Assessment and Fusion of Commercial Vehicle Electronic Control Unit (ECU) Data for Real-Time Emission Modeling

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Outline

- Comprehensive Modal Emissions Model (CMEM)
- ECU data assessment
- Fusion of ECU data with CMEM
- Data transmission protocol
- Conclusions and recommendations

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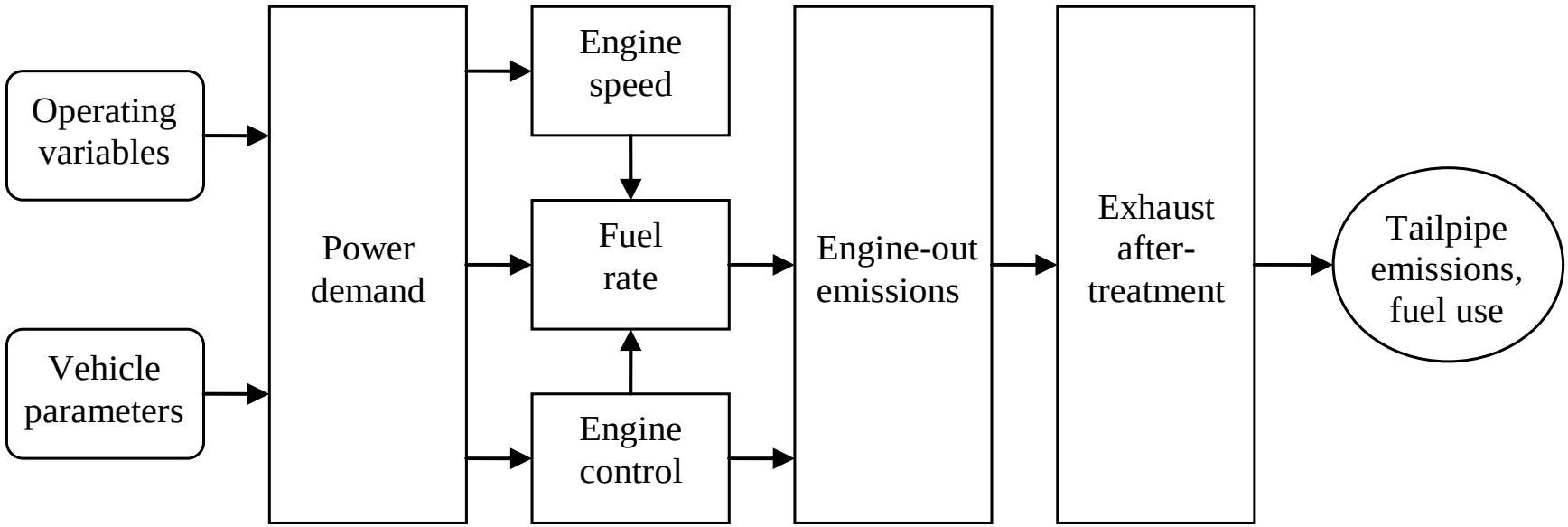
Comprehensive Modal Emissions Model

- UC Riverside has developed CMEM based upon extensive emission testing and modeling work.
- The entire fuel consumption and emissions process is broken down into components that correspond to physical phenomena associated with vehicle operation and emissions production.



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CMEM Inputs and Data Sources

- "Operating variables" are variables that describe the vehicle operating conditions, on a second-by-second basis.
  - Vehicle speed
  - Road grade
  - Accessory load (e.g., air conditioning, wipers, infotainment system)

- Second-by-second vehicle speed is usually measured (e.g., with a GPS data logger) or modeled (e.g., with traffic microsimulation software).

- Modern commercial vehicles generally are equipped to transmit operating conditions to their dispatch center.
  - Location and speed are readily available.
  - High-end tracking systems can generally access the engine data bus in the commercial vehicle electronic control unit (ECU).
  - Data bus standardization has already been achieved for commercial vehicles, i.e., SAE J1939.
  - Can CMEM input data be gathered directly from the commercial vehicle ECU?

ECU Data Scan

- 500+ data items were reviewed to identify:
  - Data items that can be used as inputs to the current CMEM, and
  - Data items that may be useful for next-generation emission models.

