UNITED STATES
DEPARTMENT OF TRANSPORTATION

Dynamic Optimization of Connected Vehicle Data

3rd SIP-adus Workshop on Connected & Automated Driving Systems

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Federal Highway Administration

15 November 2016

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From Connected Vehicle Messages to Transportation Systems Information

- Dynamic Interrogative Data Capture (DIDC) concept
  - Developed by Noblis under contract with USDOT
  - Based on BSM Emulator – an Open Source tool to generate connected vehicle data in a simulation environment
  - Dynamically optimizes vehicle messaging generation and transmission in real-time to support system performance measures
  - Allows the transportation system manager to implement dynamically configurable messaging strategies
- Advanced Message Concept Development (AMCD)
  - Developed by CAMP/VTTI team under cooperative agreement with USDOT
  - Implemented DIDC concepts in hardware and software
  - Conduct field trials of system

Dynamic Interrogative Data Capture (DIDC)

- DIDC fundamental research question:
  - *Is the potential torrent of data from large numbers of wirelessly connected devices so large that…*
    optimization of data generation and transmission may be necessary…
    to make at-scale connected vehicle/connected traveler systems technically feasible and financially viable?

    BMM/cellular world-view: ….optimized generation and transmission….
    BSM/DSRC world-view: …optimized roadside filtering….
    Full world-view: both of these things need to happen

- DIDC objective:
  - *DIDC seeks to optimize the capture and transmission of vehicle-based data under a range of dynamically configurable messaging strategies*

DIDC Controller – Targets

- The DIDC Controller adjusts the message frequency of DIDC equipped vehicles in order to meet specified targets.
  - The System Manager can set targets for specific message types, e.g., Travel Time, Queues, etc.

I'm measuring travel times, I need at least **five vehicle messages every minute for each 1000 feet of roadway**

TRANSPORTATION SYSTEM MANAGER

- The DIDC Controller can focus snapshot generation at key regions of special interest.
  - Regions can be defined by the System Manager such as intersections or automatically defined by the DIDC Controller when a specific event occurs such a vehicle's Traction Control turning on.

In addition to travel times, I'm also measuring queues, I need at least one message every second **at each intersection**

TRANSPORTATION SYSTEM MANAGER

DIDC Controller – Triggers

- The Transportation System Manager can configure event-driven triggered messages based on an explicitly defined set of pre-programmed rules.

Examples:

- Queue Message
  - Triggered by speed < 7 mph
- Turning Movement Message
  - Triggered by yaw rate > ±5 degrees/second
- Traction Control Message
  - Triggered by traction control system ON

DIDC Implications

- Defines a new message set called the Basic Mobility Message (BMM) which exploits the strengths of both BSM and PDM message protocols
- Calibrates vehicle message generation rates depending on the amount of data being generated
  - The DIDC concept is predicated on the assumption that accuracy of estimating transportation performance measures (queue length, travel time, etc.) is less dependent on the amount of message generated and more on the type, time, and location of messages
- Capitalizes on both the DSRC-based RSEs and the cellular networks to minimize gaps in coverage

Advanced Messaging Concept Development (AMCD)

Acknowledgement and Disclaimer

This material is based upon work supported by the U.S. Department of Transportation under Cooperative Agreement No. DTFH6114H00002.

Objective and Organization Responsibilities

Objective

Evaluate the ability of connected vehicles to generate and infrastructure to collect Basic Safety Message (BSM), Probe Data Message (PDM), and Basic Mobility Message (BMM) alternatives using cellular and DSRC communications under simulated data message control schemes, including emulating elements of Dynamic Interrogative Data Collection (DIDC) control where applicable, in real world driving conditions for non-safety critical applications.

Responsibilities

CAMP	• Overall program management • Administrative coordination with FHWA • Technical support and assistance
VTTI	• Technical project management and liaising • Implement BSM / BMM / PDM and emulated DIDC Concepts • Conduct Field Tests • Support Standards Development

Research Topics

- Characterize Dual Mode Communication
  - DSRC
  - Cellular
- Evaluate message control schemes:
  - DIDC
  - PMM
- Message Type Characterization
  - BSM
  - PDM
  - BMM

