City Labs for Intelligent Road Transportation Systems

New Testbeds for Research in Transportation Control

Real-time management of city services, including traffic, energy, security, and information, is a new approach to the development of "smart cities." Low-cost and easy-to-deploy sensors and wireless communication protocols are enabling control system technologies to play a much-enhanced role in this area.

City-scale testbeds are now becoming available for research and experimentation, especially for intelligent transportation systems. Such "City Labs" are spearheading efforts to study and evaluate control systems in realistic arenas accessible to researchers and engineers. The ultimate goal is the implementation of new control systems to improve the daily lives of drivers and passengers, help traffic operators optimize the network, and reduce energy consumption and environmental impact.

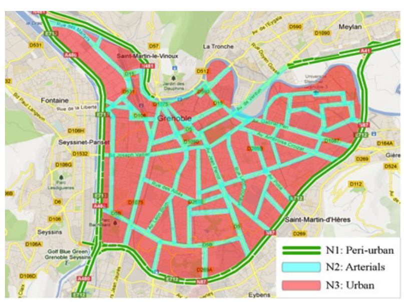
Current Traffic Management Approaches are Fragmented, Not Holistic

Nowadays, traffic problems are typically addressed at the level of a single vehicle or subsystem (e.g., in a specific arterial corridor or a part of an urban road). The current control and resource optimization strategies are inefficient when considering traffic at the global network level. Today's fragmented and uncoordinated approach is a significant obstacle for improving urban mobility and energy efficiency.

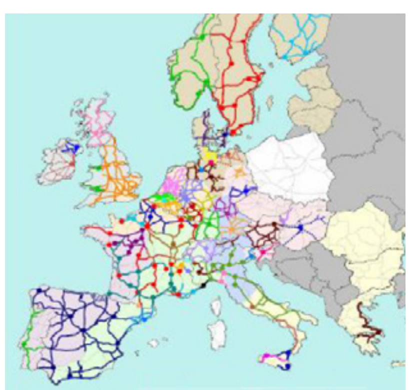
The Challenge of Heterogeneity in Road Transportation Systems

Intelligent transportation requires the modeling, analysis, and control of the transportation system as a whole. The diversity of elements in the system must be taken into account, including

- Vehicle classes (private cars, utility vehicles, trucks, buses);
- User groups (private, professional, public);
- Road networks (highways, arterial, urban);
- Transportation modes (high-speed roads, low-speed roads, bus lanes, tramways); and
- Implementation technologies (sensors, software, protocols).



Three main traffic networks in the city of Grenoble. The "peri-urban," "arterial," and "urban" networks are managed by different traffic authorities with little coordination or integration. Better control coordination with a holistic view is critical for optimal operation. (Source: NeCS team)



Main traffic management domains of the EU highway system. Optimal route planning at the EU level requires coordination of domain-level traffic management policies and better sharing of information. Technologies used in different networks and countries are heterogeneous and require greater integration. (Source: Easyway)

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Control Challenges for Intelligent Road Transportation

- *Exploiting new data sources:* Integration of various sensor technologies with different characteristics (radars, mobile phones, Bluetooth, video, magnetometers, etc.)
- *Secure and privacy-preserving data sharing:* Control with communication constrained by secure real-time information sharing and privacy-preserving data aggregation
- *Mathematical models:* New traffic models accounting for multiple modes, combination of micro and macro models, two-dimensional flows, and large network graphs
- *Model-based travel time forecasting:* Online prediction algorithms along multimodal networks
- *Coordinated control among subsystems:* Control methodologies and architectures for operating the road network as a whole in metropolitan areas
- *Optimal routing for dynamic traffic networks:* Online optimal planning algorithms accounting for traffic flow congestion and modern vehicle-to-network communication policies
- *Resilient traffic control:* Control strategies that account for the vulnerabilities introduced by subnetwork interconnections—resilience against malicious attacks on actuators (e.g., lights) and sensors

The Grenoble South Ring

This stretch of the Grenoble perimeter highway is 10.5 km long and includes 10 on-ramps and 6 off-ramps. Some 90,000 vehicles per day (5% trucks) travel on this road, taking 7 to 50 minutes for the trip. Sensing and actuation equipment includes

- 130 wireless magnetic sensors (flows and velocities),
- Four junctions with in-ramp queue measurements,
- Seven variable speed limit electronic panels (70-90 km/h), and
- Ramp metering (to be implemented).

Sensor data is collected every 15 seconds and transferred to a server with a maximum latency of one sample period (15 seconds). Variable speed limits can be actuated directly from the traffic operation center.

Grenoble Traffic Lab (GTL)

In collaboration with national traffic operators and local public authorities, a City Lab for traffic management has been launched in Grenoble. GTL collects information from the road-traffic infrastructure in real time, with minimum latency and fast sampling periods. Main components include

- A dense wireless sensor network providing macroscopic traffic variables,
- Real-time data collection and archiving for traffic classification and demand prediction,
- Traffic forecasting algorithms for traveling-time prediction up to 45 minutes ahead,
- Control algorithms for access control and variable speed limits, and
- A showroom and a micro simulator to validate algorithms and user interaction.

GTL objectives include transfer of research results to industry with the collaboration of multiple stakeholders.

The Grenoble Traffic Lab is supported by INRIA, CNRS, and University Joseph Fourier. For more information, visit http://necs.inrialpes.fr/.