No.	Name	Unit	Description
1	Engine Fuel Rate	Liter Per Hour	Amount of fuel consumed by engine per unit of time.
2	Diesel Particulate Filter Active Regeneration Status		Indicates the state of diesel particulate filter active regeneration.
3	Particulate Trap 1 Soot Load Percent	Percent [0-100]	Indicates the soot load percent of particulate trap 1. 100% is the level at which active particulate trap regeneration should be triggered.
4	After-treatment 1 Diesel Particulate Filter Outlet Gas Temp	Celsius	Temperature of engine combustion byproducts leaving the diesel particulate filter exhaust in exhaust bank 1.
5	After-treatment 1 Exhaust Gas Temperature 1	Celsius	The reading from the exhaust gas temperature sensor located farthest upstream in the after-treatment system in exhaust bank 1.
6	After-treatment 1 Exhaust Gas Temperature 3	Celsius	The reading from the exhaust gas temperature sensor located farthest downstream in the after-treatment system in exhaust bank 1.
7	Exhaust Gas Temperature	Celsius	Temperature of combustion byproducts leaving the engine.

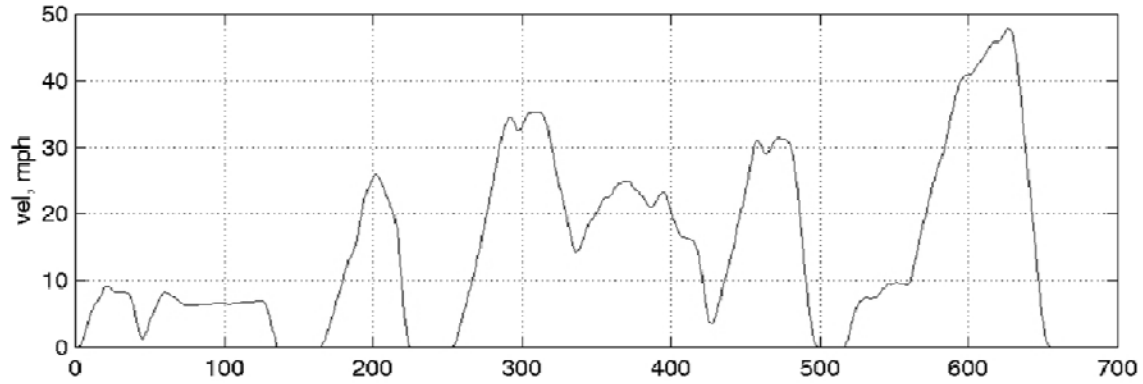
ECU Data Sample

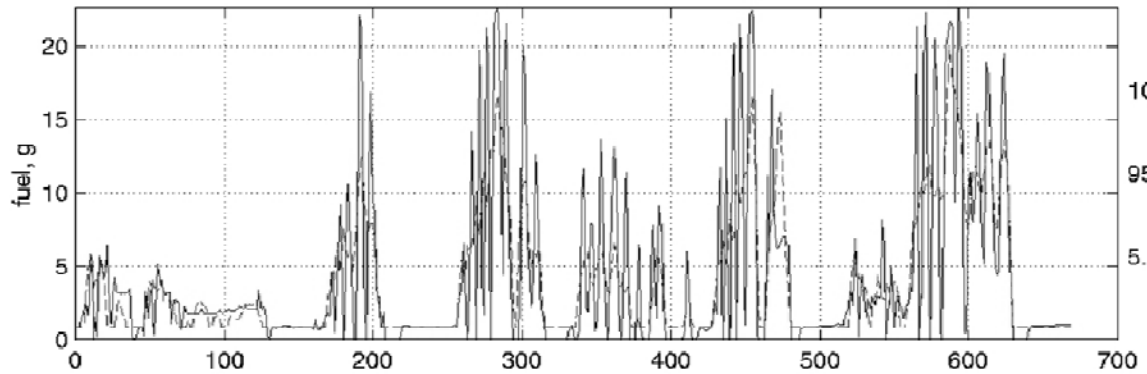
- An off-the-shelf tracking system was modified to extract additional ECU data items in 30-second intervals.