Project Tasks & Status

July 2015 – April 2017

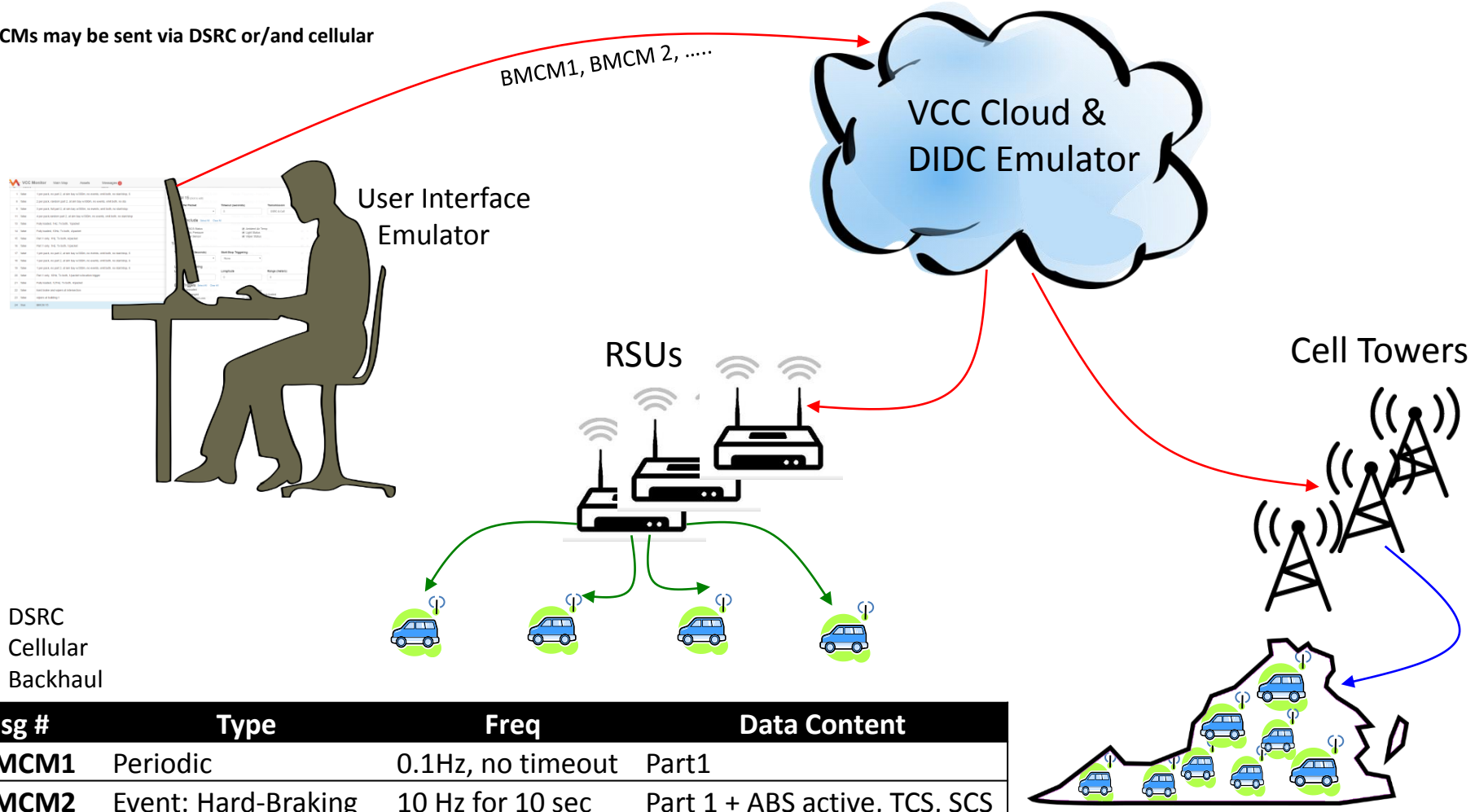
- Task 1 - Technical Project Management - *ongoing*
- Task 2 - Integration Validation Research
  - 2.1 Test Plan Development - *complete*
  - 2.2 Prototype Development - *complete*
  - 2.3 Prototype Test Execution - *complete*
  - 2.4 Field test Preparation - *complete*
  - 2.5 Conduct Field Test – *planned for November 2016*
  - 2.6 Data Analysis and Presentation – *planned for December 2016*
- Task 3 - Cross-Cutting Standards Support – *planned for Q1 2017*

AMCD Message Comparison

TOPIC	BSM	PDM	BMM
Basis	SAE J2735	SAE J2735-2009 Annex E	Designed for mobility applications
Use	V2V safety applications	Provide information on road, weather and traffic	Support mobility applications
Content	Fixed based on SAE J2945/1	Variable: Part 1 and Part 2 elements	Variable: Part 1 and Part 2 elements. Supports non-standard elements
Message collection frequency	10 Hz	Variable: single message contains snapshots generated from multiple sources - Periodically - Event triggered - Stop/start conditions	Variable: multiple messages generated from multiple sources - Periodically - Event triggered - Stop/start condition Message can contain multiple snapshots
Transmission frequency	10 Hz	Variables based on time or distance and receiver availability	Multiple message sent based on log-normal distribution set for each message thread.
Communication	DSRC	Designed around DSRC	Intended to be multi-modal
Buffering	No buffering	Buffering designed to allow for limited uplink points	Limited buffering
Control scheme	None	Limited: changes the snapshot generation characteristics	Complex: Dynamic Interrogative Data Capture (DIDC) model provides extensive control

