KY Infrastructure for Research Towards Smart-Eco Freight Transportation System

Keyword: intelligent transportation, smart cities, internet of things, big data, and autonomous vehicles

Overview: Transportation is a key component of the manufacturing ecosystem. As a pivotal node in the US's transportation networks and one of the largest cargo hubs over the world, as well as the 4th largest auto manufacturing state, Kentucky is facing a pressing demand for an efficient and sustainable freight transportation system with enhanced traffic capacity and reduced travel delays, crashes, emissions, and energy consumption. Such a demand is emphasized by the following reports: (i) the FHWA listed I-65 at I-64/I-71 interchange in Louisville as the 4th worst freight bottleneck in US in 2015; (ii) the CNN Money ranked Louisville as the 9th most polluted city; and (iii) the Louisville Airport and Cincinnati/Northern Kentucky Airport were ranked 3rd and 8th respectively in the U.S. for freight tonnage shipments in 2015.

The goal of this proposal is to create the infrastructure for collaborative and multidisciplinary research on the design and implementation of smart and eco freight transportation systems in KY by leveraging the recent advances in wireless communications, big data, autonomous driving and machine learning; and deploy such advanced systems in Kentucky's transportation networks, especially transportation bottlenecks, to boost Kentucky's manufacturing ecosystems. The proposed infrastructure will not only serve the practical needs but also lead KY to a serious competitor in high-impact research by addressing multiple areas identified by the NSF's S&CC, Wireless Research Initiative, CPS, as well as the latest LEAP HI programs. The proposed infrastructure will also strengthen the statewide collaboration among researchers with expertise in transportation, wireless communications, automotive engineering, electrical vehicles, artificial intelligence, and data science in Kentucky's universities. Further, the proposed infrastructure also aligns with UofL's strategic research directions to foster synergies between academic research and industrial development for boosting KY's economy.

Research Components: Proposed research components include, but not limited to:

1. Vehicular wireless communications will be the enabler for smart transportation system. Although continuously being studied, the progress remains limited and the existing wireless communication systems such as 802.11p (a.k.a. DSRC) and 5G hardly meet the requirements from smart transportation systems in terms of network capacity, communication latency, connectivity reliability, service coverage, network scalability, and privacy and security. Significant research efforts will be spent on advancing wireless technologies so as to enable intelligent traffic monitoring and control.
2. The proposed Smart-Eco transportation system will rely on advanced traffic management strategies to optimize transportation efficiency and sustainability by harnessing the emerging connected (V2I and V2V communications) and autonomous vehicles as well as machine learning technologies. The system is targeted at significantly improving the transportation bottlenecks with recurrent congestions, such as freeway interchanges and weaving areas, as well as intersections. Innovative traffic management strategies to be explored include autonomous intersection/interchange, yield-less weaving, automated truck platooning, cooperative truck signal priority, and work zone cooperative merging.
3. Big data and machine learning play important roles in smart-eco transportation. With large volumes of real-time traffic data generated, they need be managed, communicated, interpreted, aggregated, and analyzed to support active traffic control decisions. Innovative big data processing and mining as well as optimization techniques will be developed and applied to support real-time, automated traffic control. Research will target at real-time big data graph embedding (into lower vector space) to enable machine learning-based decision making, such as multi-label traffic status classification and advanced control.

Broader Impacts: Results of this project will lead to a new knowledge frontier for the design and optimization of complex transportation systems by leveraging the advanced technologies such as ubiquitous high-speed and low-latency wireless communications as well as the big-data-enabled advanced traffic control at transportation bottlenecks. Results will be integrated into the course modules in Civil and Electrical Engineering for next-generation workforce development. Industrial and governmental collaboration, as key element of this project, will seek technology transfer as well as commercialization of the developed smart-eco transportation solutions. Once implemented, these solutions are expected to substantially improve transportation safety, efficiency, energy consumption, and vehicle emissions.

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Conceptual Research Framework:

KY Infrastructure for Research Towards Smart-Eco Transportation System

--- An essential ***PUZZLE*** to complete KY's Advanced Manufacturing Ecosystem

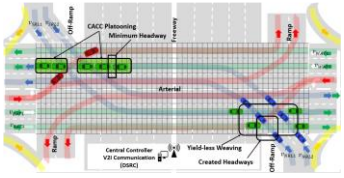
Smart-Eco Transportation System

- Less Congestions and Delays
- Less Emissions
- Less Energy Consumption
- Less Crashes

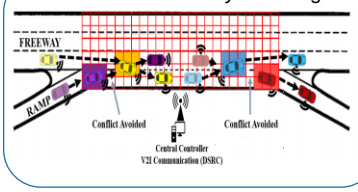
Supported by Four Technology Pillars

Connected Vehicles: Wireless Communication	Autonomous Driving	Machine Learning	Big Data & Data Mining
Network capacity	Level 2: partial automation	Deep learning	Data fusion
Communication latency	Level 3: conditional automation	Reinforcement learning	Data warehouse
Connectivity reliability	Level 4: High automation	Support vector machines	Big data graph embedding
Service coverage	Level 5: Full automation	Clustering	Big data Interpretation
Network scalability		Decision tree	
Privacy and security			

Autonomous Intersection/Interchange



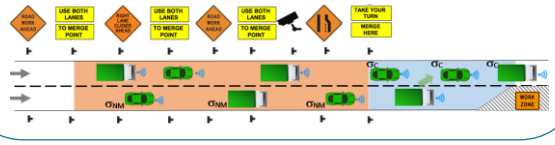
Yield-less Freeway Weaving



Cooperative Truck Signal Priority

Cooperative, Automated Truck Platooning

Work Zone Cooperative Merging



Expected Benefit: improved transportation efficiency by 20-50% & reduced traffic-induced emission and energy consumption by 20-30%.

Kentucky's Advanced Manufacturing Ecosystem