Connected Vehicles: Are We There Yet?

Angshuman Guin

March 2019
Fatalities and Fatality Rate per 100 Million VMT, by Year, 1975–2016

Sources: FARS 1975–2015 Final File, 2016 ARF; Vehicle Miles Traveled (VMT): FHWA.
10,874
DEATHS FROM DRUNK-DRIVING CRASHES IN 2017

29%
PERCENTAGE OF MOTOR VEHICLE TRAFFIC FATALITIES CAUSED BY DRUNK DRIVING IN THE UNITED STATES IN 2017

220
CHILDREN 14 AND UNDER KILLED IN DRUNK-DRIVING CRASHES IN 2017

20%
PERCENTAGE OF NIGHTTIME WEEKEND DRIVERS WHO TESTED POSITIVE FOR DRUGS IN THE 2013-2014 NATIONAL ROADSIDE SURVEY

481,000
PASSENGER VEHICLES DRIVEN BY PEOPLE USING HANDHELD CELL PHONES DURING THE DAY IN 2016

3,450
NUMBER OF PEOPLE KILLED BY DISTRACTED DRIVING IN 2016

90,000
MOTOR VEHICLE CRASHES INVOLVING DROWSY DRIVING IN 2015

Source of stats: NHTSA
Image source: https://www.denvergov.org/content/denvergov/en/vision-zero.html
Research shows the global market for connected cars could grow as much as 270% by 2022.

Source: https://www.electronicdesign.com/automotive/put-it-reverse-why-it-s-time-design-connected-cars-backward
Connected Vehicle Technology Battle

C-V2X (4G / 5G)
- Volkswagen
- Ford
- Audi
- BMW
- Daimler
- Ducati
- Baidu
- Qualcomm, Ericsson, Huawei, Intel, Nokia

DSRC
- Honda
- Toyota / Lexus
- Cadillac
- Nissan
- GM

While Ted Klaus, of Honda R&D Americas, told the 2018 AutoMobility LA show in November that the carmaker remains “agnostic” in the battle between 5G and DSRC, it’s clear the on-board Safe Swarm technology looks more geared to the latter rather than the former.

Source: https://www.tu-auto.com/honda-safe-swarm-v2x-tech-looks-dsrc-facing
Georgia Tech Partnership Projects

City of Atlanta / Renew Atlanta

Gwinnett County


Photo Credit: http://smartcities.gatech.edu/georgia-smart
GDOT Deployments

Current

Phase 1

Phase 2

Photo Credit: GDOT
North Avenue Smart Corridor

Connected Vehicle
- Vehicle Detection
- Smart Waste System
- Travel Safely App
- Automated Vehicle Demonstration
- Bike and Pedestrian Detection
- Smart Lighting

Connected Vehicle Equipment

On Board Unit (OBU)

Road Side Unit (RSU)

App Interface

Photo Credit: GDOT
Research Objective and Motivation (1)

What?

Hybrid traffic simulation model - mix of preprogrammed and real-time data-driven intersections

How?

An optimized real-time architecture that:

- Uses in-field detectors, SPaT, and BSM data to drive simulation signals and demand
- Generates travel-time, energy, and emissions KPIs in real-time
Why?

Assess feasibility of using a real-time data-driven transportation simulation model to provide dynamic operational feedback in a real world environment

Really why: Improve the quality of life of city stakeholders – residents, employees, and visitors
Fields of Focus Towards Smart City Vision

1. Smart City Vision
   Integration of smart technologies with physical infrastructure

2. Real-Time Traffic Simulation Model
   Real-time data integrated into operational analysis

3. Handling Large Amount of Data
   Use of big data concepts for injecting data into simulation
North Avenue Test Bed – DDDAS Approach

**DDDAS – Dynamic Data Driven Application Systems**

- **RSU** - Roadside Unit
- **OBU** – Onboard Unit
- **DSRC** – Dedicated Short Range Communication
  - V2R – Vehicle to Roadside Communication
  - V2I – Vehicle to Infrastructure Communication
- **WWAN** – Wireless Wide Area Network