Setup BMCMs and transmit Queue to vehicles

*BMCMs may be sent via DSRC or/and cellular



Msg #	Type	Freq	Data Content
BMCM1	Periodic	0.1Hz, no timeout	Part1
BMCM2	Event: Hard-Braking	10 Hz for 10 sec	Part 1 + ABS active, TCS, SCS

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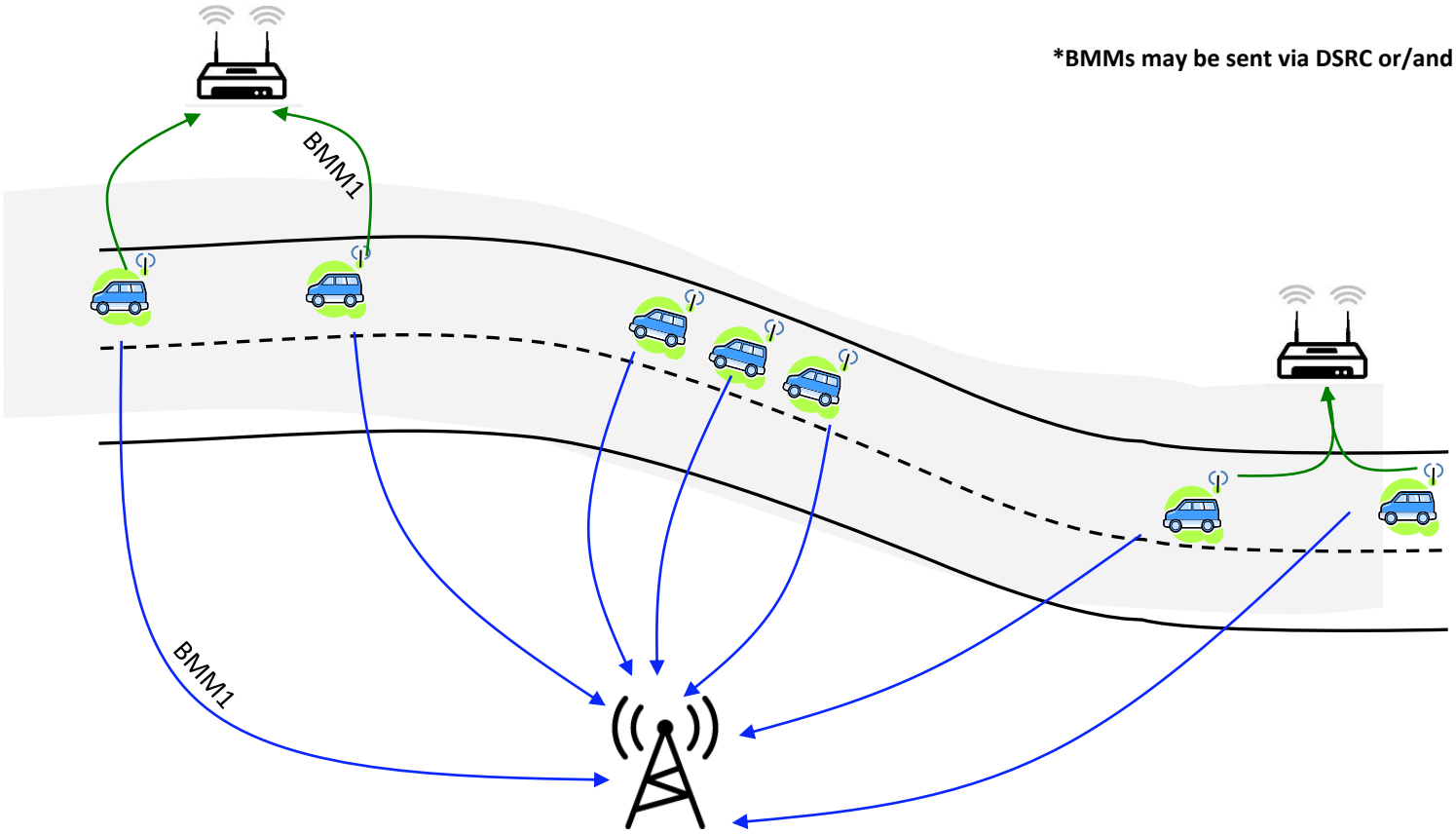
Periodic Snapshots Generated, Packaged into BMM1s, and Transmitted According to BMCM1 Configuration

