MAC Address-Based Delay Measurements at Rural "Gateways"

Yegor Malinovskiy, Yinhai Wang and Un-Kun Lee

University of Washington STAR Lab

Ted Bailey and Matt Neely

WSDOT

Presentation Outline

- Bluetooth Review

- Bluetooth Accuracy

- System Updates (New Technologies)
  - Hardware Updates
  - Software Updates

- Truck Performance

- Field Experiments

- Discussion

Bluetooth Review

- Bluetooth basics
  - Each device has unique 48-bit MAC address
  - A device can be found when its "visible" or in "discovery mode"
  - More popular than ever before in Washington due to recent cell phone use regulations

- Travel time estimation
  - Obtain MAC addresses at various locations and match identical ones

Bluetooth Review

- 2.402 – 2.480 Ghz Radio Frequency
- Weak signal to prevent interference:
  - Cell phone: up to 3 W
  - Class I: 100 mW ~ 100 m
  - Class II: 2.5 mW ~ 10 m
  - Class III: 1 mW ~ 1 m
- Uses spread-spectrum frequency hopping
 - 79 randomly chosen frequencies
  - Changes frequency 1600 times a second

Bluetooth Review

- How to find a device
  - Full spectrum must be scanned, randomly jumping from frequency to frequency

- From Bluetooth specs:
  - "The inquiry substate may have to last for 10.24 seconds unless the inquirer collects enough responses and determines to abort the inquiry substate earlier." - [Bluetooth SIG]
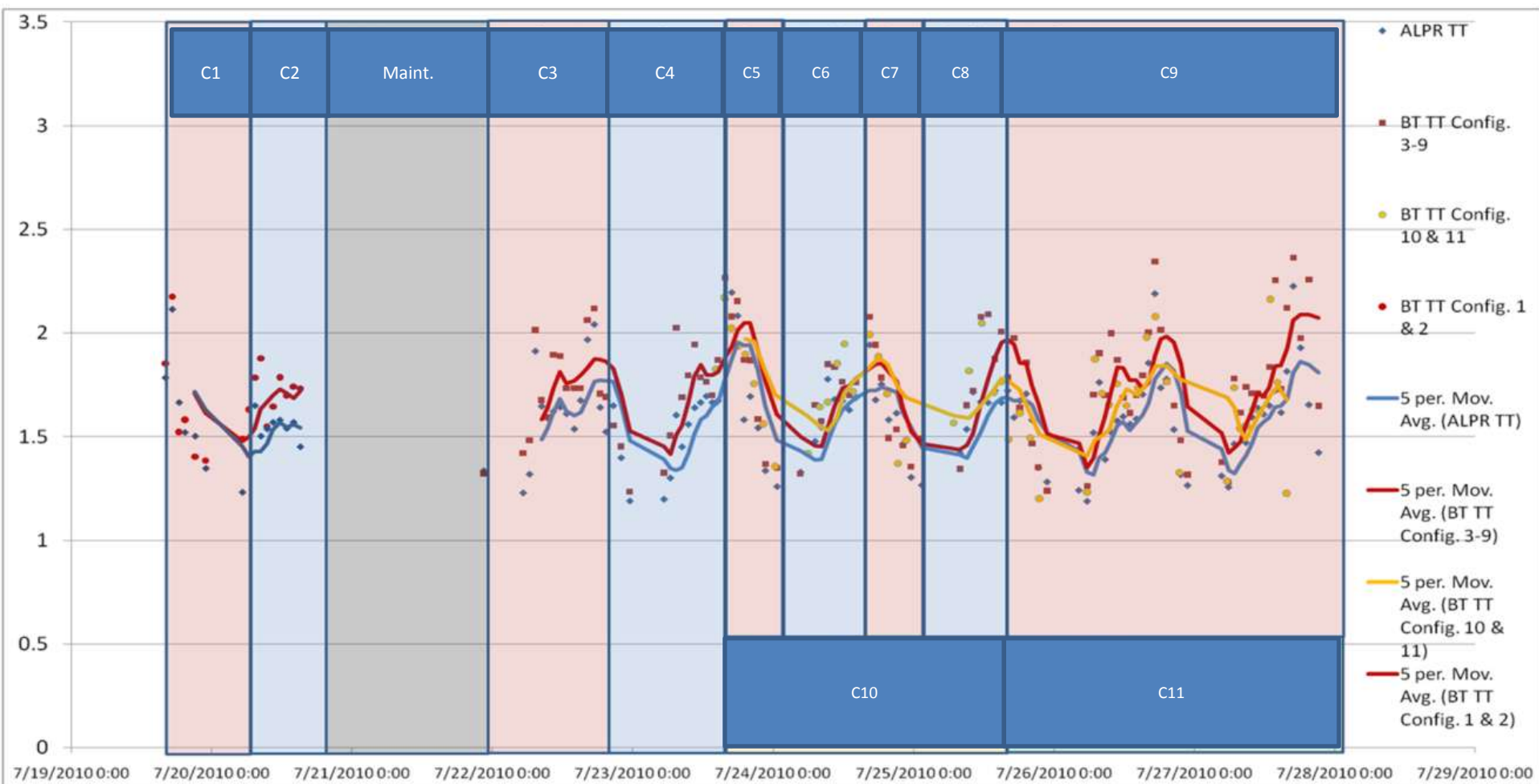
Bluetooth Accuracy

- Completed comparison of BT with ALPR
  - Error rates between 4 and 10 percent
  - Vary depending on configuration of antennae

- Comparison with BlueToad
  - Soon?