*Communication between vehicle, roadside, and cloud may occur via DSRC or other WWAN application (e.g. cellular)*

**DDDAS Processing Loop**

- **Sense**: vehicle determine current position, speed, acc., etc.
- **Predict**: project likely future locations, energy, emissions
- **Adapt**: determine KPI, recommend driving and signal adjustment

---

**Notes:**

- **RSU** - Roadside Unit
- **OBU** – Onboard Unit
- **DSRC** – Dedicated Short Range Communication
  - V2R – Vehicle to Roadside Communication
  - V2I – Vehicle to Infrastructure Communication
- **WWAN** – Wireless Wide Area Network

*Communication between vehicle, roadside, and cloud may occur via DSRC or other WWAN application (e.g. cellular)*
Simulation Model - North Ave Smart Corridor

North Avenue NW Corridor

Real-time data driven signal controls and side street vehicle volume driven

Glen Iris

Ponce City Market

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
VISSIM - A microscopic, stochastic traffic simulation model that represents the real world dynamic traffic environment for freeways and streets

Models individual vehicle behavior, various traffic control devices, intersections and interchanges, dynamic demands, flexible network layouts, roadway geometry, merging, vehicle routing, etc.

Utilizes Psycho-physical car following model (Prof. Wiedemann, 1974 and 1999)
Model Architecture Primary Components

1. Inject real-time data into the simulation model
2. Run the traffic simulation model
3. Generate and visualize KPIs

- Dynamic link between three tasks
- Simulation runs faster than real-time operations
Simplified Architecture

Vehicle Count Data at Intersection (6 minute aggregates)

Data Driven VISSIM → Generate Simulated BSM → EPA MOVES Model

Signal Status (1 second)

Generate KPI → Visualization
Energy-Emission Computation Architecture

Energy and CO2 emissions profile based on Motor Vehicle Emission Simulator (MOVES) matrix is estimated in real-time using data from the trajectory output file.

Compute Energy and Emissions from Vehicle Position

Generate Heat Maps

- Energy Heat-maps every 60 seconds
- Emissions Heat-maps every 60 seconds
Energy and Emissions

- The USEPA’s MOVES model predicts energy consumption and emissions as a function of vehicle onroad operating conditions, expressed as vehicle-specific power (VSP)
- The modeling approach developed by Georgia Tech yields a huge multi-dimensional matrix of emission rates, from which individual vehicle and fleet emission rates can be quickly derived and applied at any modeling scale

\[
VSP = \left( \frac{A}{M} \right) v + \left( \frac{B}{M} \right) v^2 + \left( \frac{C}{M} \right) v^3 + \left( \frac{m}{M} \right) \left( a + g \times \sin \theta \right) v
\]

VSP = Vehicle Specific Power (KW/metric tonne)
M = Fixed mass factor for the sourceType (tonnes)
m = Source mass (tonnes)
A = Rolling resistance (kW/meter/second)
B = Rotational resistance (kW-sec²/meter²)
C = Drag coefficient kW-second³/meter³
v = Vehicle velocity (meters/sec)
a = Vehicle acceleration (meters/second²)
g = Gravitational acceleration (9.8 m/second²)
\( \theta \) = Road grade angle (radians or degrees, as needed)
Energy and Emissions

FTP VSP Bin Distribution

FTP Driving Cycle

X

Example CO₂ Emission Rates by VSP Bin

Energy Consumption

FTP Cycle:
63,684 kJ
60,361 BTU
0.52 Gallons
Result and Discussion: Model Sensitivity to Real-Time Input

Energy and Emissions
- Energy and emissions estimated from preset and real-time inputs were compared
- Results were comparable as shown in the scatterplots and CDF

![Energy Consumed vs Travel Time: Route 3](image)

![Energy CDF for Route 3](image)
Result and Discussion: Model Sensitivity to Real-Time Input