*BMMs may be sent via DSRC or/and cellular



DSRC
Cellular
Backhaul

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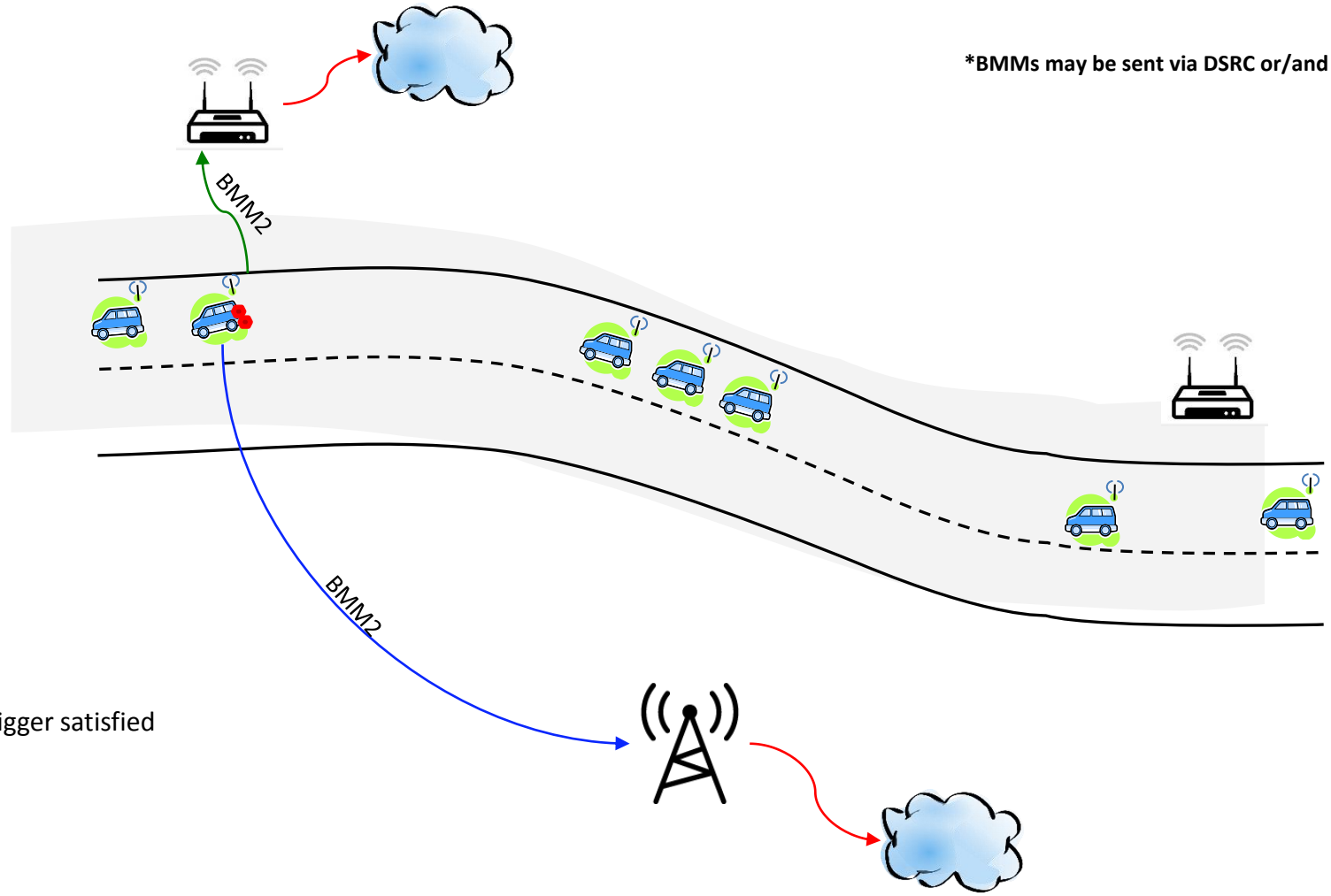
Event Snapshot(s) Generated in Response to Hard Brake, packaged into BMM2s and transmitted according to BMCM2 config.