Bluetooth Accuracy SR522
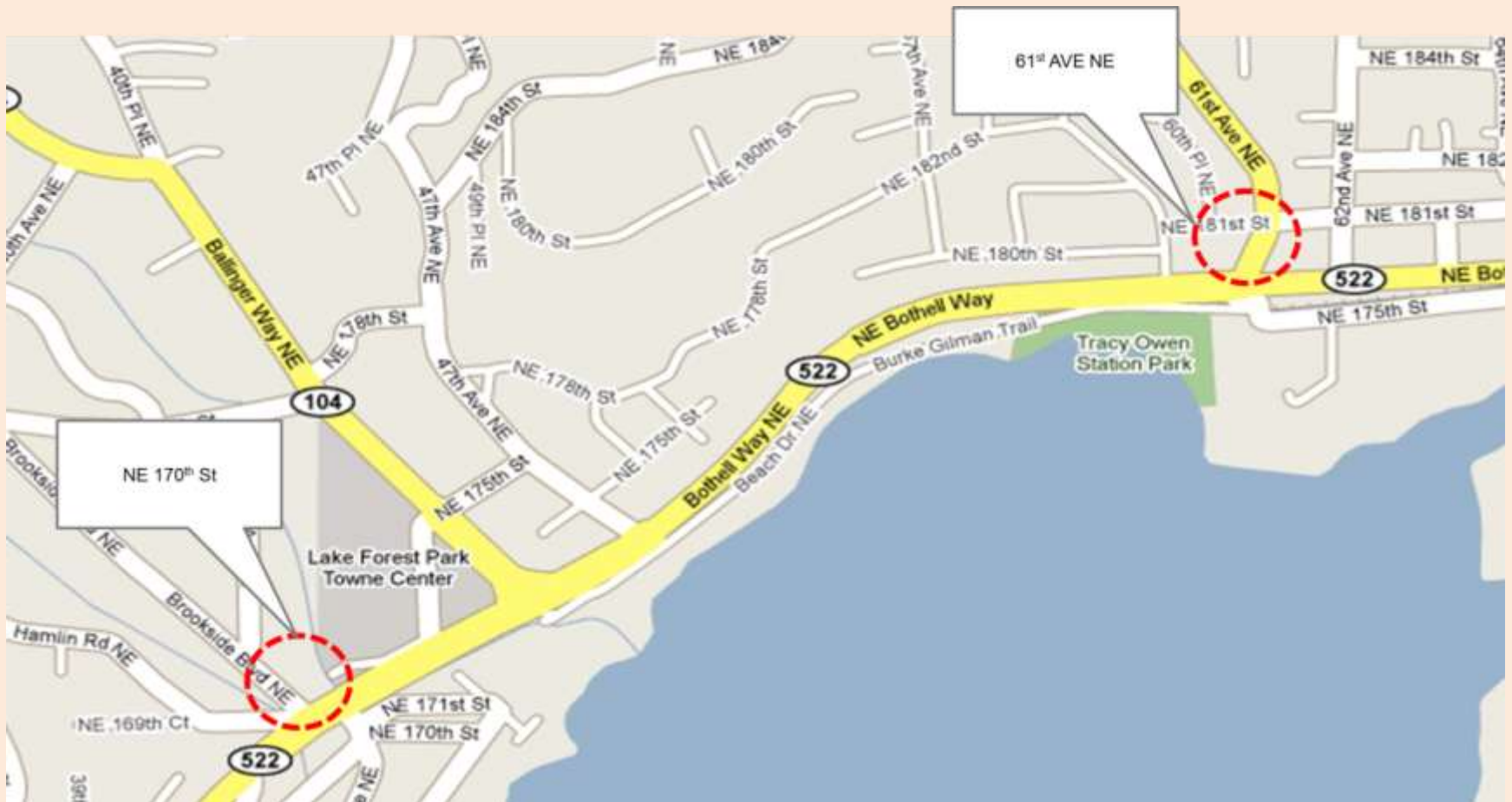
Bluetooth Accuracy SR522

ALPR Travel Time (ALPR TT) vs. Bluetooth Travel Time (BT TT) Westbound SR-522

Bluetooth SR522 Summary

- Bluetooth-based travel times are likely overestimates
  - Slower vehicles tend to be over-represented

- Site-specific evaluation may be necessary
  - Nearby signals may superimpose additional travel time
  - Extraneous sources of delay, such as bus stops, should also be considered

- Combinations of sensors working in tandem help reduce error
  - Tandem setups greatly increase the detection and matching rates
  - Important for time-critical applications such as real-time travel information

- Sensor configuration affects performance
  - Especially if the chosen corridor has a short travel time
  - Average errors between 4% and 13% when compared to aligned ALPR sensors

WSDOT – Bluetooth Applications

- Signalized Corridors – Operational Performance
- Interstate and Rural Mountain Passes
- Weigh Stations
- Border Crossings
- Chain-up areas
- Work Zones
- Anywhere else Travel Time tracking would be beneficial.