Vehicle Travel Time
- Travel times compared for 10 random seeds of simulation with preset and real-time inputs
- Travel times varied within plausible bounds

Average Vehicle Travel Time versus Simulation Time Intervals Plots for

(a) Westbound Route 4

(b) Eastbound Route 6
Status…

- Digital Twin is Possible - Dynamic integration of real-time field data
- Critical Component is the Data Streams (Volume, Variety, Velocity, and Veracity)
  - Data Sources
  - Level of aggregation
    - Time
    - Space
  - Missing data streams
    - Temporary
    - Permanent
  - Data accuracy
  - Data storage
Next Steps

- Scaling – moving toward distributed simulation solution
- Validation of KPIs - Energy and CO$_2$ emissions generated from the simulation model to be compared with in-field connected vehicles
- Fast-forward simulation!
Connected Vehicle Technology Master Plan

Project Vision

• Set the standard for the application of connected vehicle technology

• Improve traffic congestion and reduce crashes

• Have broad applicability across the Atlanta Region and Country

• Support goals of the recent Comprehensive Transportation Plan, Connect Gwinnett Transit Plan, and Intelligent Transportation Systems Master Plan update
Peachtree Industrial Boulevard Smart Corridor

- Infrastructure maintained by Gwinnett County
- Has activity centers and rural sections
- Passes through 7 cities
  - Norcross, Peachtree Corners, Berkeley Lake, Duluth, Suwanee, Sugar Hill and Buford
- 6 fire stations within 1.5 miles
- Identified for Transit system expansion

Photo Credit: Gwinnett County
Available Signalized Intersections for CV Deployment Within Corridor Impact Zone
Potential Applications (Safety and Mobility)

Emergency Vehicle Preemption (EVP)

Transit Signal Priority (TSP)

Freight Signal Priority (TSP)

Mobile Accessible Pedestrian Signal System (PED-SIG)

Rail Intersection Blocked Alert

Construction and Maintenance Vehicle Alert

Signal Phase and Timing (SPaT)

Information
What?

Evaluate the potential for improvements in safety and operations of emergency response vehicles in and around the Peachtree Industrial Boulevard corridor with Connected Vehicle technology deployment.

- Reduction in delay in response
- Improvement in mobility
- Improvement in safety
- Implementation strategies for maximizing benefits

Photo Credit: https://www.cnn.com/2013/04/10/us/georgia-firefighters-hostage/index.html
How?

Bottleneck analysis to identify congestion hotspots for
- Emergency Vehicles
- Passenger Cars

Delay pattern analysis for First Responder Vehicle paths
Data

- GPS data collection on 15 Firetrucks from 6 Fire Stations
- GT equipment deployed on Gwinnett county firetrucks
- 2-4 months of second by second location data
Analysis

• Delay patterns for Emergency vehicles
• Response request patterns (response logs)
• Multiple firetruck arrival patterns at intersections
• Identification of intersection approaches with
  • Maximum delay
  • High frequency of potential preemption demand
Benefits

Signal Preemption with Connected Vehicle

- Multi-signal look-ahead preemption
- Queue flush downstream of Emergency Vehicle
- Minimization of Congestion Impacts on passenger cars

Photo Credits
https://www.its.dot.gov
https://ascelibrary.org/doi/full/10.1061/JTEPBS.0000062
https://www.semanticscholar.org/paper/GPS-and-ZigBee-based-traffic-signal-preemption-Kodire-Bhaskaran/b1d0e1034d5c147b44f6fb51ab06d722b30acaa
Connected Vehicles: Are We There Yet?

Angshuman Guin
angshuman.guin@ce.gatech.edu
1. Atkins, 2018. [https://www.youtube.com/watch?v=QtFl800e0XU](https://www.youtube.com/watch?v=QtFl800e0XU),
2. CEE at Georgia Tech, 2018.
8. IPAT, CEE at Georgia Tech, 2018?