*BMMs may be sent via DSRC or/and cellular



Hard brake trigger satisfied
DSRC
Cellular
Backhaul

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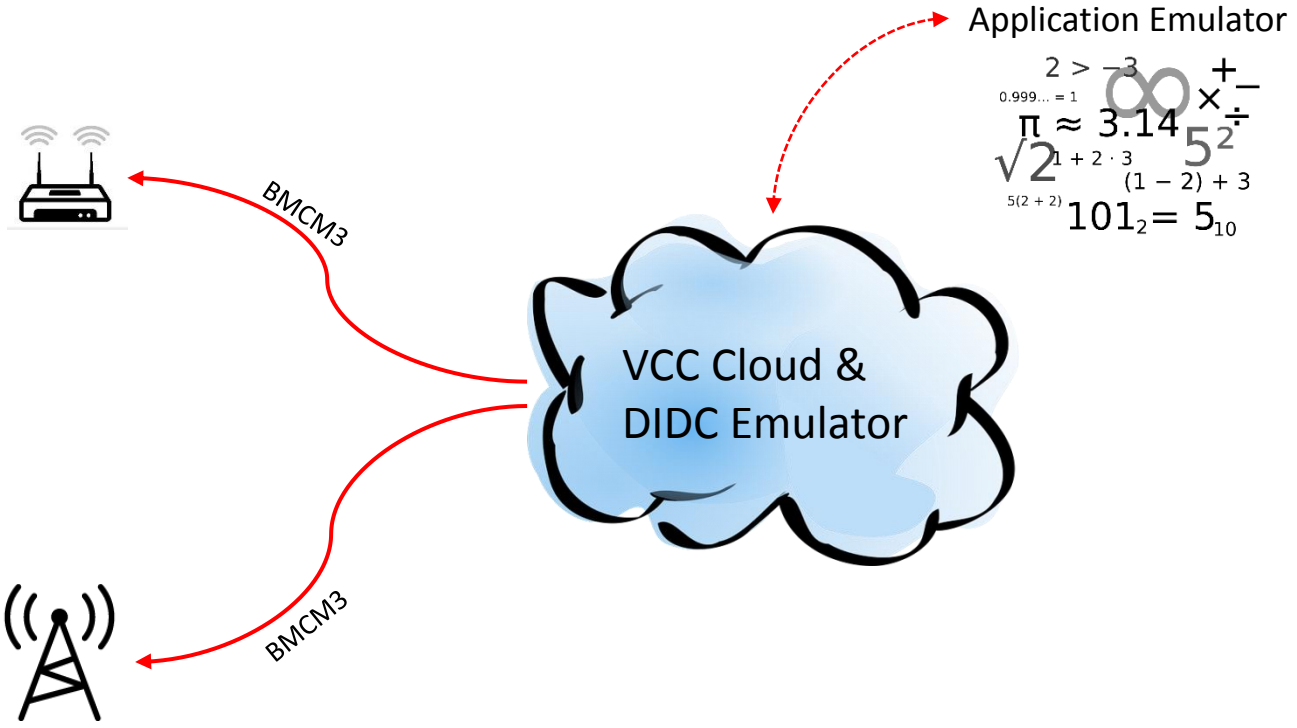
Infrastructure Application Listens for BMM2 and Responds by Requesting DIDC to add BMCM3 Queue



- DSRC
- Cellular
- Backhaul

Msg #	Type	Freq	Data Content
BMCM1	Periodic	0.1Hz, not timeout	Part1
BMCM2	Event: Hard-Braking	10 Hz, 10 sec	Part 1 + ABS active, TCS, SCS
BMCM3	Event: Geo-Ref to BMCM2 event	5 Hz, 60 sec	Part 1 + wiper, air temp, atm press

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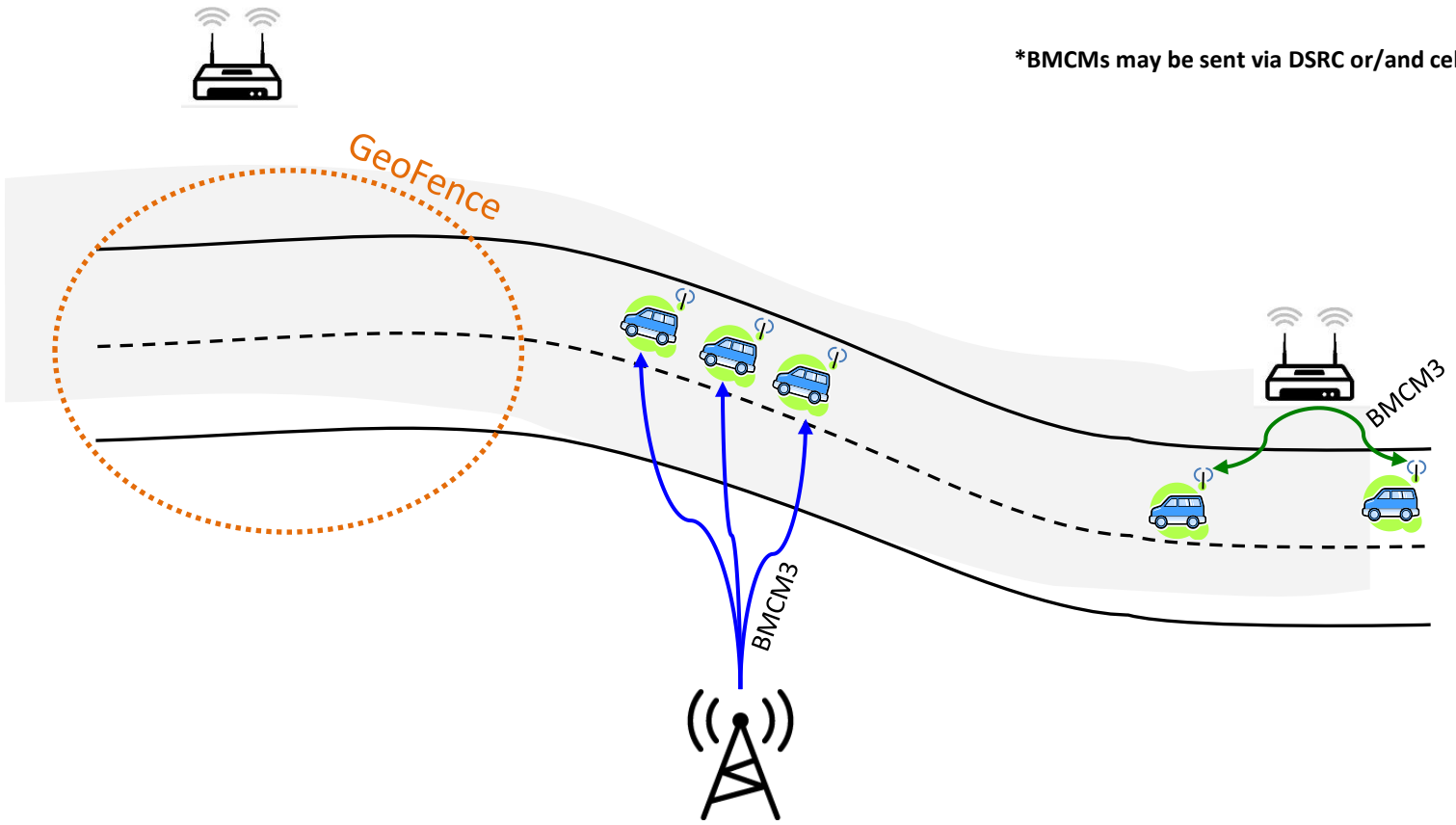
CAMP LLC
Vehicle to Infrastructure (V2I) Consortium