No.	Name	Unit
1	Accelerator1Position	%
2	Aftertreatment1DieselParticulateFilterOutletGasTemp	Fahrenheit
3	Aftertreatment1ExhaustGasTemp1	Fahrenheit
4	Aftertreatment1ExhaustGasTemp3	Fahrenheit
5	AmbientAirTemp	Fahrenheit
6	BarometricPressure	PSI
7	CoolantTemp	Fahrenheit
8	DieselParticulateFilterPassiveRegenerationStatus	4 States
9	EngineExhaustGasTemperature	Fahrenheit
10	EngineFuelRate	gallons/hour
11	EngineFuelTemperature	Fahrenheit
12	EngineLoadPercent	%
13	EnginePercentTorque	%
14	EngineSpeed	rpm
15	ExhaustGasRecirculation1ValvePos	%
16	FuelLevel	%
17	FuelPressure	PSI
18	IntakeManifoldPressure	PSI
19	IntakeManifoldTemp	Fahrenheit
20	Odometer	mile
21	ParticulateTrap1SootLoadPercentage	%
22	TotalFuel	gallons
23	TransmissionActualGearRatio	Double (0 to 64.255)
24	VehicleSpeed	mph

Example Data Comparison

- Modeled fuel rate is underestimated by 5.2%. Using fuel rate data from ECU directly can prevent this error to propagate and result in larger errors in emission estimates.





1002.19 gm (Measured total fuel use from ECU)

950.06 gm (Modeled total fuel use)

5.20 % diff

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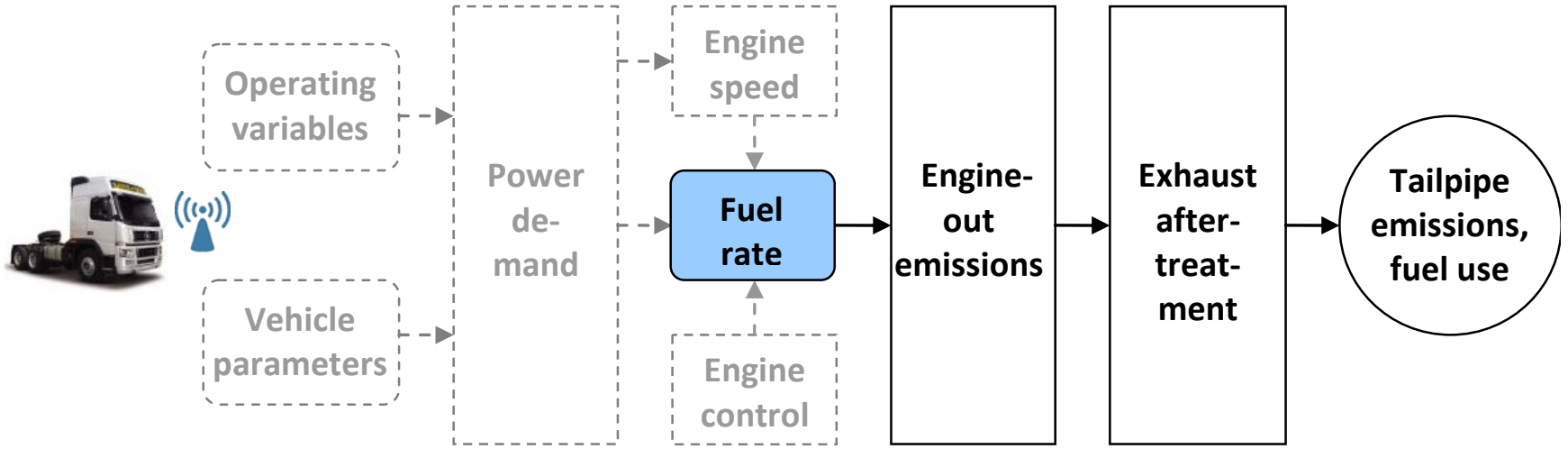
Emission Modeling - Centralized Architecture

- Trucks send fuel rate data from ECU (and location data from GPS) wirelessly to a central server.
- The server performs emission calculation, aggregation, and reporting.



- Need to design what data items to be sent and how to best send them in order to not take up a lot of bandwidth.

