NEW YORK CITY
CONNECTED VEHICLE
PILOT PROJECT

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New York City is aggressively pursuing “Vision Zero”
“Traffic Death and Injury on City streets is not acceptable”
Vision Zero Goal: to eliminate traffic deaths by 2024

NYC CV Pilot will evaluate

- Safety benefits of CV technology
- Address CV deployment challenges
  - With a large number of vehicles & types
  - Issues associated with the dense urban environment
V2I applications work where **infrastructure is installed** (along highlighted streets).

V2V applications work **wherever** equipped vehicles encounter one another.

**The CV project leverages the City’s transportation investments.**

**Advanced Traffic Controller (ATC)**

**NYCWiN**

**Traffic Control System**

**LOCATIONS (MANHATTAN, BROOKLYN)**
Vehicles
- Up to 8,000 fleet vehicles with Aftermarket Safety Devices (ASDs):
  - ~5,800 Taxis (Yellow Cabs)
  - ~ 700 MTA Buses
  - ~ 1,050 Sanitation & DOT vehicles
  - ~ 400 DCAS vehicles

Pedestrians
- Pedestrian PIDs
  - Visually Impaired
  - 100 Subjects – PID
- PED in Crosswalk
  - 10 Fully Instrumented Int.

Operating Statistics:
- Vehicles are in motion or active ~14 hours per day!
- Average taxi drives 197 miles per day
- Fleet total Vehicle Miles Traveled:
  - >1.3 Million Miles per day
  - ~40 Million Miles per month
SAFETY APPLICATIONS

Vehicle-to-Vehicle (V2V) Safety Applications
- Vehicle Turning Right in Front of Bus Warning
- Forward Collision Warning
- Emergency Electronic Brake Light
- Blind Spot Warning
- Lane Change Warning/Assist
- Intersection Movement Assist

Vehicle-to-Infrastructure (V2I) Safety Applications
- Red Light Violation Warning
- Speed Compliance
- Curve Speed Compliance
- Speed Compliance/Work Zone
- Oversize Vehicle Compliance
  - Prohibited Facilities (Parkways)
  - Over Height
- Emergency Communications and Evacuation Information (Traveler Information)
**ADDITIONAL APPLICATIONS**

**Pedestrian**
- Mobile [Visually Impaired] Ped Signal System – *navigation assistance*
- Pedestrian in Signalized Intersection Warning – *to vehicles*

**Traffic Management**
- CV Data for Intelligent Traffic Signal System
  
  Roadway segment travel times

**Operations, Maintenance, and Performance Analysis**
- RF Monitoring
- OTA Firmware Update
- Parameter Up/Down Loading
- Traffic data collection
- Event History Recording
- Event History Up Load

*To Evaluate the benefits*
Where are we now?
PROTOTYPE INSTALLATION AND TESTING

- Developing MAP message Content (USDOT tool)
- RSU - Planning installation sites
  - Establishing Installation “partners”
  - Optimizing for triangulation and location accuracy testing
- ASD - Developing vehicle installation kit designs
  - Working with vendors – NY Specific Software
  - Working with Fleet owners – Establish installation procedures
  - Running samples – awaiting prototypes – checking coverage and interference

~360 Roadside Units
36 Units at key locations
**Vehicle Installation**

- 80 Samples installed in fleet vehicle
- Testing through the glass and drilled mountings
- Working with various different vehicle types
- Verifying calibration and RF radiation patterns
NYC DOT INSTALLATIONS

- NYC DOT Installation
  - Various Makes/Models/Year NYC DOT vehicles are being equipped with prototype ASDs in order to fine tune and optimize installation methods and approaches
  - NYC DOT Vehicles 770
    - Toyota
      - Prius, RAV4
    - Ford
      - Fusion
      - F-150 – F-550
    - Chevrolet
      - Silverado
      - HD3500
      - Economy
The buses were installed to test RF DSRC communication with light vehicles, and to develop an installation template.

Key element for MTA – Through the glass Antenna
Taxi Installations are estimated at 5000 vehicles between the participating fleet owners

- 2 authorized technology installers
- Taxi fleet is expected to include:
  - Toyota
  - Prius
  - Sienna
  - RAV4
  - Nissan NV 200
Some Lessons Learned
and Challenges
Pilot vs. Deployment

- Ambiguities within the standards
  - Need for “how to use” in many cases!
  - Complexity of deploying the security (1609.2) is significant
  - Protocols & Data elements must be the same for interoperability
- Three pilots worked together
  - Review of all standards
    - insure same “objects” for the same purpose and meaning
  - Requirements for messages all the same
    - Optional vs. Mandatory
- Product certification (US DOT Requirement) – OmniAir and their program
  - Trusted devices - - protect the integrity of the trusted environment
  - Fundamentals – messages, channel usage, security usage, timing, etc.

