MOBILE TECHNOLOGIES FOR TRAFFIC CONTROL

Article Summary

Mobile technologies are becoming increasingly prevalent, and their ubiquity has significant potential to improve traffic congestion control. These technologies show promise as both data acquisition tools and application platforms that integrate directly into the transit space experience. Through a combination of stationary sensors and mobile devices, new traffic congestion control methods offer a means to both improve public health and raise new ethical issues for consideration.

Introduction

Traffic congestion is a constant pain for all societies and by extension for drivers and passengers themselves. A 2012 Urban Mobility Report compiled by the Texas Transportation Institute (2010) estimates that traffic congestion is a $121 billion cost on the U.S. economy annually. This cost is not only financial, but both social and environmental. For the typical commuter, the report further found that congestion forced “the average urban resident to spend an extra 38 hours of travel time and use 19 extra gallons of fuel, which amounts to an average cost of $818 per commuter.” Severe delays in public service response teams including emergency first responders, police, and firefighters can result from bottlenecks and traffic congested areas. The quality of life for commuters who endure traffic is significantly worsened as well. An IBM (2010) survey reported that “30% of respondents reported increased stress from traffic; 27% increased anger; 29% reported that traffic has harmed their performance in work or school; and 38% reported having cancelled a planned trip due to anticipated traffic.” Clearly, this is an issue that with any improvements can have significantly positive implications.

Across disciplines and careers, ranging from city planners, to innovators, to engineers, teams of designers and thinkers have tried to combat these costs. The exciting development in mobile technologies in the 21st century has sprouted a range of solutions and possibilities for integrated and robust methods to control traffic congestion and actively monitor its development through combinations of public policy, devices, and algorithms. In particular, the widespread adoption of cell phones brought into the foreground fields of study that, while in the past were impractical, are quite likely the future of transportation. This article intends to review ECE technologies that fall under the umbrella term of Intelligent Transportation

Systems (ITS) and illuminate on some design requirements that are unique yet vital to a successful transportation architecture.

Intelligent Transportation Systems (ITS)

As defined by the U.S. Department of Transportation (2015), Intelligent Transport Systems incorporate transportation infrastructure as well as vehicle technologies for the sake of improved "transportation safety and mobility." ITS systems generally have two types of components: fixed sensors and vehicular sensors. The fixed sensors are infrastructural and at fixed locations along transport areas such as highways, tunnels, railways, runways, and sea ways. In vehicles, traditional ITS consisted of sensors and hardware that were embedded into the vehicles themselves. In particular, traffic congestion control is one application of ITS development and research and has direct impact on infrastructure, quality of life, and public safety.

To begin, traditional static solutions to traffic congestion are explored before describing these newer vehicular embedded technologies.

The Goals for Traffic Congestion Control

What problems do traffic congestion control try to address first? The limitations of infrastructure such as highways with a fixed number of lanes, limited parking, and situational problems such as traffic accidents call for a physical solution to a physical problem. The goal of all traffic congestion control systems is to try to reach at least one of two objectives: 1) Get vehicles off of the road, or 2) increase the traffic capacity of infrastructure.

To illustrate this point, a study done in Japan by the Mathematical Society (2008) recorded a simple yet insightful experiment. It depicted a circular road with evenly spaced vehicles driving at a constant speed. Even with strict directions to drive at 50 mph, random and small variations in people's driving speed propagated to have major effects, with jams piling up in one part of the circle while the rest of the circle became completely underutilized. After scaling this scenario to a typical rush hour, it is obvious that traffic congestion is essentially inevitable.

Traffic engineers and transportation planners, in an absolute case, face an impossible problem, but their goal is not to eliminate traffic congestion as a whole but rather to try and minimize its effects.

Immobile Solutions Without Intelligence

The first solutions for traffic congestion control provide a framework from which newer solutions adopted their strategies.