Vehicles Receive BMCM3 and Configure a Geofence Trigger

Virginia Tech Transportation Institute

*BMCMs may be sent via DSRC or/and cellular



DSRC
Cellular
Backhaul

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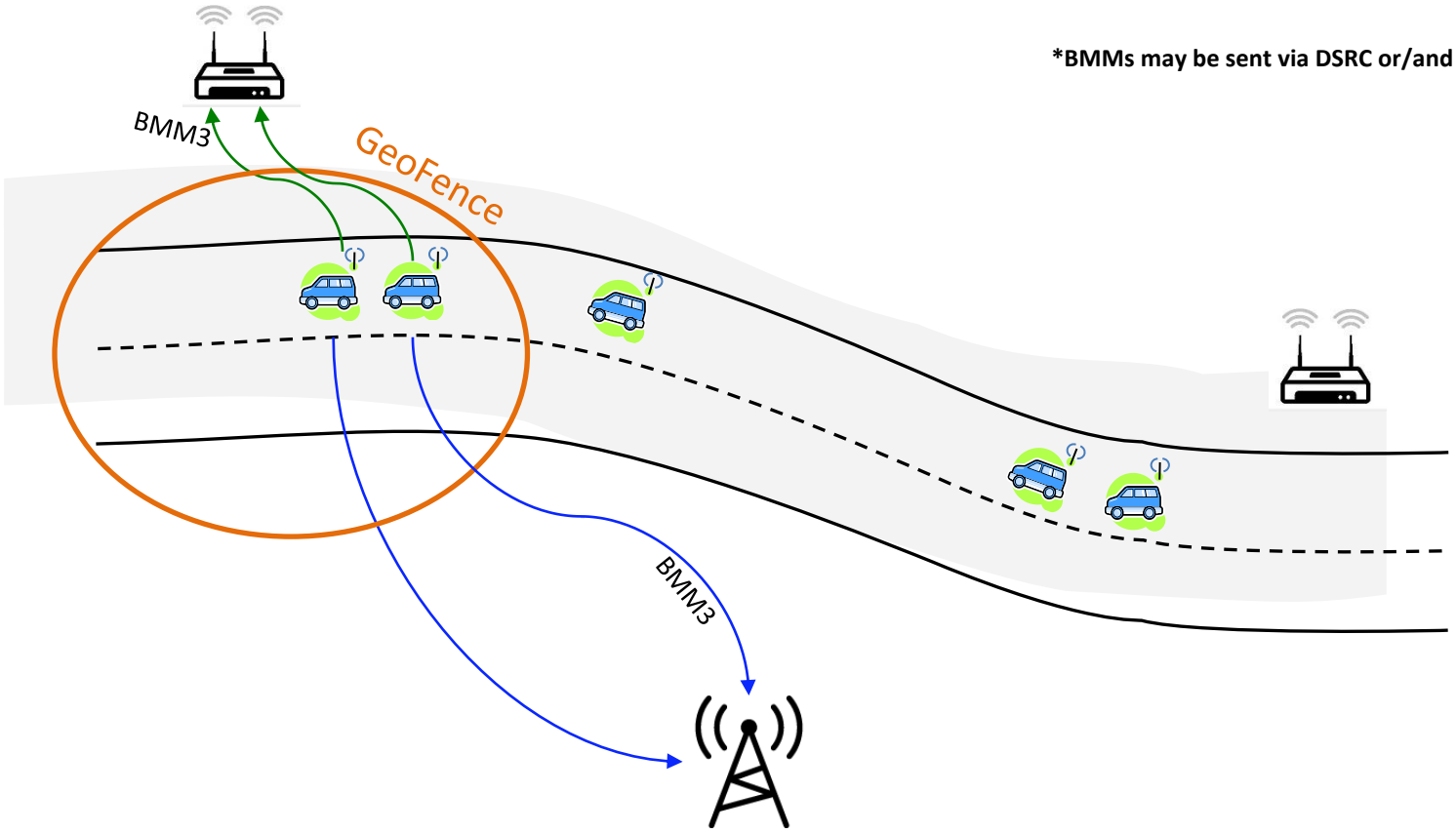
Vehicle Transmits BMM3(s) When Inside Geofence

