Fleet-Oriented Real-Time Vehicular Tracking at Urban Scale

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4/17/2017 at 12:30 pm
Core 301A

Abstract

Nowadays, vehicular sensing has become increasingly important to collect urban data to understand and address mobility challenges. A straightforward to achieve this goal is to build fine-grained city-scale sensing infrastructures to instrument all vehicles with sensors and centralized communication interfaces, which lead to very expensive costs. Therefore, the previous work in urban sensing explores some less expensive methods in two categories: (i) Centralized methods where a small number of well-equipped vehicles with centralized real-time cellular connections to upload sensing data in real time, which leads to data sparsity due to limited number of vehicles; (ii) Distributed methods where a large number of minimally- equipped vehicles with peer-to-peer communication devices to upload sensing data in an offline fashion, which leads to long delay due to peer-to-peer communication. To address these issues, this dissertation explores a new direction of combining centralized sensing and distributed sensing together for a hybrid vehicular sensing framework based on two new opportunities, as a part of intelligent transportation system (i) Recently, we have witnessed a surge of commercial vehicular fleets, e.g., taxis, buses, and trucks, with advanced sensing, and centralized/distributed communication devices. (ii) There has been a trend to consider mandating all private vehicles to broadcast their status (potential sensing data) to nearby vehicles, e.g., using peer-to-peer communications to broadcast safety message to nearby vehicles including ID, speed, locations, and sensing status for safety applications. Therefore, the key question this thesis is trying to answer is can we use a small number of well-equipped commercial vehicles to track (and then collect data from) a large number of minimally- equipped private vehicles for urban scale sensing in real time. Real-time vehicle tracking at urban scale is essential to various urban services. To track vehicles at individual levels, most existing approaches rely on static infrastructures (e.g., cameras) or mobile services (e.g., smartphone apps). However, these approaches are often inadequate for urban-scale individual tracking because of their static natures or low penetration rates. In this thesis, we design a tracking system called coTrack to utilize commercial vehicular fleets (e.g., taxis, buses, and trucks) for real-time vehicle tracking at urban scale, given (i) the availability of well-equipped commercial fleets, and (ii) an increasing trend of mandating all vehicles to broadcast their status for safety applications. The key technical challenge we addressed is how to recover spatiotemporal tracking gaps by considering various mobility patterns of commercial vehicles with a hidden Markov model. We evaluate coTrack with a preliminary road test and a large-scale trace-driven evaluation based on vehicular fleets in the Chinese city Shenzhen, including 14 thousand taxis, 13 thousand buses, 13 thousand trucks, and 10 thousand private vehicles. We compare coTrack to infrastructure and cellphone-based approaches, and the results show that we increase the tracking accuracy by 42.2% and 23.2% on average. Further, we design a service to utilize private vehicle tracking to infer travel time between 24,1081 region pairs, and the results show that given the diverse mobility of private vehicles, we can infer travel time between 15% more region pairs than using commercial vehicles alone.

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