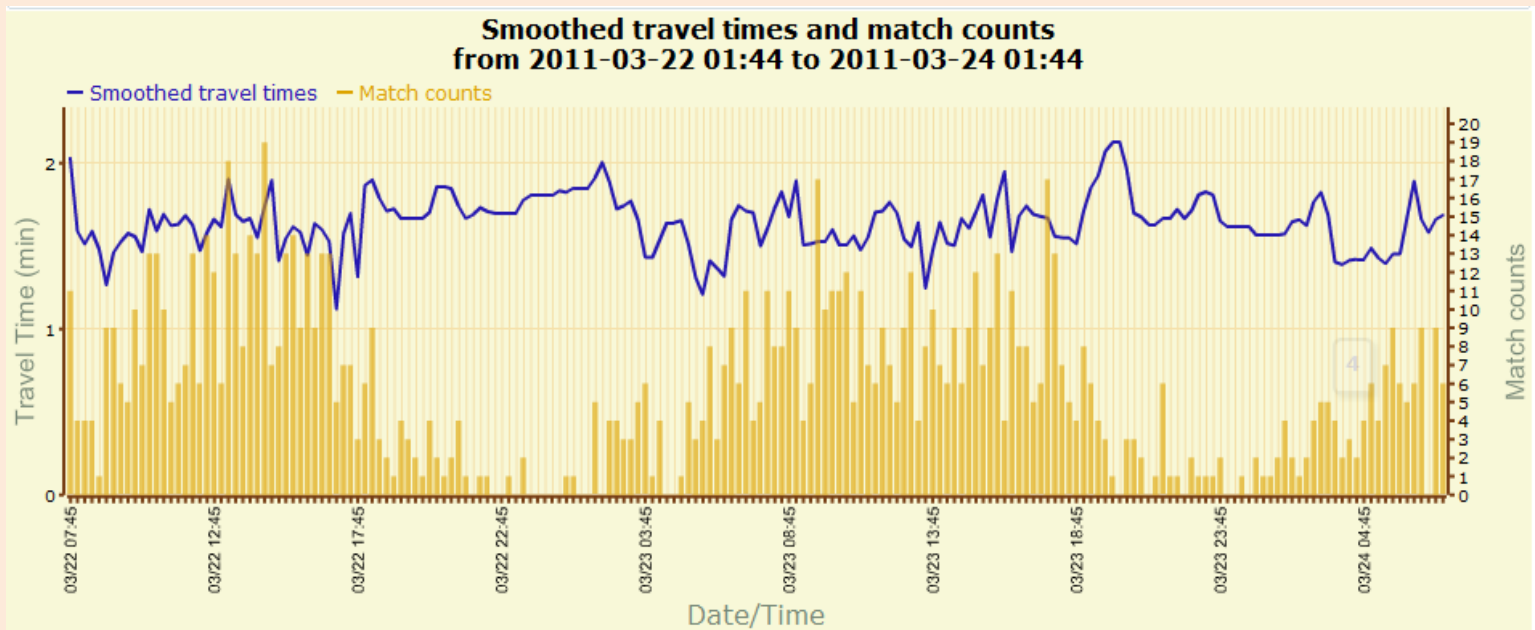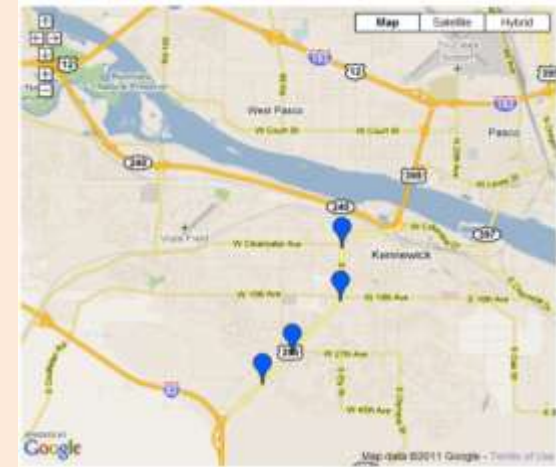# WSDOT – BlueTOAD Installation
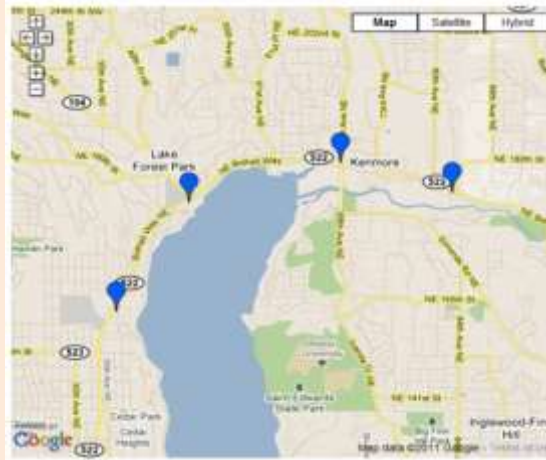
WSDOT – BlueTOAD Installation
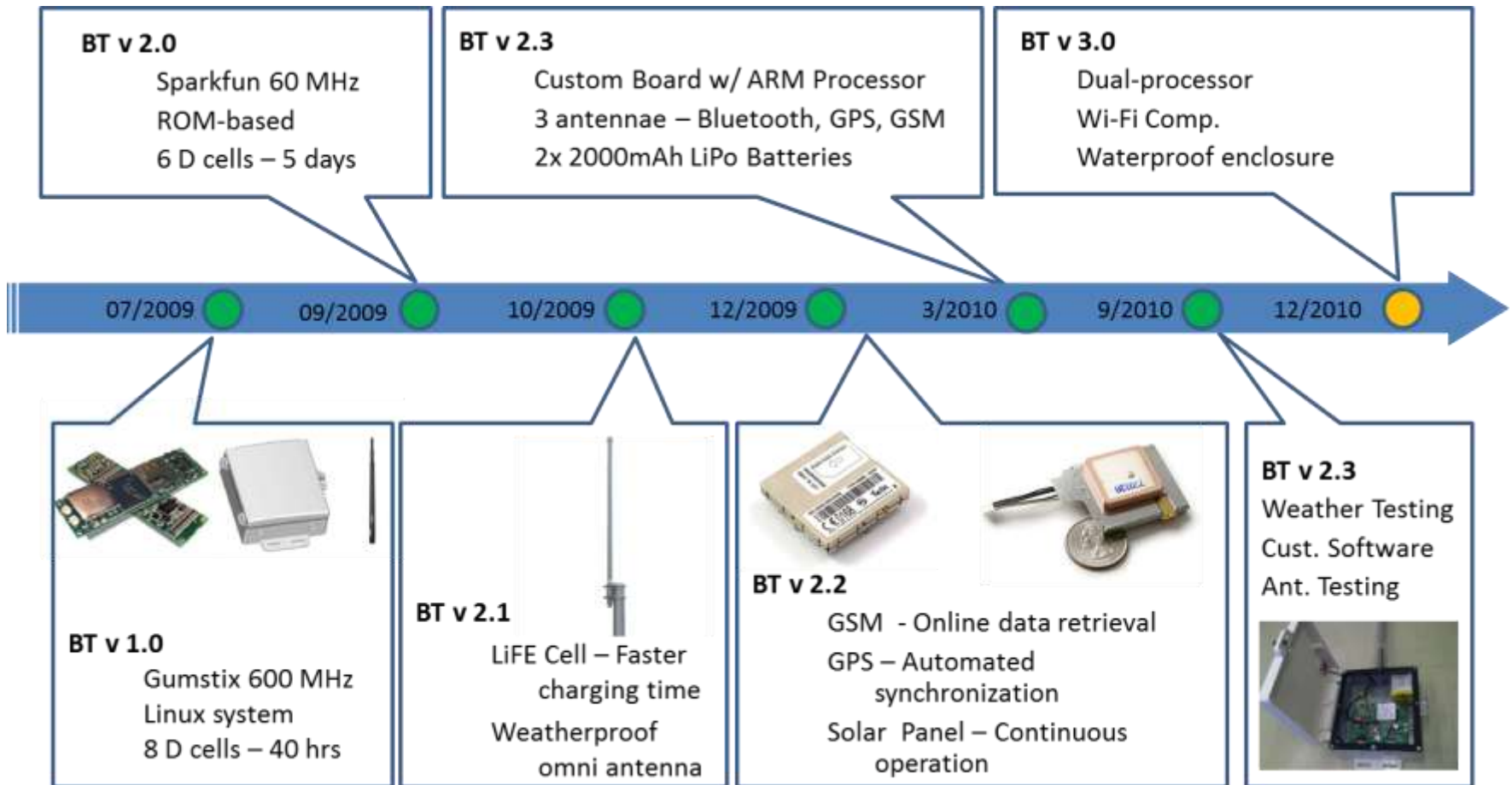
WSDOT – BlueTOAD Data

Website Login Instructions
https://bluetoad.trafficcast.com/

Login: WSDOT_User
Password: GoldenGophers#1

Smoothed travel times and match counts
from 2011-03-22 01:44 to 2011-03-24 01:44

System Updates

BT v 2.0
Sparkfun 60 MHz
ROM-based
6 D cells – 5 days

BT v 2.3
Custom Board w/ ARM Processor
3 antennae – Bluetooth, GPS, GSM
2x 2000mAh LiPo Batteries

BT v 3.0
Dual-processor
Wi-Fi Comp.
Waterproof enclosure

07/2009   09/2009   10/2009   12/2009   3/2010   9/2010   12/2010

BT v 1.0
Gumstix 600 MHz
Linux system
8 D cells – 40 hrs

BT v 2.1
LiFE Cell – Faster charging time
Weatherproof omni antenna

BT v 2.2
GSM - Online data retrieval
GPS – Automated synchronization
Solar Panel – Continuous operation

