New York City’s Connected Vehicle Pilot Deployment Project

Highlights and a look at the complexities of an end-to-end CV system

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Before you start a *Connected Vehicle* project

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*Lessons from the - The New York City Connected Vehicle Pilot Deployment Project*

understand the whole picture!
Outlook

Traffic Controller → RSU → SPaT → Done?  Not!

This presentation will examine [some of] the complexity of CV deployment

- Quick overview of the NY project
- Overview of the end-to-end systems to support CV
- A more detailed look at the issues:
  - Intersection “systems”
  - Vehicle “systems”
  - Back office “systems”
  - External “systems”
  - Backhaul considerations
- Data collection considerations
- Security Considerations
New York City’s
Connected Vehicle Pilot Deployment Project
Quick Overview

This is a **DEPLOYMENT** project [driven by R&D]!

“After more than a decade in trials, proof of concept, etc. the pilots will leverage and deal with the issues of practical deployment”

Big, ambitious plans:

- Large fleets to get many vehicle interactions
- Identify dense urban (canyon) environment solutions
- Assess CV technology’s application for Vision Zero
8,000 fleet vehicles with Aftermarket Safety Devices (ASDs/OBUs) *(Initially started at 10,000)*
- Taxis (Yellow Cabs)
- MTA Buses
- Sanitation & DOT vehicles
- DCAS vehicles

100 Pedestrian Information Devices (PIDs)
- Visually Impaired Navigation

400 Roadside Units (RSU)
- Manhattan Avenues
- Manhattan Cross Streets
- Flatbush Avenue
- FDR
- Support locations (where vehicle linger)
  - Airports,
  - River crossings
  - Terminal facilities
  - Additional to support location accuracy

Source: USDOT
Overall Deployment Concept

ASD – Aftermarket Safety Device (OBU)
RSU – Roadside Unit (includes DSRC radios)
NYCWiN – New York City’s Wireless Network
SCMS – Security Credential Management System
IE – Independent Evaluator
RDE – Research Data exchange
TMC – Traffic Management Center
NYC CV Safety Applications

Vehicle-to-Vehicle
- 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
- Red Light Violation Warning
- Speed Compliance
- Curve Speed Compliance
- Speed Compliance/Work Zone
- Oversize Vehicle Compliance
  - Prohibited Facilities (Parkways)
  - Over Height warning
- Emergency Communications and Evacuation Information

Pedestrian Applications
- Pedestrian in Crosswalk (RSU)
- Visually Impaired Crossing (PID)

Foundation of Operations, Maintenance, and Performance Analysis

Other Applications
- OTA Firmware Update
- OTA Uploading of Data Collected
- Application Parameter Modifications (Tuning)

Customized Applications

Data Collection:
- CV Data for Intelligent Traffic Signal System
- RF Monitoring
- Traffic data collection
- Event History Recording
- Privacy protection
V2V applications work **wherever** equipped vehicles encounter one another.

V2I applications work where **infrastructure is installed** (highlighted streets).

Additional Sites not Shown:
- FDR north to Triboro Bridge
- Queensboro (59th St) Bridge Intersections (4) in Queens
- Williamsburg Bridge Intersections (2) in Brooklyn
Connection Diagram for NYC CV Pilot System

- **NYCWIN**
- **Wired Network**
- **DSRC**
- **4G/LTE Carrier**

**Icon Legend**
- 0: TMC Pass Through (random as needed)
- 0: TMC Controlled Push or Pull (long periods)
- 0: E-mail or File Transfer (infrequent)
- 0: Planned for Future
- 0: TMC Pull (hourly)

**Diagram Elements**
- **Traffic Controller**
- **HUB**
- **POE Inserter**
- **Wireless Router**
- **Network Operations Center**
- **NWS**
- **SCMS**
- **16 HSM**
- **TMC**
- **SDC**
- **Stakeholder Systems**
- **RTCM Stations**
- **RSU Vendor**
- **ASD-1 Vendor**
- **ASD-2 Vendor**
- **Amazon Cloud**
- **NYU**
- **PID Vendor**
- **400**
- **100**
- **GPS**

**Connections**
- Connections are represented by lines with icons indicating the type of communication.

**Note:** The diagram illustrates the connectivity and flow of information within the NYC CV Pilot System, with various nodes and interconnections highlighting the system's infrastructure and data pathways.
The Roadside Infrastructure