On the government's end, its responsibilities in society give it the capabilities to develop infrastructure on a scale impossible for private companies. The Federal Highway Administration (2014) outlines "three coordinated approaches – construction, preservation, and operation" as its main strategies for handling congestion. Clearly, construction entails expansion and development of new infrastructure, preservation entails repair, and operation entails maintenance and upkeep. Both policy and physical systems have been developed specifically to help these target areas. High Occupancy Vehicle (HOV) lanes, Park and Share facilities, and in some extreme cases regulation that limits which cars can be on the road during peak hours are examples of these kinds of solutions (Sayare, 2014).

While these solutions have been helpful, their intention mitigates problems and simply maintains transportation systems. Without an intelligent solution to inform these approaches, their impact is difficult to measure and the decisions made are difficult to evaluate.

How Can Technical Solutions Help Inform Decisions and Policy?

Nontechnical solutions are certainly beneficial, but ECE technologies improve much of the decision-making process and solutions going into traffic congestion control. A number technical solutions have reached the transportation industry through mobile technology under the umbrella term of Intelligent Transportation System (ITS) technologies. In essence, ITS technologies both inform travelers and traffic professionals and "support [the] development" of tools that they "never had before" (Federal Highway, 2014).

Even so, ITS systems that rely on purely stationary data sources have their own limitations as well. While Intelligent Transportation System development certainly help capture real-time traffic conditions, fixed sensors are only able to gather information around stationary areas (Rabie, 2002). Traffic by nature is an organic and fluid process, so naturally parts of a stationary ITS are at times either underutilized or overworked.

A major technological advancement in the last 20 years that has significantly affected the reach and scope for Intelligent Transport Systems is the embedded sensors in mobile technologies such as the smart phone. Even beyond mobile phones, mobile technologies are able to dynamically handle and capture traffic flow with minimal infrastructural development. As an example, the mobile phone can be a rich source of data with added functionality for Intelligent Transport Systems to leverage. GPS, WiFi access, BlueTooth, automatic synching, an array of different sensors, camera and video; all of these add ons are now expected of the once modest phone and are excellent tools for ITS to use.

For example, in a study using a mobile phone to monitor road conditions, the accelerometer of a smart phone was used to measure “road [anomalies],” such as a pothole or bump that significantly impair driving conditions and, by extension, worsen traffic congestion (Fazeen, 2012). In this example, the accelerometer in the smart phone was a perfect tool to monitor road conditions because the readings from the sensor are directly related to the vibrations felt by the car.

Selected Mobile Applications

Below are a few examples that leverage mobile networks for data gathering and analysis.

The Global Positioning System (GPS)

The most well-known technology integrated into mobile phones is the Global Positioning System (GPS), a satellite navigation system that can precisely determine the position of a GPS receiver. In essence, a GPS satellite has a well-defined position in space and an extremely accurate clock. The GPS receiver uses any four visible GPS satellites’ information to compute its own position relative to the satellites. Each satellite allows the receiver to determine an additional part of its location, meaning that four satellites help the receiver determine its 3D position and time (U.S. Air Force, 2013).

In the 21st century, GPS is absolutely obligatory for a smart phone user. This cultural popularity makes the aggregated data extremely valuable as a real-time traffic estimator. By having each mobile phone (each its own GPS receiver) to broadcast its position, the aggregated data from numerous phones paint a thorough picture of traffic in a given area. A well-known product that takes advantage of this technology, Google Maps, crowdsources this information across many users and create the traffic visualization maps now integral to Google Maps features (Barth, 2009).

To measure a region’s estimation quality, each region’s “penetration rates” are calculated and analyzed (Minh, 2012). The penetration rate is defined as the percentage of vehicles that are streaming relevant information about their current state and location out of the total number of vehicles in the area. A low penetration rate implies that the traffic estimation system is less effective. With this intuition, it makes sense why services that have had their popularity and user base grow over time, such as Google Maps, have significantly improved their quality and reliability of information.