BT v 2.3
Weather Testing
Cust. Software
Ant. Testing
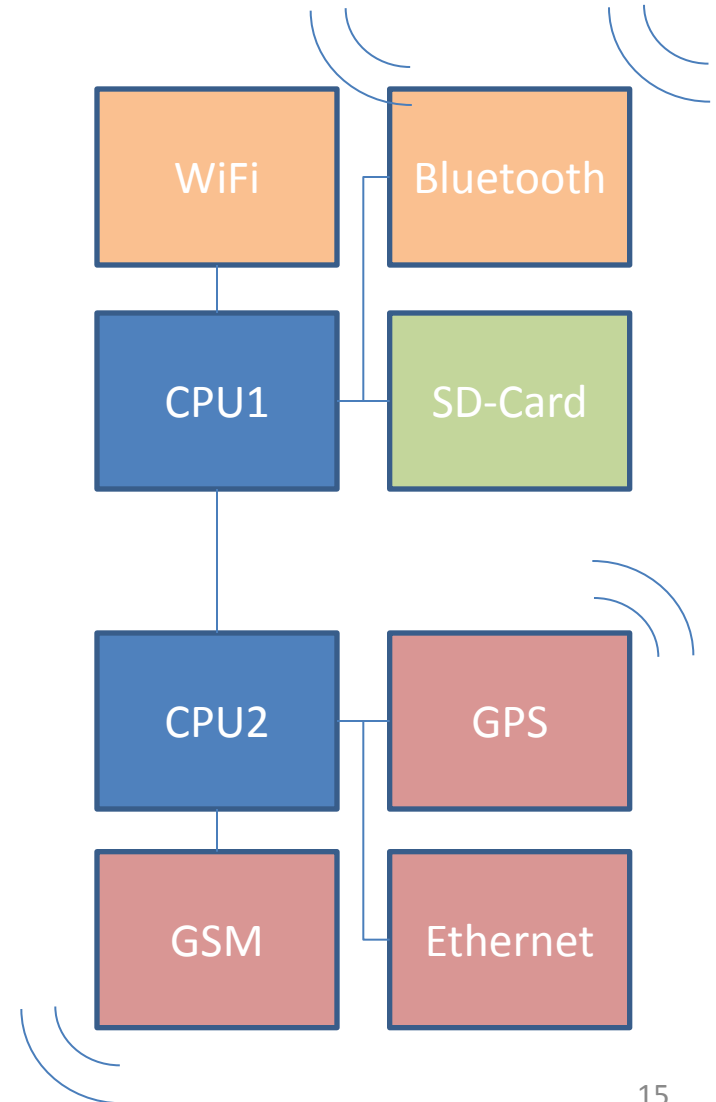
Hardware Updates - Architecture

- Dual Processor design
  - CPU 1
    - WiFi Scanning
    - Bluetooth Scanning
  - CPU 2
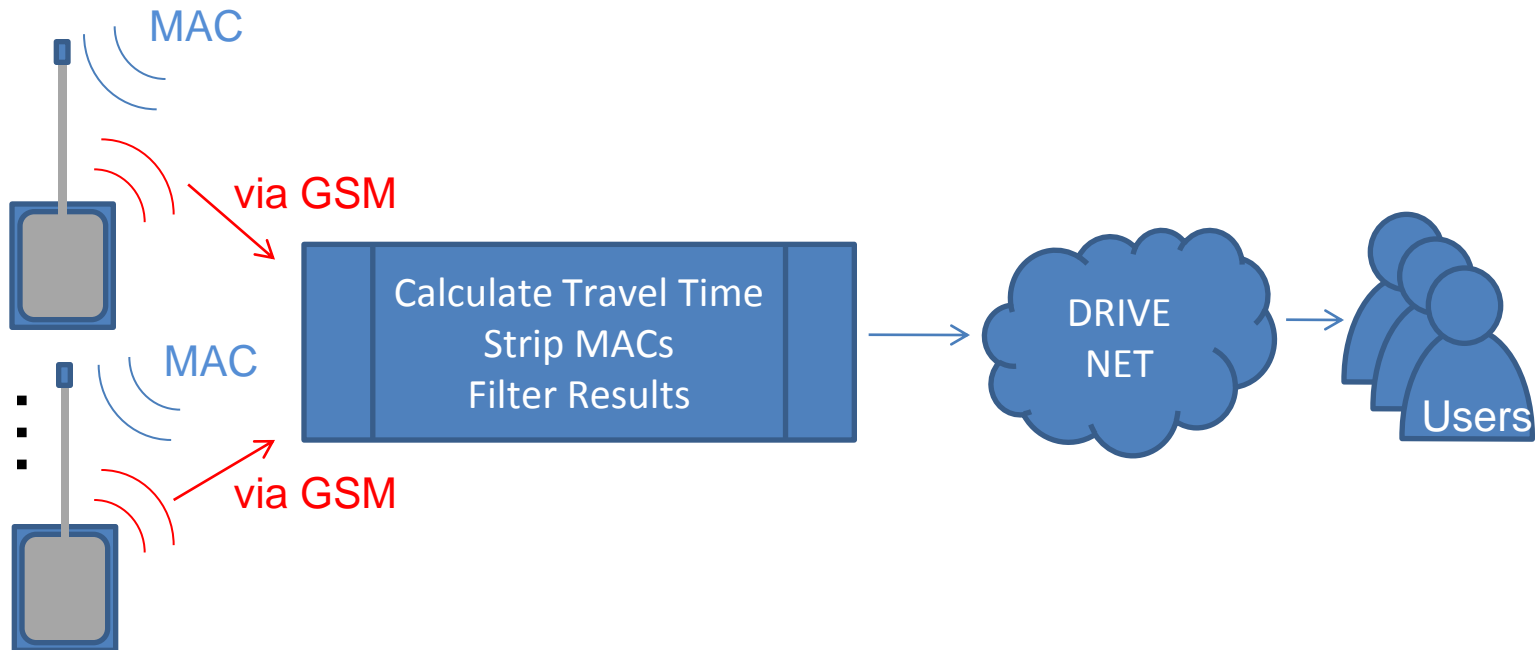   - GPS
    - Ethernet
    - GSM

Hardware Updates - WiFi

- Option 1 – packet interception
  - High success likelihood of getting MAC
  - Unfortunately illegal
- Option 2 – passive monitoring
  - Pose as hotspot
    - Capture scanning devices looking for WiFi
    - Disappoint potential surfers
  - Record WiFi signal strength
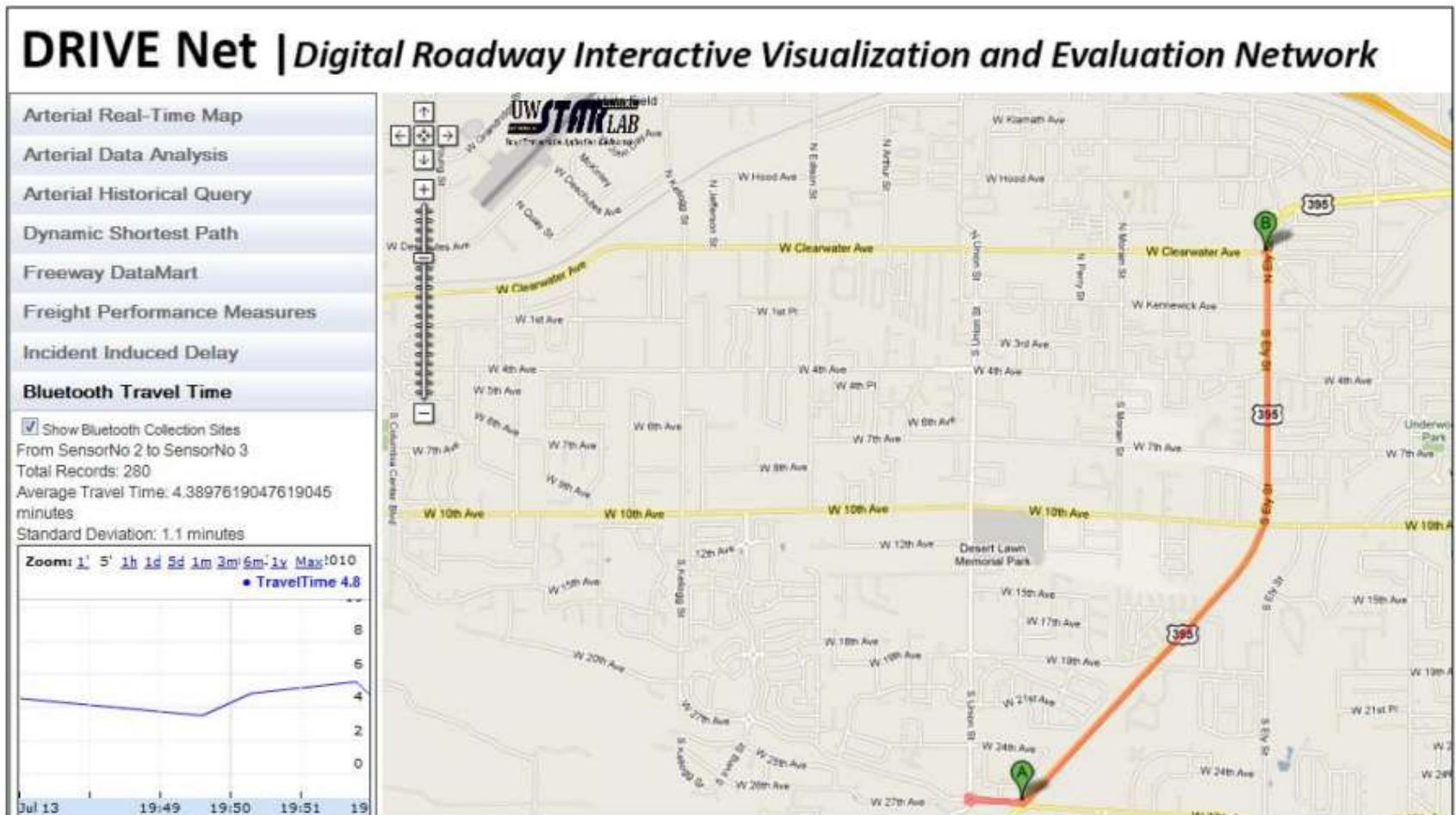   - Proximity-based applications