Interoperable Incremental Deployment
Need Standards for the Applications

- “Demonstrations” by 6 vendors
  - Fundamental operation ~same
  - **BUT** – Differences
    - Configuration management
    - Operating parameter management
      - “Intensity” of application
  - “Need for ability to test applications
    - Controlled environment
    - Need “testable” requirements for applications – Precision!

- Need more extensive “**certification**” that applications meet some minimum?
CYBERSECURITY IS FUNDAMENTAL TO CV DEPLOYMENT

CV depends on a “trusted” environment - vehicles & infrastructure

- Message authentication (BSM, SPaT, MAP, TIM, etc…)
- Data encryption of (To preserve privacy)

- Requires Equipment Certification
- Organizational IT security
  - Physical security of the TMC systems
  - Agency login and security practices

- Protection for all connections and data exchanges – need to Secure
  - TMC-ATC, ATC-RSU, TMC-RSU - - DTLS with X.509 Certificates

- CV Hardware Impact
  - Hardware Security Module (HSM) for the TMC system
  - HSM inside the ASD/OBU and RSU
**SECURITY ISSUES – EXTEND EVERYWHERE**

**Connected Vehicle has security requirements – well defined and standards**

- **Issue**
  - All of the ITS and IT systems need to adjust operations
  - Classic ITS – adopted security measures
  - Certificate management
  - Certificate Revocation Lists
  - Need for real time access to SCMS
  - Secure Boot of all field devices
    - OBU, RSU - Traffic Controller?
  - Physical security re-visited (cabinet keys)
  - Password policies
  - Firewall rules - etc.
  - Misbehavior detection coming soon!

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<tr>
<th>Item</th>
<th>Connection Description</th>
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<tbody>
<tr>
<td>0</td>
<td>TMC Pass Through (random as needed)</td>
</tr>
<tr>
<td>0</td>
<td>TMC Controlled Push or Pull (long periods)</td>
</tr>
<tr>
<td>0</td>
<td>E-mail or File Transfer (infrequent)</td>
</tr>
<tr>
<td>0</td>
<td>Planned for Future</td>
</tr>
<tr>
<td>0</td>
<td>TMC Pull (hourly)</td>
</tr>
</tbody>
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**Connection Diagram for NYC CV Pilot System**

Filename: NYC CVPD Connections IPv6-I Pv4_v2.vsd
SCALEABLE AND RELIABLE DEPLOYMENT

- 100 vehicles – no problem
- 8,000 revenue generating vehicles
  - Cannot physically access - $$$ per minute/hour etc.
  - Project specifications stressed reliability and un-manned recovery
  - Work with the “experts” for installation
- Applications subject to changes
  - Schedule cannot wait until everything is “perfect”
    - 23 weeks to deploy
  - Needed reliable means to update and add applications
  - Needed reliable means to “tune” the applications
  - Likely future changes in communications media and standards
Push (20 MB+) software updates to 8,000 vehicles efficiently over DSRC

- No WiFi and No LTE/4G

Developed Scheme to support broadcast updates

- ASD’s read WSA from Control Channel
- Directed to Service Channel if RSU supports Updates
- RSU broadcasts available updates
  - Some updates broadcast (continuous) some available by unicast
  - Vehicles initiate update using unicast or monitor broadcast streams
  - Using licensed software to manage the efficient breakdown and assembly
  - Efficient Channel Use
  - Privacy is maintained
CHALLENGE – LOCATION ACCURACY

- Location Accuracy –
  - Urban Canyons pose issues *(both relative V2V and absolute V2I)*
    - Dropout at underpasses
    - Loss of GPS lock
  - ASD vendor demonstrated RSU triangulation
  - Established Compound ASD requirements:
    - Dead reckoning,
    - Triangulation with static DSRC locations,
    - Map matching,
    - Tethered to the vehicle - vehicle interface
  - Testing is ongoing 10 RSU’s worst locations
RSU TRIANGULATION

V2X Locate uses

- standard RSUs and OBUs
- standard V2X over the air messages to determine position of vehicle by ranging

RSU location known — Requires High Accuracy! thanks to standard advertisements

Fuses vehicle sensors and GNSS when available.

* Based on recommended deployment set-up
OTHER TECHNICAL CHALLENGES

- Adjusting the applications for 25 MPH and Freeway speeds

- CAN/J (vehicle) Bus Interface –
  - Vendor (OEM) resistance to providing necessary information
  - Purchasing a gateway device

- Many different vehicle types and model years
  - Varied installation kits
  - Fortunately – they are fleets – we drill holes! – and - - -
    - Agency can establish terms and conditions of support!
FLEETS VS. OEMs

- There is a need for standard [secure] vehicle interface
  - Steering Wheel Angle, Yaw Rates, “hard breaking”
  - Speed, roadway friction, etc.
- Aftermarket devices NEED access to the vehicle data bus
  - Speed, directional, minimum – location enhancement
  - Transitional period to embedder safety systems
- Instead – OEMs reacting to “security” scares – making it harder!
- Future: CV can augment AV –
  - Regulations, Intersection operation, Map Dynamics (lane changes, construction, crash/incident/special event mitigation
- NYC – vehicle manufacturer cooperation (data interface and design sharing) – non existent!
- 2 Vendors – 2 different approaches – headache for everyone!
DATA RECORDING ISSUES

NYC was not an R&D project!