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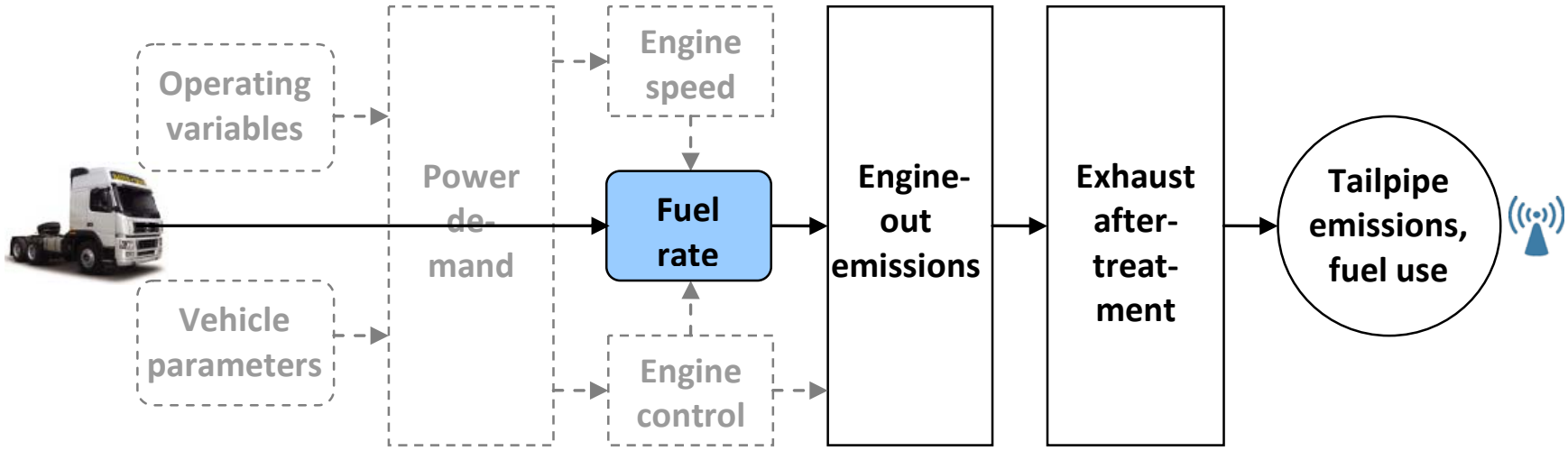
Emission Modeling - Decentralized Architecture

- Trucks use fuel rate data from ECU to perform emission calculation and aggregation on board before sending emission results (and location data from GPS) wirelessly to a server.



- Can also send emission results directly to roadside infrastructures or other vehicles in the proximity under the framework of Connected Vehicles.
- Require model calibration and telematics software programming for individual trucks beforehand.

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Considerations

- Data frequency
  - Second-by-second, or
  - Other pre-set intervals (e.g., 30 seconds), or
  - Trigger events (e.g., data sent at the end of each roadway link)?

- Geographical scale of data aggregation
  - Roadway link, or
  - Corridor, or
  - City or county?

- Data reduction techniques
  - Aperiodic messaging - data points sent only when there are significant changes in the data pattern
  - Data compression - similar to MP3 for music

Data Transmission Protocol – SAE J2735

- Define messages and message structures for DSRC-related applications.
- Existing data elements are not geared directly towards environmental applications, such as emission monitoring and reporting.

- However, some data elements can be useful. For example:
  - DE_Speed
  - DE_Acceleration
  - DE_AmbientAirTemperature
  - DE_Elevation
  - DE_VehicleMass
  - DE_J1939-71-Cargo Weight
  - DE_J1939-71-Trailer Weight
  - DE_J1939-71-Tire Pressure

- It is possible to develop new messages, data frames, and data elements within the framework of SAE J2735 to support other emerging applications.

Data Element: DE_EngineFuelRate

ASN.1 Representation:

```
EngineFuelRate ::=  INTEGER  (0..8191) -- Units of 0.1 g/s
            -- The value 8191 indicates that
            -- engine fuel rate is unavailable
```

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Conclusions

- Commercial vehicle ECU has many data items that are related to emission production. These data items can be extracted in real-time.
- The business relationship for the collection of ECU data from private fleets is essential. This is already in place and can be expanded.
- The CMEM model is well positioned to take ECU data as model inputs to improve the accuracy of emission estimates. This can be done in both centralized and decentralized (on-board) fashions.
- SAE J2735 provides a good foundation for ECU or emission data transmission protocol. New messages, data frames, and data elements may need to be defined to support environmental applications.
- Little work has been done on establishing the uses of fuel consumption and emissions data to better manage the transportation system.

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Recommendations

- Establish research programs to advance the science of vehicle emission modeling based on ECU data, and to explore innovative applications that take advantage of this new modeling capability to benefit the environment.

- Enhanced emission modeling research program would seek to answer such questions as:
  - How to improve the model to accommodate new data items from the ECU (e.g., air-conditioning and wiper status)?
  - How the exhaust conditions (e.g., exhaust gas temperature) and after-treatment technologies affect truck fuel economy and emissions?
  - How the aged engine or degraded components affect truck emissions?

- Innovative environmental applications research program would develop or further enhance environmentally beneficial applications such as:
  - Truck platooning
  - Truck tolling
  - Truck eco-routing
  - Truck active engine control

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