CONNECTED VEHICLES AT EARLY DEPLOYMENT – BRINGING VALUE TO EARLY USERS

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SOCIETAL BENEFIT

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.
HOW LONG?

Noblis Study performed for USDOT: Projected Market Penetration - Single Vehicle Exposure

High consumer adoption
CUSTOMER EXPERIENCE?
SOLUTION?

- Connect vehicles with something else → Vehicle to Infrastructure (V2I)

- Find innovative V2V applications that provides early customer value
V2I COMMUNICATIONS

- Stationary road side unit provides a “reliable communication point to vehicles
- Sends information about the road infrastructure
- May deliver dynamic information gathered from vehicles or backbone
- May offer additional value by collecting and analyzing road data
V2I- RED LIGHT VIOLATION WARNING (RLVW)

- RSU broadcasts:
  - Geometry of the intersection (MAP message)
  - Traffic signal phase and time (SPaT)

- Approaching connected vehicle received the messages and:
  - Map matches its location to the intersection
  - Determines whether or not the driver will run a red light and warn the driver
**V2I-SPAT**

- **status**: provides the status of the traffic signal controller in the intersection such as fixed time operation only (no actuated traffic control) and SPaT information availability from the controller.

- **timestamp**: an optional millisecond timestamp in coordinated universal time (UTC) at which the current SPaT is constructed.

- **enabledLanes**: an optional list of active lanes for driving in the current intersection (have their RevocableLane bit set to one). This is used to describe different regulatory states for the driving maneuvers in the intersection. An example of such regulatory states would be a rightmost lane that has the right turn on red permission activated and deactivated at different times of the day.

- **states**: a list of different movement states in the intersection with a description of their current phases (and possibly their future phases):
  
  - **signalGroup**: the identifier of the lanes group which is represented in the current movement state.
  
  - **state-time-speed**: this field contains the core information about SPaT data for up to 16 movement events including:
    
    - **eventState**: a representation of the multiple states (e.g. permissive, stop and proceed, stop and remain) associated with different phases (red, green and yellow).
    
    - **timing**: an optional field that provides the timing details of the phase being represented in the current movement event. Examples of this timing information include phase start time, minimum and maximum end time (given that the end time may get extended in actuated traffic signals), and next time representing an estimate of when the next phase will start. Accurate prediction of phases timing in non-fixed time traffic controllers is very challenging as can be inferred from these different times complicating V2I applications development for such controllers.
V2I-ADDITIONAL SPAT/MAP APPS

- Eco-approach and departure (greenwave)

- Pedestrian in crosswalk
V2I- CURVE SPEED WARNING

- The purpose of this application is to reduce vehicles skidding or rolling over at curve as a result of navigating the curve at a high speed.
- RSU sends curve information such as curve geometry, banking angle, the radius of curvature, the coefficient of friction to the vehicle.
- The vehicle then map matches itself to the curve approach using geometry data received from infrastructure.
- Afterwards, the vehicle can use its kinematics and as well as the curve data to estimate the critical speed at which the vehicle would slip or rollover whichever is smaller.
- The driver can then be alerted if the speed surpasses a certain threshold below the critical speed.
V2I- REDUCED SPEED WORK ZONE WARNING/LANE CLOSURE

- This application is intended to provide information to the vehicle about an upcoming work zone.
- Road workers safety in construction areas is a major concern for road owners and operators agencies.
- Also, lane closures in these areas may create backups generating additional problems for these agencies.
- For example, a “reduced speed sign where workers are present” sign may exist but it may difficult for the driver to gauge workers presence due to road geometry, lighting conditions or weather conditions.
- Also, a warning originating from the vehicle in case of work zone regulations violation may result in a stronger impact on the driver compared to an advisory sign.
V2I- BASIC INFORMATION MESSAGE (BIM)
V2X LOW PENETRATION APPS

- Hard safety (collision warning) is the primary benefit of V2X

- However, connected vehicles extend the capability of information collection

- Thus V2X opens up more opportunities for innovative advanced driver assistance systems (ADAS)
HOW TO EVALUATE APPS PERFORMANCE?

- It is difficult to deploy and test apps benefit to the driver under different penetration rates
- Simulation platforms present themselves as potential alternative for evaluating such apps
- Microscopic traffic simulations provides means to simulate large traffic networks while controlling each individual vehicle
- The simulation can be calibrated to resemble the real traffic flow and speed
EXAMPLE- LANE SPEED MONITOR (LSM)

- LSM is intended to assist the driver in selecting the lane with the best traffic flow condition.
- The guidance relies on the estimate of downstream lane-level vehicle states, i.e., instantaneous speeds, obtained from dedicated short range communication.
LSM- LANE-LEVEL TRAFFIC SPEED ESTIMATION

- Based on the real-time information, lane-level traffic speed that may affect the lane selection decision by: 1) minimum speed; and 2) average speed.

- Average lane speed can be calculated by:

\[ \bar{v} = \frac{\sum_{t_0}^{t_0+\Delta t} VMT(t)}{\sum_{t_0}^{t_0+\Delta t} VHT(t)} \]
LSM- SIMULATION SETUP

- PARAMICS traffic simulator was used
- A section of the SR-91E was modeled, which consists of a 15-mile corridor between the Orange County Line and Tyler Street in Riverside, California
- The number of lanes ranges from 4 to 6 and there are 9 pairs of on-/off-ramps.
- The speed limit is 65 miles per hour, and traffic conditions
- Traffic demands, origin-destination (O-D) patterns, and driving behavior have been calibrated to match that of a typical weekday morning
Customer survey (including 1453 drivers as respondents) was used to calibrate the simulation on:

- The preferred information update frequency
- The maneuver (i.e., lane change or not) that drivers will take.
The following major measures for effectiveness (MOEs) of the developed apps were used:

- **Conflict frequency (CF):** the number of conflicts (CN) for equipped vehicle relative to other vehicles. A conflict corresponds to TTC below 1.5 seconds.

\[
CF = \frac{MOE_e - MOE_{ue}}{MOE_{ue}} \times 100\%
\]

where; \( MOE_e \) = the metric of equipped vehicles, CN caused by equipped vehicles; and \( MOE_{ue} \) = the metric of unequipped vehicles, CN caused by unequipped vehicles.

- Statistical analysis demonstrates the high correlation between conflicts and crashes\(^2\)

\[
\frac{Crashes}{Year} = 0.119 \times \left( \frac{Conflicts}{Hour} \right)^{1.419}
\]

- **Average speed (\(\bar{v}\)):** the average speed improvement of equipped vehicles compared to other vehicles

\[
\bar{v} = \frac{\sum_{i=1}^{n} \sum_{t=1}^{T_i} VMT_{i,t}}{\sum_{i=1}^{n} \sum_{t=1}^{T_i} VHT_{i,t}}
\]

where; \( VMT_{i,t} \) = vehicle miles traveled for vehicle \( i \) in timestep \( t \), miles; and \( VHT_{i,t} \) = vehicle hours traveled for vehicle \( i \) in timestep \( t \), hours;

LSM- SAFETY RESULTS
LSM- MOBILITY RESULTS
OTHER USE CASES

- Predicting traffic abnormality using crowdsourced data
- Sensor data sharing
CONCLUDING REMARKS

- V2X systems are expected to provide tremendous safety benefits

- We should encourage early adopters by providing day 1 benefits

- Other communication modes as well as non traditional V2X apps may help in incentivizing drivers to embrace the technology
REFERENCES


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THANK YOU!