What to collect

- What could I collect?
  - What is the raw data available
- What Do I need?
  - What is the intended use of the data?
- What should I collect?
  - To Justify the costs!

What are the costs

- Backhaul communications
- Storage
- Processing
- FOIA requests
- Subpoena

Privacy Issues

- Prohibition of keeping PII
- Combination with other sources.
- Data Ownership
EXAMPLE – TRAVEL TIME

- Block Spacing ~70M Feet (230’)
- 20 MPH – 30 feet per second
- DSRC Range ~300M (1000’)
- BSMs Xmit @ 10 Hz
- Time between blocks ~8 seconds
- BSMs transmitted 80
- BSMs needed 2 - 3% a 97% reduction

**Edge computing @ RSU**

- RSU looks for vehicle entry to Intersection
- Transmits one BSM to TMC per vehicle
- TMC matches BSM – Vehicle ID
- TMC computes travel time
- Or TMC data times out - -
OPTIMIZED INTERSECTION CONTROL

- Edge computing @ traffic controller
  - Queue length - Stopped Vehicles
  - Vehicle speeds – Reported in local BSM
  - Priority and preemption – With local communications
  - Incident detection – deviation around obstacle
  - Pedestrian presence

- Send to TMC only what needs to be used
  - Platoon management (Freight priority)
  - Alternate route management/diversion
  - Incident detection
  - Travel Times (average link speed)
  - EVP progress (if not provided directly by the vehicle)
1.2 M vehicles in NYC broadcast **83 TB/day**

13,000 NYC intersections broadcast **3 TB/Day** SPaT & Map

8,000 vehicles collect **2 TB BSM data/day**

Data **needed** for benefits analysis:

- How many crashes per day did we prevent
- How many crashes per day did we mitigate

Edge computing – Onboard Unit (OBU)

- OBU monitors vehicle operation (S, Yaw, etc.)
- OBU monitors surrounding vehicles’ operation
- OBU assesses threats
- OBU alerts driver to mitigate threat
- OBU records what the caused alert and driver actions
“Alert” triggers and event record data collection

All of the data collected during $T_b$ is transferred to the event record, and after the trigger the data is collected and added to the record until $T_b$ expires.
DATA REDUCTION AND PRIVACY PROTECTION

Magnitude of Data

- Instead of 2 TB – only 116 GB per day
  - 17 times less – and more useful detail (@4 events/hour)
  - Includes SPaT and MAP information
  - @1 event / hour / vehicle = 29 GB/day or 67x reduction!

Privacy Concern

- If BSM data were to be collected - -
  - Provides vehicle locations at 0.1 second intervals
  - Time-of-day Stamped to 0.1 second accuracy
  - Police Records indicate “final position” of vehicles and time of day
  - CV data could be used to recreate the accident scene
- Even though CV vehicle ID is randomly changed – the raw data can be tracked to an individual vehicle
Obfuscation of OBU Action Logs

- Obfuscation process to scrub precise time and location data
  - Relative details retained
  - Non-obfuscated data will be destroyed following the obfuscation process
OTHER EXAMPLES – OPERATIONS DATA

- **RF Data – Proactive Analysis**
  - Records first and Last BSM heard from each OBU
  - Time-out to find dropouts
  - At 1000 ft. vehicle “hears” RSU for 50 seconds
  - Actual BSMs from that vehicle – 500
  - Assuming 4 dropouts – actual BSMs needed – 8 or 2%
  - Edge computing RSU – monitor OBU keep first/last
  - Same for OBU – 98% bandwidth reduction!
  - Only 8 BSMs actually captured

- **Guess who I saw today**
  - Track other OBUs seen throughout the City
  - Approximately 2 bytes per encounter
The CV technology *could* make “mountains of data” available – but there is a cost

- DSRC Channel time
- Cellular media monthly limitations
- Processing and storage
- Retrieval (FOIA) & Subpoena

**NYC pilot deployment project**

- Tailored data collection to meet needs
- Concept is to distribute processing to the edge
- Added RSU locations to collect data

**NYC System – DSRC only V2I**
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Visit CV Pilot and Pilot Site Websites for More Information:

- CV Pilots Program: http://www.its.dot.gov/pilots
- NYCDOT Pilot: https://www.cvp.nyc/
- Tampa (THEA): https://www.tampacvpilot.com/
- Wyoming DOT: https://wydotcvp.wyoroad.info/