Hardware Updates – Bluetooth 4

- Bluetooth Low Energy
  - Same frequency, different protocol
    - 3 dedicated advertisement channels
    - 3 ms connection time
    - 10 times lower power consumption
  - Device ID, Type and State
    - "I am valve cap 01:AA:11:22:BB:CC, pressure 44psi"

Software Updates - DRIVE Net

MAC

via GSM

MAC

via GSM

Calculate Travel Time
Strip MACs
Filter Results

DRIVE
NET

Users

Software Updates - DRIVE Net

Software Updates - Filtering

- Filtering makes a big difference
  - Threshold
  - Moving median/average
  - Standard deviation-based

- How long do you wait until MAC deletion?
  - Privacy
  - Match quality/quantity

System Maintenance

- Device Maintenance
  - Pour out rain water
  - Dry out
  - Repeat

- Battery Maintenance
  - Standard Li-Ion practices
  - ~5hr charge time

Design Philosophy

- Lightweight
  - Portable deployment
  - Quick studies

- Standalone communications
  - GSM/GPS on board

- Configurable antenna
  - Adjustable signal strength
  - Swappable antenna types

Measuring Truck Performance

- "It is estimated that commercial motor carriers save $1.25 for every minute that they are not idling in weigh station queues."*

- Delay happens at "Gateways"
  - Weigh Stations
    - Some pre-cleared, others not
    - Need to pull over and drive slowly or stop
  - Borders
    - Delays can be very long
    - Estimates are necessary not only for trucks

*According to WSDOT CVISN Program

Performance Measurement

- What is the average delay?

- The longest delay?

- How does delay vary through the day?

Wait Time on Truck Scales

- Transponder based system
  - Weight, size and registration of truck checked
    - Green – clean bill, proceed
    - Red, pull over to station
  - Average stop is 5 minutes long
    - Potential for a VERY long stop
  - 113,000 hours of time saved by pre-clearance
   - $ 8.5 million*

Source: WSDOT

*According to WSDOT CVISN Program

Measuring Delay

- Capture entire length of detour
  - Check in time
    - At entrance - prior to deceleration
  - Check out time
    - At exit – near full speed

- Subtract travel time without delay
  - Assume no congestion
  - Better approach is to compare to moving average