Vehicular Cloud Computing

In order to compete in a market demanding more advanced and integrated on-board entertainment systems, car companies have outfitted their models with increasingly sophisticated technology. With these advancements researchers have found that these systems are widely underutilized, and the concept of vehicular clouds (VCs) was developed. The goal was to make networks that take advantage of these "idle" devices and provide network-wide capabilities such as shared information and notifications (Yan, 2013).

In particular, there are two types of vehicular clouds. The *Infrastructure-Based VC* takes advantage of roadside infrastructure, while the *Autonomous-Based VC* form "on-the-fly" connections and can manage "emergencies and other ad hoc events" (Yan, 2013). Distinguishing between the two in this way makes their responsibilities more transparent: the "on-the-fly" connections are well-suited to the dynamic changes of traffic, while the vehicular clouds that use infrastructure can effectively monitor and assess a particular environment.
Among other applications, VC computing can be helpful for traffic congestion control in scenarios of anything from "safety applications," to "accident alerts," to "road condition sharing" (Yan, 2013). The mobile nature of these systems helps to dynamically inform the network with valuable information that requires almost no added infrastructural support.

Electronic Toll Collection (ETC)

Electronic toll collection is a service used to expedite the payment process for travelers to pass into toll roads. Traditionally, the manually-operated booths cause severe choke points for traffic flow, but transponder electronics such as the widely used E-Z Pass help to provide faster service. In more general contexts, while E-Z Pass operates using Radio-frequency Identification (RFID) tags, smart cards with a variety of technological standards are used for Electronic Toll Collection in public transport areas such as the CharlieCard for the MBTA. In all cases, the travelers carry electronic information with them and use this data to pay for tolls automatically. The benefit of using electronic devices is that these transactions can be easily timestamped and stored to provide useful traffic analytics for many different types of transit.

One downside, however, is that there is a requirement for extra electronic devices to be carried with the travelers. Mobile phones have allowed traffic control professionals to experiment with integrating ETC into mobile applications. The benefit is two-fold: more user transactions can be recorded for more accurate analysis, and fewer infrastructural changes are needed to integrate this technology into people's lives (Lin, 2008).

Security and Privacy in Intelligent Transport Systems

With complete adoption of these mobile technologies in Intelligent Transport Systems, the transportation industry has much to gain. These technologies bring into light, however, ethical concerns of security and privacy for both engineers and designers to consider.

To take vehicular cloud computing as an example, some of the main obstacles to VC adoption are vulnerabilities precisely related to security and privacy (Yan, 2013). These characteristics are particularly important to every driver and passenger in a vehicle; a vulnerability or flaw in the system can have immediate repercussions for those within the vehicles, regardless of whether it was malicious or the result of a flawed design.

Because a potential attacker and its targets share the same network, vehicular clouds are more vulnerable to attacks than a typical network bombarded from the outside (Yan, 2013). The typical threats to a standard system are still possible for a VC, including spoofing, Denial of Service, or information tampering, among others (Yan 2013).

While the vulnerabilities to the computer network are the same, the tradeoffs and risks for security are different. The most direct tradeoff is where pseudonyms as identifiers for individual vehicles need to both provide a trustworthy and genuine identity while also maintaining the privacy of those on board. Tracking vehicle information and locations certainly adds value to the computing capabilities of VCs, but necessary privacy is also a prerequisite for most users. Vehicles by nature place security as one of utmost importance because vehicles have a responsibility of safety to passengers, drivers, and nearby vehicles.

This concern is relevant to not just VCs, but also any service that hopes to take advantage of mobile networks that have valuable information about its users.

Looking Forward

Mobile technology as a crowd-sourcing medium for transportation applications is clearly becoming a standard unlikely to diminish in the near future. The opportunity for traffic infrastructure to incorporate mobile data is clear, but a few concerns are important to address: mainly privacy and authenticity. Addressing and standardizing how data can be disassociated from a personal user yet still useful are of equal importance. Even so, the use of ECE technologies has and will provide clear benefits for the transportation industry.

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