*BMMs may be sent via DSRC or/and cellular



- DSRC
- Cellular
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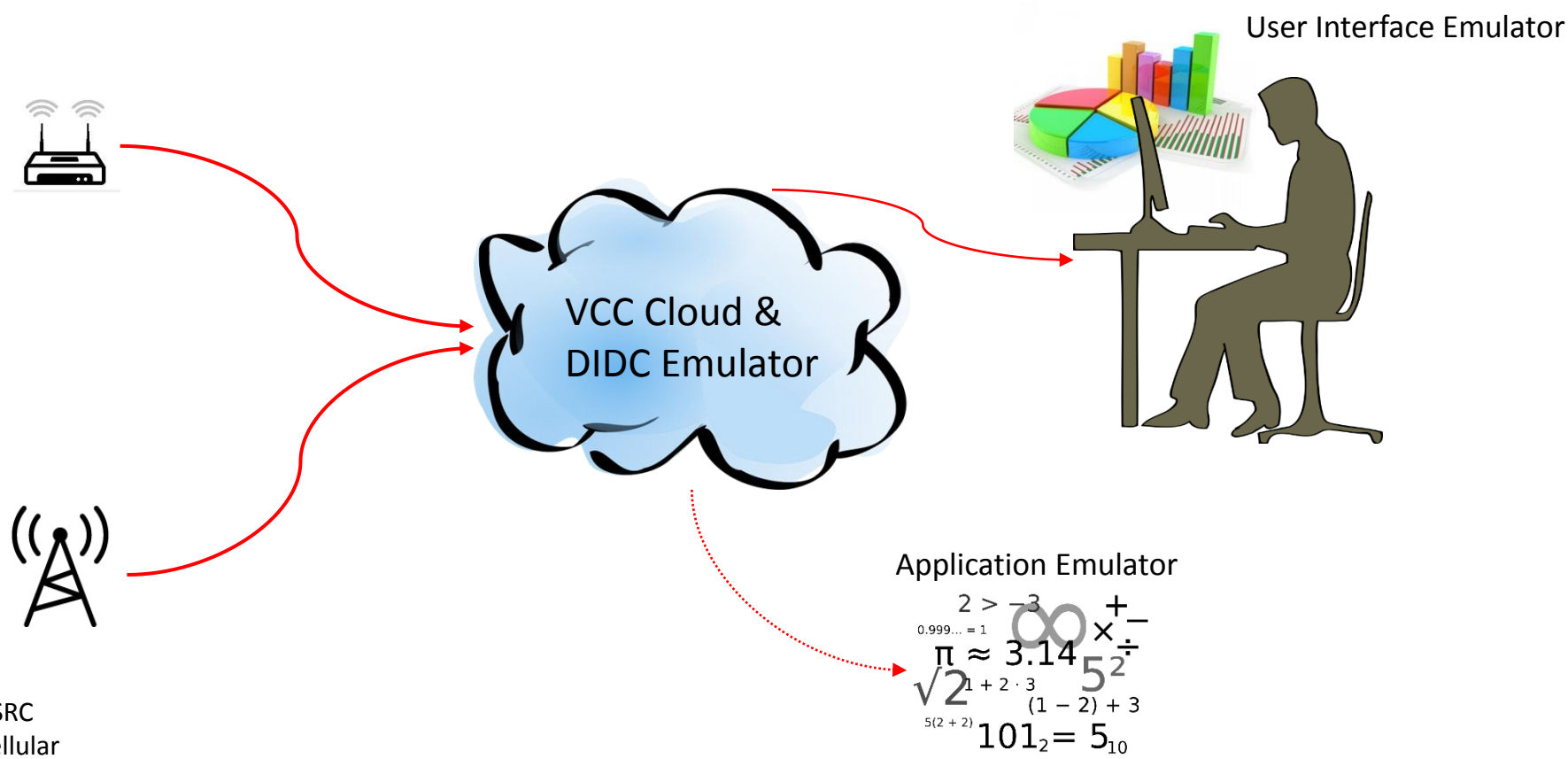
All BMMs Received are Processed by Infrastructure Applications and Operators to Determine Responses