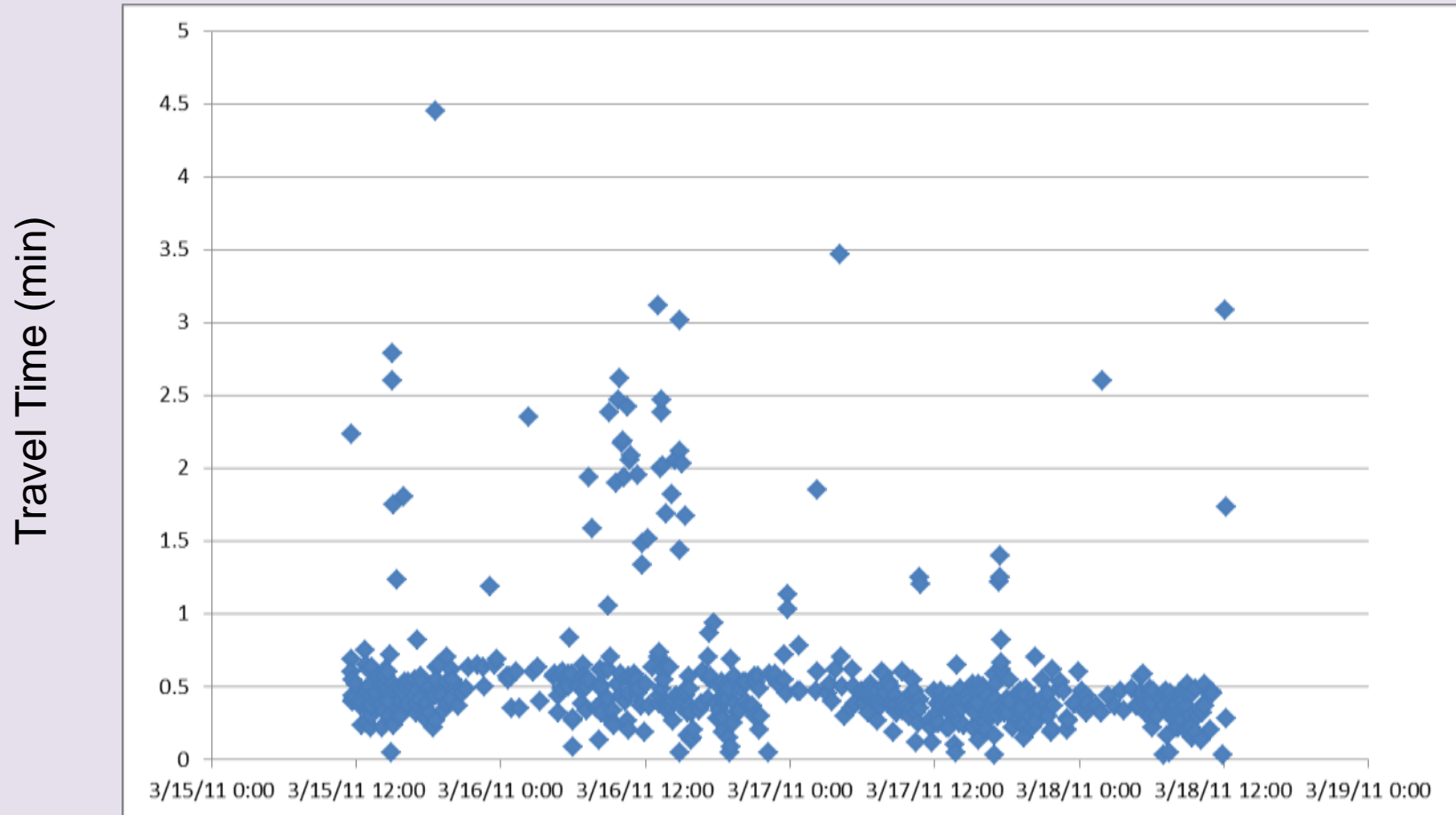# Weigh Station Site – I-5 Ft. Lewis

- 3/15 – 3/18

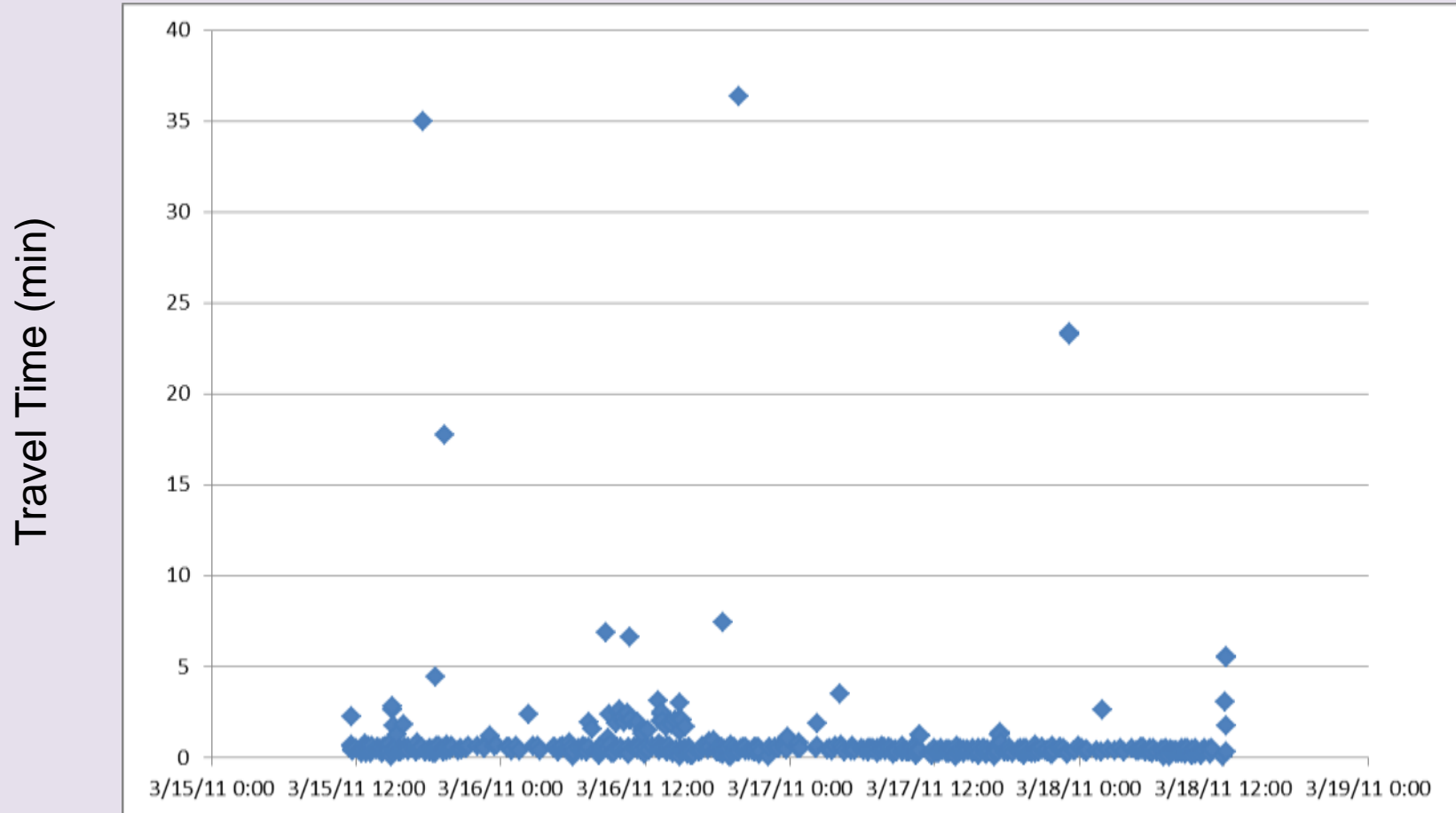- Speed Limit 60 (FWY)

- Speed Limit 10 (STN)