- **ATC Software Upgrades**
  - Export SPaT information – to TMC/RSU
  - Configure PED information (SPaT)
  - NTCIP 1202v3 or Battelle 2009 “Blob”
- **Security**
  - TMC to ATC: (DTLS, TLS, VPN ...)
  - ATC to RSU: DTLS – SNMPv1? SNMPv3?
  - TMC to RSU: DTLS – SNMPv3
  - Manage the certificates X.509
  - **Where are messages “signed”**
    - RSU (SPaT), TMC (MAP, TIM)
- **OTA** software updates (RSU & ASD)
- OTA log files retrieval from ASD
- Managing WSA/PSID/Channel usage
- **Pedestrian Detection** for PED in crosswalk
- PoE for RSU and proper surge protection
  - Verify proper power grounding
- **Network interface**
  - Port mapping
  - IP address assignments/Subnetworks
  - Security management
- **MAP message** generation – *Pedestrian Info*
- Precision location of the RSU (X, Y, Z)

- **Data Collection** (Edge Computing)
  - Event data
  - RF Data
  - System log data
  - Scalability
- Privacy considerations
  - **Encryption**
- Spare parts and maintenance plan
- What specification? 4.1 modified?
  - Custom Developed – for NYCDOT
Other Roadside Infrastructure Considerations

- **Testing of the “revised” ATC software**
  - Timing relationship SPaT data and the actual timing (PCAP, Sniffer, Wireshark)
  - Check for timing disruption due to communications loading
  - Timing during transition, EVP, TSP, CIC, Adaptive control, clock changes, etc.

- **Network connectivity**
  - IPv4 or IPv6 – Proxy or Firewall Gateway – SCMS, AWS (MQTT)
  - Router and switches – Config. Security
  - Compatibility with other network traffic – Video, ETC readers, ...

- **Mounting Structures**
  - Line of Sight requirements – optimal for traingulation
  - Mast Arm – interference with signal heads etc.
    - Wind loading
    - Dead weight
    - Other co-hosted devices (signs, antenna, video)
  - In NYC – Parades move mast arms – indexing for proper orientation
  - Changes to the hardscape
    - Scaffolding for façade maintenance
    - Changes in Vegetation

- **Cross Intersection RSU wiring link**

- **Location Accuracy – Urban Canyon – placement of RSU**
  - RSU Triangulation – Time of Flight
    - Specific chip set
    - Affects WSA frequency of transmission

- **Installation Crews – Contract or Agency (NYCDOT)**
Vehicle Equipment Considerations

• **CAN Bus Interface**
  - Existing devices (e.g. Geotab)
  - Interference with CAN bus
  - Passive vs. Active interface
  - Manufacturer’s cooperation – *(Toyota helped us)*
  - What data is available – what do you need
  - Future Encryption – “right to repair”
• **Device calibration (Inertial Navigation Parameters)**
• **Antenna Installation**
  - Shark Fin - Drill vs. no drilling
  - Diversity (heavy vehicles)
  - Through the glass (Buses)
• Make sure the vehicle is OK **BEFORE** you start
  - Disconnect Battery **BEFORE** install
• **Professional Installation Companies?**
  - Consider mobilization complexity
• **Power considerations**
• **Connection to turn signals**
• **Professional Installation Companies?**
  - Consider mobilization complexity
• **HMI – Audio, Visual, (both), Mounting, Speakers**
  - Confirmation of alerts
  - Distraction issues – know your stakeholders
• **Privacy & liability issues**
  - Consent agreements
  - Public Agency Vehicles/Private Vehicles
  - 48 Hour self purge of log files (privacy)
• **Connection to turn signals**
• **Power considerations**
  - Ignition on/off
  - Quiescent Current Draw
  - **Finishing “work in process”**
  - Battery Disconnection
  - Inrush and fusing
  - Grounding
• **Supporting Smartphone Apps.**
  - **DSRC or Cellular Service**
• **Control Group vs. Active**
• **Maintenance Tracking**
• **Fail-safe OTA survival**
Central System Considerations

- **Message Generation and Signing**
  - MAP Message Management
  - TIM message Management
  - RTCM [not for NYC]

- **Data Collection**
  - Monitoring RSU health (RF)
  - Monitoring ASD health (RF)
  - Event Logs (performance measurement)
  - Travel Time (ISIG/MIM)
  - System Logs for troubleshooting
  - BSM – “breadcrumb” [not for NYC]

- **Performance Measurements/Analysis**
  - Project performance metrics
  - Report generation

- **OTA download management**
  - Configuration Management
  - ASD firmware upgrades
  - ASD Application Tuning
    - Application parameters

- **User Interface/Database Management**
  - RSU parameter management
  - ASD parameter management

- **Privacy Protection**
  - Obfuscated data
  - Aggregated data for export to SDC

- **Management of CV and ITS devices**
  - RSU – configuration files
  - RSU Firmware updates
  - Traffic Controller 1202v3 additions
  - Security enhancements (DTLS)

- **Security management**
  - Hardware Security Module
  - Security profiles for all messages
  - X.509 or TMC-RSU/ATC security
  - Firewall rules – external connections

- **Tools for operations management**
  - System logging
  - Operations alarms
  - Device status displays (visualization)
  - Security monitoring
External System Connections