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Next Step – On-road Testing

Mobility Applications:

- Dynamic re-routing capability
- Travel-time estimates
- Transit bus/parking availability
- Operational use of dynamic data at traffic center
- Lane closure situations
- Stopped school bus notifications
- Pavement maintenance
- Signal timing
- Driver decision support
- Improved work zone safety

This image first appeared on the cover of ITS International magazine, March/April 2014.

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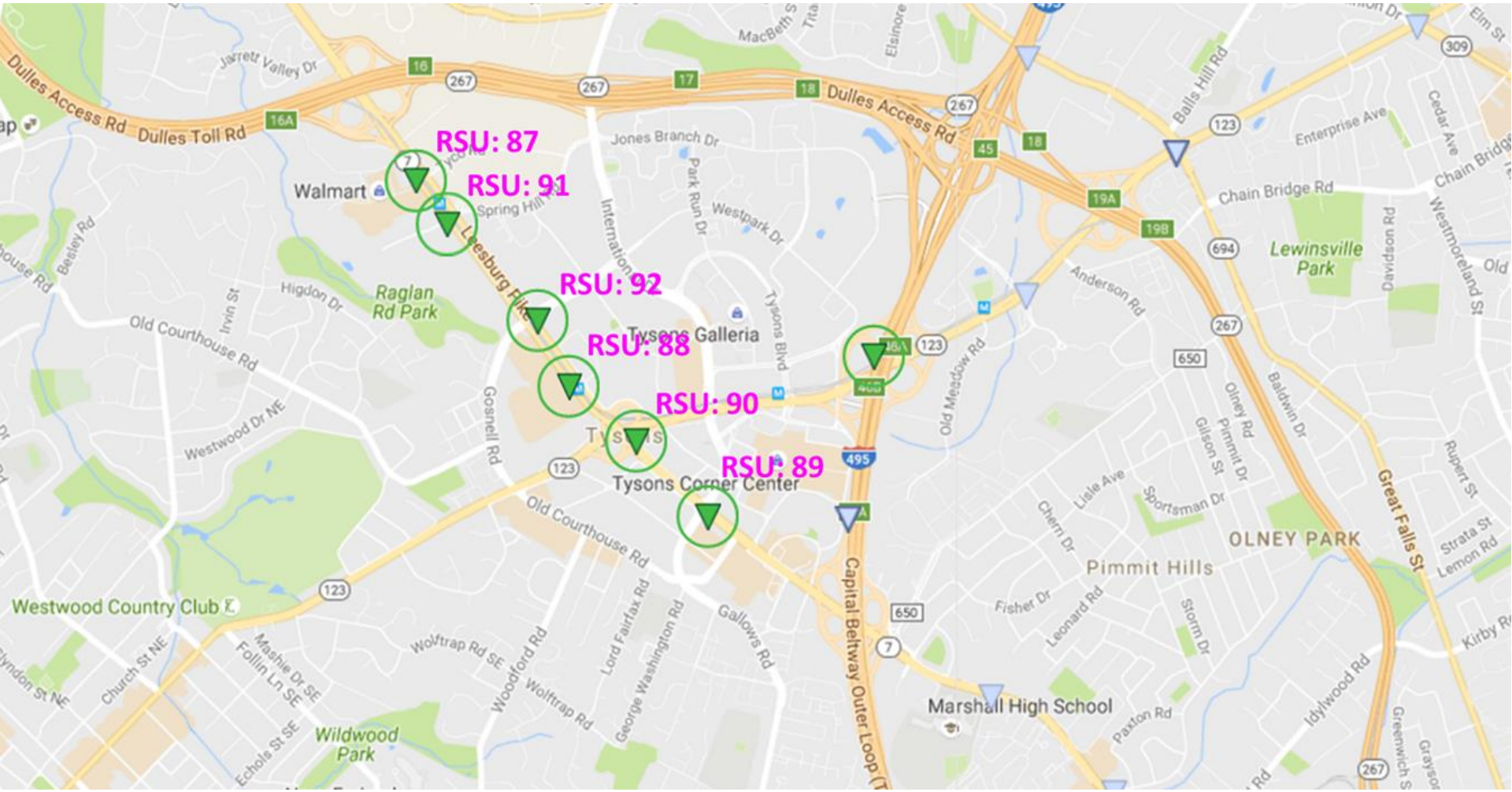
AMC VCC Testbed



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感謝

Thank you!