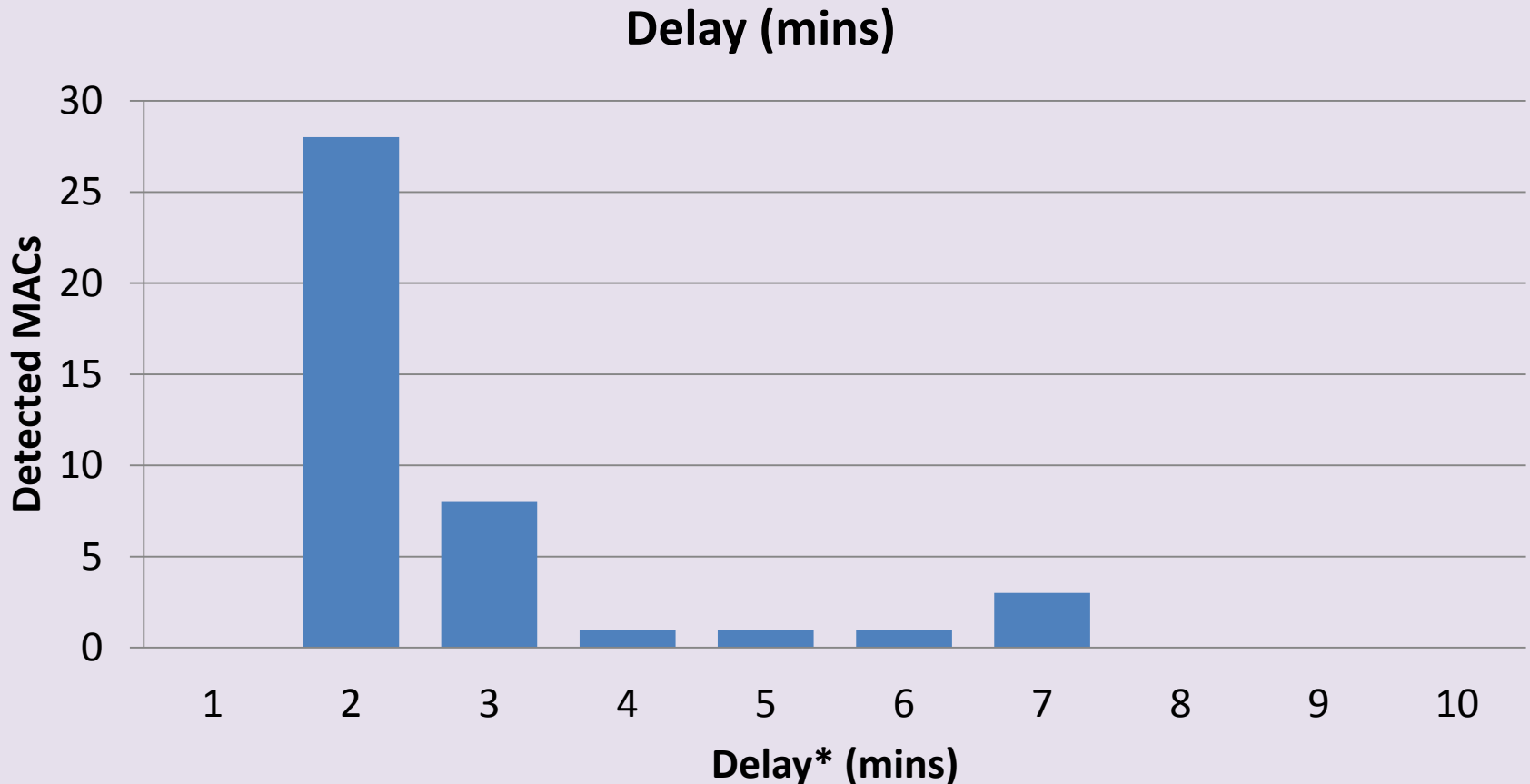# Weigh Station Site – I-5 Ft. Lewis
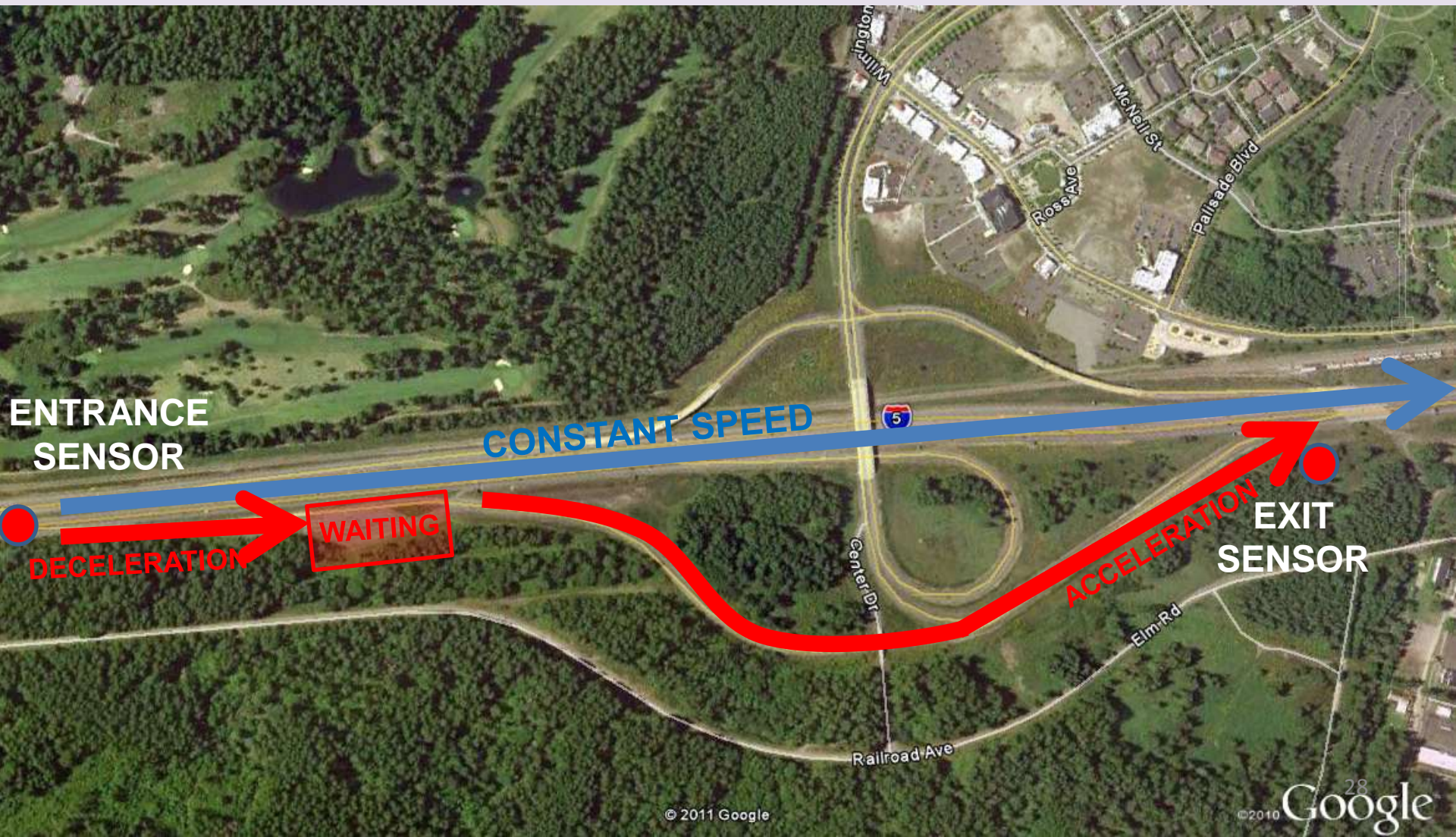
Weigh Station Results (5 min)

Weigh Station Results (40 min)

Weigh Station Results

Delay (mins)

*After subtracting free-flow travel time of .53 minutes.
(513 devices detected with no delay)

Test Conclusions

- Range too large – captures many bypassing vehicles
  - Difficult to discriminate between slow vehicles and delayed trucks
  - Congestion can skew results

- Shorter range on exit sensor or additional wait sensor would mitigate above concerns

Wait Time on Borders

- Passenger and truck delays
  - Estimated using ALPR + loop sensors
    - 5 min intervals
  - Shown via video
  - Displayed on dynamic message boards

