Energy Efficient Platooning of Connected Electrified Powertrains 
Enabled by a Novel Hybrid Electric Powertrain Architecture

Motivation
- Increasing demand for hybrid electric vehicles (HEVs) powertrain systems place stringent requirements on performance, durability, and reliability of their architectures.
- Platooning grants better vehicle mobility, energy efficiency, safety, and road capacity.
- Optimal motion planning and control in platooning can minimize energy consumption in fleet operations.

Fundamental Research Questions
- How to optimize drive schedule and controller for platoons of electrified vehicles accounting for specific powertrains, given information of road loads and subject to constraints (safety, headway, size, power management of each vehicle)?

Objectives
- Implement platoon model with intravehicular coupling, vehicle dynamics, and powertrain operations.
- Formulate drive schedule and vehicle control optimization problem for a homogeneous platoon (identical vehicles).
- Extend the methodology to heterogeneous platoons.
- Perform parametric studies for both homogeneous and heterogeneous platoons.

Approach

Problem structure

Define desired headway for all vehicles
\[ d_{i,\text{ref}} = 0 \]
\[ d_{i,\text{ref}} = d_{i,0} + h_{\text{dx}}v_{i,\text{ref}} \]

Select state variables and control inputs
\[ x = [d_1, v_1, \ldots, d_n, v_n]^T, \quad u = [F_1, \ldots, F_n, F_v]^T \]

Express actual and simplified platoon dynamics
\[ \frac{dx}{dt} = f(x, u) \]

Define residual function
\[ f(x) = \frac{dx}{dt} - f(x, u) \]

Linearize system and determine the error dynamics
\[ \frac{dx}{dt} = f(x) + \frac{\partial f}{\partial x}(x, u) \cdot dx + \frac{\partial f}{\partial u}(x, u) \cdot du \]

Approach, Continued
- Determine control inputs from control demands using adaptive ECMS (A-ECMS) on full powertrain model.
- Formulate drive schedule optimization problem subject to time and acceleration constraints.
- Complete optimization process.
- Optimize with simplified powertrain model.
- Optimize with full powertrain model.
- Apply solution explorations to avoid early convergence to narrow/local optimal solutions.

Results
- Parametric analysis for desired headway.
- Observed energy reduction.

Summary of energy savings

Future Work
- Expand parametric study to more parameters that could affect the performance of the platoon.
- Investigate effects of platoon heterogeneity.

Powertrain Architecture in This Study

Energy Reduction and Drive Cycle Designs in Optimization Process

From left to right: (desired constant headway) 3m, 10m, 30m