Closing the loop between traffic/pollution sensing and vehicle route control

The Vision: Our planet has become more urban than rural in the last decade, and the share of people living in metropolitan areas continues to rise with each passing year. Urban traffic has increased dramatically over the past three decades, making driving more stressful, costly, and unhealthy. According to the Texas Transportation Institute, the overall cost of (in the form of wasted fuel and lost economic productivity) metropolitan traffic congestion in the U.S. topped $87 billion in 2007, more than $750/year for every U.S. traveler. Drivers are not the only ones who suffer from the consequences of urban traffic. For residents, the health risks of air pollution seriously undermine the advantages of living in the city. As such, a systematic approach to traffic management requires a solution that must rely on real-time collection of traffic density and air pollution data, and it must feature real-time communication mechanisms for fine-grained traffic control.

Our vision is to use modern wireless technology, environment monitoring, and urban traffic management to "close the loop" between urban sensing and vehicle route control with the aim of simultaneously reducing congestion, pollution, and traveler delays. The pivotal elements of this vision are the "intelligent" traffic signal, the traffic center, and the on-board navigator. In addition to the traditional control of vehicular flow at signalized intersections, *future signal systems* will sense traffic characteristics and vehicular emissions, collect data from vehicle sensors (pollution, emission, position, etc.), and broadcast traffic advisories, routings, and restrictions to on-board navigators. *Central traffic controllers* simulate traffic conditions, air pollution models and calculate traffic restrictions and incentives. Finally, *the on-board navigators* receive traffic information and incentives and calculate best routing taking into account drivers' preferences. All this is enabled by efficient vehicle to roadway infrastructure communications, from 3G channels to DSRC radios (roadside and on-board) that enable real-time, low cost, scalable information exchanges among the various architecture components.

Evidence: Compared with inter-city traffic, metropolitan travel presents a more complex set of conditions. Unlike inter-city highways, metropolitan transportation systems are multi-modal – accommodating pedestrians, bicycles, and motor scooters in addition to trucks and passenger vehicles. The large number of intersections in urban areas introduces many potential traffic conflicts and greatly reduces effective road capacities. Clearly, the granularity required for monitoring and managing urban traffic and air quality must be much finer than what is required outside of urban areas.

Today, there is a broad spectrum of largely disconnected solutions to alleviate traffic congestion. At one end, there are system-focused solutions, such as coordinated, dynamic traffic signal timing and control. At the opposite end, there are vehicle-based solutions such as on-board navigators, which offer "optimal" routing options to drivers ignoring any external constraints. As a result, on-board navigators provide little help to drivers in calculating accurate driving times or determining fastest routes through a city, since such route planning critically depends on real-time, fine-grained information like signal timings and vehicle speeds that is not presently available to navigators. Moreover, current navigators completely ignore emissions effects and, therefore, are of little use in environmental planning. Congestion pricing, which aims to link the demand for travel with road capacity via variable priced tolls, has long been touted by economists, but in the absence of adequate vehicle monitoring and toll collection techniques it has been impractical to implement.. The question we aim to answer is how to connect existing solutions via state-of-the-art communications and networking to provide efficient, coordinated real-time traffic and air quality control.

Details: The overarching goal of the proposed project is to develop and evaluate the benefits of a *"green city" traffic management architecture* that is composed of: (i) traffic sensors, (ii) traffic control center, (iii) intelligent traffic signals, and (iv) on-board navigators. Traffic sensors consist of both mobile urban sensors on vehicles and infrastructure sensors. The central traffic control system receives traffic and pollution data from vehicles and infrastructure elements, models congestion and pollutions using this data, and dispatches routing information and positive or negative incentives to vehicles. Intelligent traffic signals help the traffic center in the implementation of the global traffic plans by broadcasting traffic instructions to vehicles in their region. In addition, they locally adjust timing, and compute and broadcast traffic light state for vehicles approaching them. On board navigators use the provided information to choose the best route taking into account navigation costs/credits, driver's goal and constraints. The closing of the loop between traffic and air quality data sensing and vehicle routing will enable an urban traffic management that can adjust to the rapidly changing traffic and air quality conditions typical of large cities.

Such a project will necessarily be highly interdisciplinary; it will benefit from the collaboration and expertise of atmospheric science researchers, auto manufacturers, traffic signalization and control engineers, and vehicle navigation developers. To implement the proposed vision, research must address multiple challenges in the areas of urban sensing, emission models, traffic and pollution simulation, traffic management, control and enforcement, wireless networking, usability and human-computer interfaces, and security and privacy.

For instance, pollution modeling is a major challenge. Pollution is non-uniformly distributed, being on average higher in close proximity to roadways, but vary widely on time scales of hours, which can change exposure levels dramatically. Pollution levels near roadways depend on traffic density, vehicle speeds, congestion and local wind speeds and direction. More precisely, air pollution can vary on length scales of tens of meters for some pollutants, but the distribution of pollutants on this scale is poorly characterized due to lack of spatially resolved measurements. The spatial heterogeneity arises from the interplay between the complex topography, the variable atmospheric mixing and the highly non-homogeneous emissions. Thus, the potential for mapping of pollutants with high spatial resolution via sensors integrated into a smart traffic sensing system is largely untapped, and will likely produce insights beyond those currently available. This will go a long way toward developing more accurate models, which will be simulated in real time to provide input for traffic control.

Credentials: Liviu Iftode is a Professor of Computer Science at Rutgers University. His research interests are in the areas of mobile, pervasive, vehicular and social computing. Dr. Iftode has been the PI of several NSF grants including a CAREER, a medium ITR on cooperative computing for distributed embedded systems and a NeTS grant on vehicular computing systems. .As early as 2004, he proposed and prototyped TrafficView, one of the first university projects in the area of vehicular computing, which used car-to-car communication to allow driver to see the traffic ahead. **Mario Gerla** is a Professor of Computer Science at the University of California, Los Angeles (UCLA). He has been Co PI on the NSF WHYNET project, which developed a "constellation" of models, simulation tools and geographically distributed testbeds addressing advanced radio and physical layer environments. WHYNET project offered an embryonic form of vehicular testbed, which was later expanded into the UCLA Campus Vehicular Testbed (C-VeT). **Giovanni Pau** is a Research Scientist in the Department of Computer Science at UCLA. His interests are in the areas of vehicular computing, mobile computing and distributed systems. He is a member of the Vehicular Lab at UCLA, which is building CVeT. **Badri Nath** is a Professor of Computer Science at Rutgers University. As part of the Dataman Group, he led the research in mobile and wireless computing resulting in several protocols in wireless and sensor networks such as I-TCP, APS and AoA. **Suzanne Paulson** is a Professor of Atmospheric Chemistry in the Department of Atmospheric and Oceanic Sciences at UCLA. Her research interests are in the area of atmospheric chemistry of aerosols, climate impacts, health impacts and formation.