services) and various complex queries in a wide spectrum of pervasive networking and mobile systems, e.g., mobile ad-hoc networks, wireless sensor networks, and wireless broadcast systems, and peer-to-peer networks. He has published extensively in leading conferences and journals, including Mobicom, MobiSys, PerCom, GIS, ICDE, ICDCS, INFOCOM, TKDE, TPDS, TMC, TDSC, and VLDB Journal.

## 2 Pervasive Transportation Services - a Vision

Under the vision of *intelligent transportation systems (ITS)*, many advanced applications and pervasive transportation services have been identified to battle the growing traffic congestion problems and to enhance travel safety and convenience [1]. The following are two transportation services encompassed by the ITS vision.

**Traffic Control.** This service aims to improve the traffic flow on streets/highways and minimize congestion by intelligently managing street and freeway control mechanisms (e.g., adaptive signal systems, dynamic message signs, ramp metering, etc). To realize this service, effective and efficient techniques for gathering data from the transportation system, *anywhere*, *any time*, and fusing it into usable information for pedestrians, vehicles and drivers, need to be developed. The collection and processing of ubiquitous traffic information is essential for implementing proactive control strategies and getting feedback on their effect.

**En-Route Driver Information Service.** This service aims to provide *real-time travel-related information* such as traffic, congestions, weather conditions, incidents, construction, etc, to drivers on the road. This service also supports in-vehicle displays of roadway signing, hazardous road conditions, safe speed, traffic controls, and special roadway conditions.

As observed in the above examples, the "pervasive heartbeats" of the transportation system (i.e., various real world situations regarding the happenings on the roads) needs to be captured, transformed into useful information, and delivered in a timely fashion to meet the needs of transportation applications and users. For example, various traffic surveillance sensors/cameras and probing vehicles may be used in data collection in order to derive enhanced traffic information such that traffic control systems can act on traffic conditions via street and freeway control mechanisms. To realize the ITS vision, various transportation services need to monitor and interact closely with the *pervasive transportation heartbeats* in order to function well. Moving towards this vision, recent technological advances in automotive systems, e.g., advanced cruise control, emissions testing and mitigation and active suspension, have also started to use some pervasive transportation heartbeats (e.g., road information) to combat the issues of fuel efficiency, emissions and safety. Nevertheless, "smarter" cars alone are not sufficient for realizing the grant vision of ITS. The roads (i.e., transportation infrastructure) also need to become smarter by equipping themselves with timely pervasive transportation heartbeats information for smart cars' and travelers' consumption. From our discussions above, we can easily see the importance of pervasive transportation heartbeats (e.g., road slopes, traffic lights, congestions, traffic throughput, weather condition, and so on) to pervasive transportation services. For instance, given the knowledge of an on-going congestion up front on its route to the destination, a smart car, enabled by the en-route driver information service, may inform its driver the situation and recommend her to make an informed detour decision.

## 3 Participatory Sensing of Pervasive Transportation Heartbeats

Enabling high-quality pervasive transportation services is a very challenging task due to the nature of transportation applications and various requirements such as timeliness, criticality, scalability, reliability, accuracy, etc. Efficient collection of fresh and timely pervasive transportation heartbeats and transform them into useful information that reflects the road condition in the real world is very important. Roadside sensors and probing vehicles are two different approaches typically adopted for collecting data. The former is currently the primary approach adopted by transportation management agencies. While the roadside sensors based approach may easily obtain steady data feeds for monitored spots, it is too expensive to achieve a full coverage of all the roadways. On the other hand, the probe vehicle based approach may potentially cover almost all segments of the road networks if we have enough number of those "mobile sensors" on roads. With recent development of participatory sensing activities, we argue that participatory sensing of the pervasive transportation heartbeats via volunteered probe vehicles has a great potential to provide *complementary coverage* to the roadside sensors approach and alleviating the cost in battling the various transportation problems we are facing today.

Research effort is needed to incorporate participatory vehicle sensing and address various arising technical issues. For example, how to coordinate a massive number of participatory vehicles to collect needed road information for *timely* delivery to transportation management centers (TMCs) for processing. Given that not all vehicles are expected to pay commercial services to get connected with a TMC, opportunistic data collection schemes via vehicle-to-vehicle or vehicle-to-roadside communications are anticipated. Since data may be missing due to unreliable opportunistic data communications, data processing and mining algorithms aiming to discover useful information for pervasive transportation services need to take this missing data issue into account. Finally, how are we going to ensure the valuable knowledge derived from the pervasive transportation heartbeats efficiently disseminate to users at the *right place*, and again in a *timely* fashion.

We envisage the need of developing a pervasive transportation services framework, which consists of three components corresponding to data collection, data processing/mining, and data dissemination. Aiming at the goal of supporting participatory sensing of the pervasive transportation heartbeats, the pervasive data access (PDA) group at Penn State University is pursuing research in the following directions towards the pervasive transportation services framework.

- Develop data collection schemes for participatory vehicle sensing by taking design factors, such as i) opportunistic vehicle-to-vehicle and vehicle-to-infrastructure communications; ii) real-time scheduling requirements in terms of data freshness, timeliness and criticality; iii) data sampling strategies in terms of temporal and spatial coverage, into consideration.
- Develop data processing and mining techniques for transportation information discovery from various data (e.g., vehicle data accessible via On-Board Diagnostic System) collected from participatory probe vehicles, with an emphasis to handle missing data.
- Develop pervasive dissemination techniques for timely delivery of transportation information that support both of broadcast services and on-demand retrieval services in an integrated manner. Particularly, these techniques need to enable real-time data dissemination by taking into account various factors of service urgency, service overhead and service productivity.

In summary, timely information of pervasive transportation heartbeats is the soul of ITS and thus is crucial for various pervasive transportation services. Enabling techniques that support participatory vehicle sensing may provide technological advances and great benefits to facilitate high-quality pervasive transportation services.

## References

[1] Intelligent Transportation Systems. http://www.its.dot.gov/.