- **Security Credential Management System SCMS**
  - RSU acquires certificates
  - ASD acquires certificates
  - Product enrollment
  - Maintenance - re-enrollment
  - Test or Production certificates
  - CRL distribution
  - Misbehavior export
  - Disabling crypto content - “lost” devices
  - IPv4 or IPv6 – proxy server or direct firewall

- **Secure Data Commons, RDE, etc. USDOT**
  - Privacy issues
  - Reliability of the data
  - Metadata required

- **Controlled Access (from vendors)**
  - City receives firmware updates
  - City manages distribution
  - Vehicles assigned into groups
    - Testing
    - Upgrade management / Fleets

- **Developed a Security Plan**
  - Security Management & Operations Concept (SMOC)
  - Certificates per week? NYC 60
  - Life of certificates – NYC 7 days
  - Certs loaded onto a Device – 2 weeks
  - Security profile for messages
    - Pilots developed Profiles for each:
      - SPaT, MAP, BSM, TIM
Communications Technology Considerations

- **Data Requirements**
  - Number of remotes
  - SCMS updates
  - Expected log file sizes
  - Number of vehicles
  - Frequency of encounters/alerts

- **Media available**
  - Wireless
    - Carrier
    - Trunk/microwave
    - Private network
    - 5G future
  - Fiber
  - Leased/Cable etc.
  - Mixed media

- **IPv4/IPv6**
  - ASD – IPv6

- **IPv4/IPv6**

- **“localized” communications**
  - V2V and V2I
    - 5G
      - Unproven in CAV
    - DSRC – 802.11p
      - 10 Years testing/trials

- **Role of local communications**
  - Smartphone apps
  - Pedestrian apps
  - In-Vehicle apps
  - ASD apps

NYC:
- DSRC: V2V & V2I
- 4G SPaT Data for PED apps
- 4G Backhaul to TMC
- IPv4 proxy to SCMS
- MQTT to AWS
Other considerations
Is this Deployment or R&D?

What Data to collect

• What could you collect?
• What is the raw data available

• What do you need?
  • What is the use of the data?
  • Resolution and frequency

• What should you collect?
  • Need to justify the costs
  • Protecting Personal Information
  • Focus on the Metrics

Consider the costs?

• Backhaul communications
• Storage (backup, recovery, etc.)
• Processing (using)
• Supporting FOIA requests
• Supporting Subpoenas

Privacy Issues

• Prohibition of keeping PII
• Combination with other sources
• Data Ownership
Other Challenges

• There is no **standard specification** for an OBU/ASD
  • There are no “standards” for the applications
  • NYC used – information from the Safety Pilot
  • Developed requirements and typical based on controller

• **Applications need tuning for your environment**
  • Speed at which they become active was >city speed limit

• **RSU standard specification (4.1) has issues**
  • Our needs for data collection – were not addressed
  • Central signing of MAP and TIM not supported

• **NTCIP 1202v3 did not work as needed**
  • Modified and created a block object

• **Time relationship line frequency vs. GPS time**
  • Environmental requirements for in-vehicle systems

• **Automotive antenna radiation patterns**

• **Quality control & consistency**

• **Procurement issues** for multiple vendors and “experimental” products involved
Where are we now - - - -

- Procurement – all under contract
  - Installing Production RSUs – about 100 so far
  - Installed about prototype 100 ASDs in a variety of vehicles
- **Solved CAN bus interface problems**
- Working through the backhaul issues
- MQTT Access to AWS
- SCMS Proxy Server
- Have 20 complete backhaul sites running
- **Achieved close to 1.5 M accuracy in Dense Urban Env**
  - RSU triangulation setup and tested Manhattan
- Preparing for end-to-end testing **(worked 4/29/2019)**
- Security is all in place (some bugs)
- OTA bench tested and verified
- Central software is operational
- Preparing for 400/week installation starting in July
- Preparing for 100/week starting middle of June
Summary

It takes more than installing an RSU & transmitting SPaT . . .

. . . to deploy a useful connected vehicle system.

Deploying CV without including security . . .

. . . is not interoperable with anyone else.

Determine your real [useful] data needs . . .

Is your system sustainable?

Can you continue operation?

Is there a business case for your system?

Thank you

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Join us for the *Ready to Design, Build, and Test Operational Systems* Series

- Discover more about the CV Pilot Sites
- Learn the Essential Steps to CV Deployment
- Engage in Technical Discussion

Visit the Pilot Site Websites for more Information:

- NYCDOT Pilot: [https://www.cvp.nyc/](https://www.cvp.nyc/)
- Tampa (THEA): [https://www.tampacvpilot.com/](https://www.tampacvpilot.com/)
- Wyoming DOT: [https://wydotcvp.wyoroad.info/](https://wydotcvp.wyoroad.info/)

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