- Nationwide effort to monitor border delays
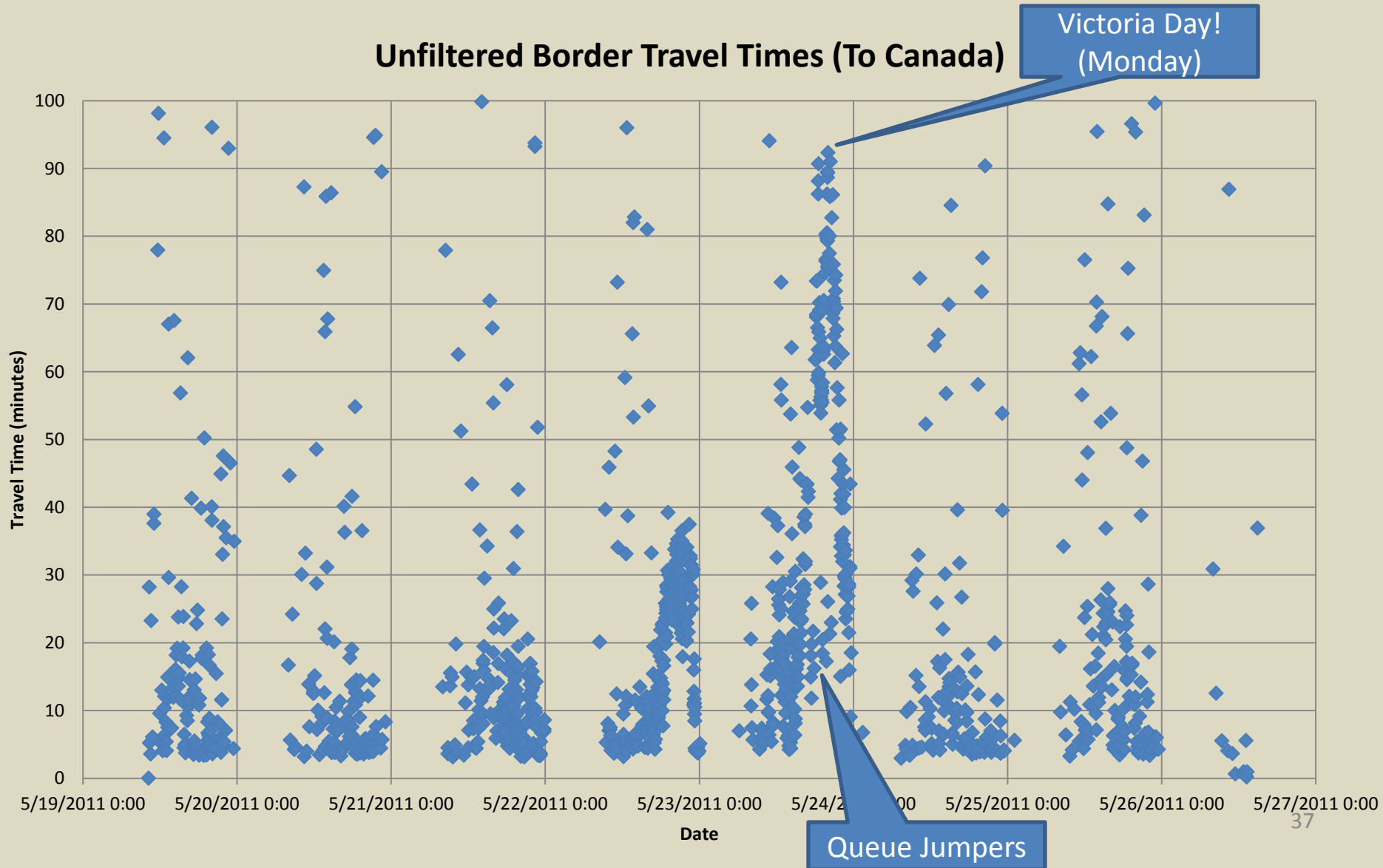 - Radar, Bluetooth, Loops, ALPR

Border Site: SR 539

2.64 miles

- 5/19 – 5/26

- Weekend Delays

- Low Volume

- Speed Limit 40

- Northbound Delay

- Queue Jumping

1x 9dBi Omni-Directional Antenna

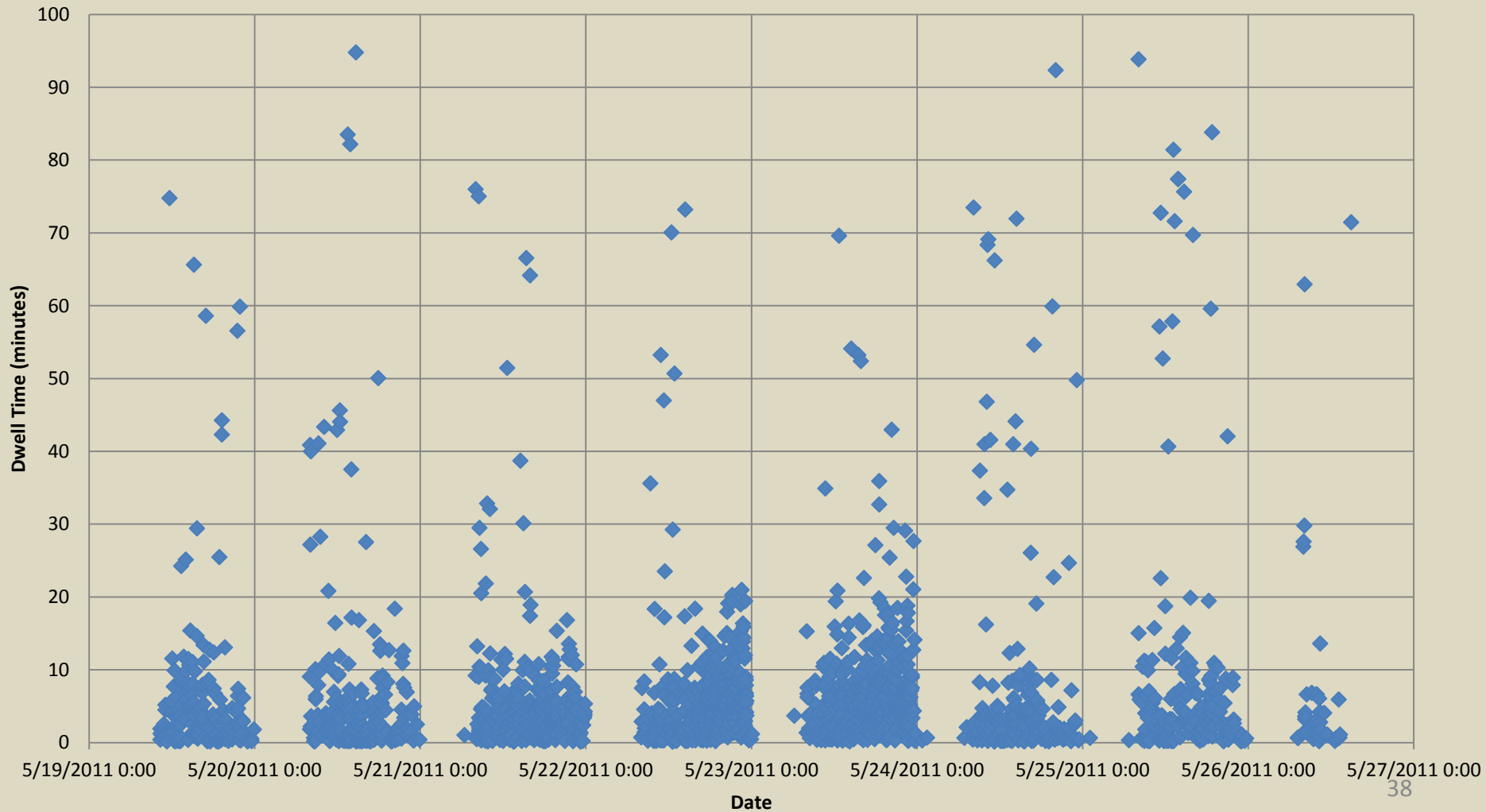1x 9dBi Omnidirectional Antenna

Border Travel Times

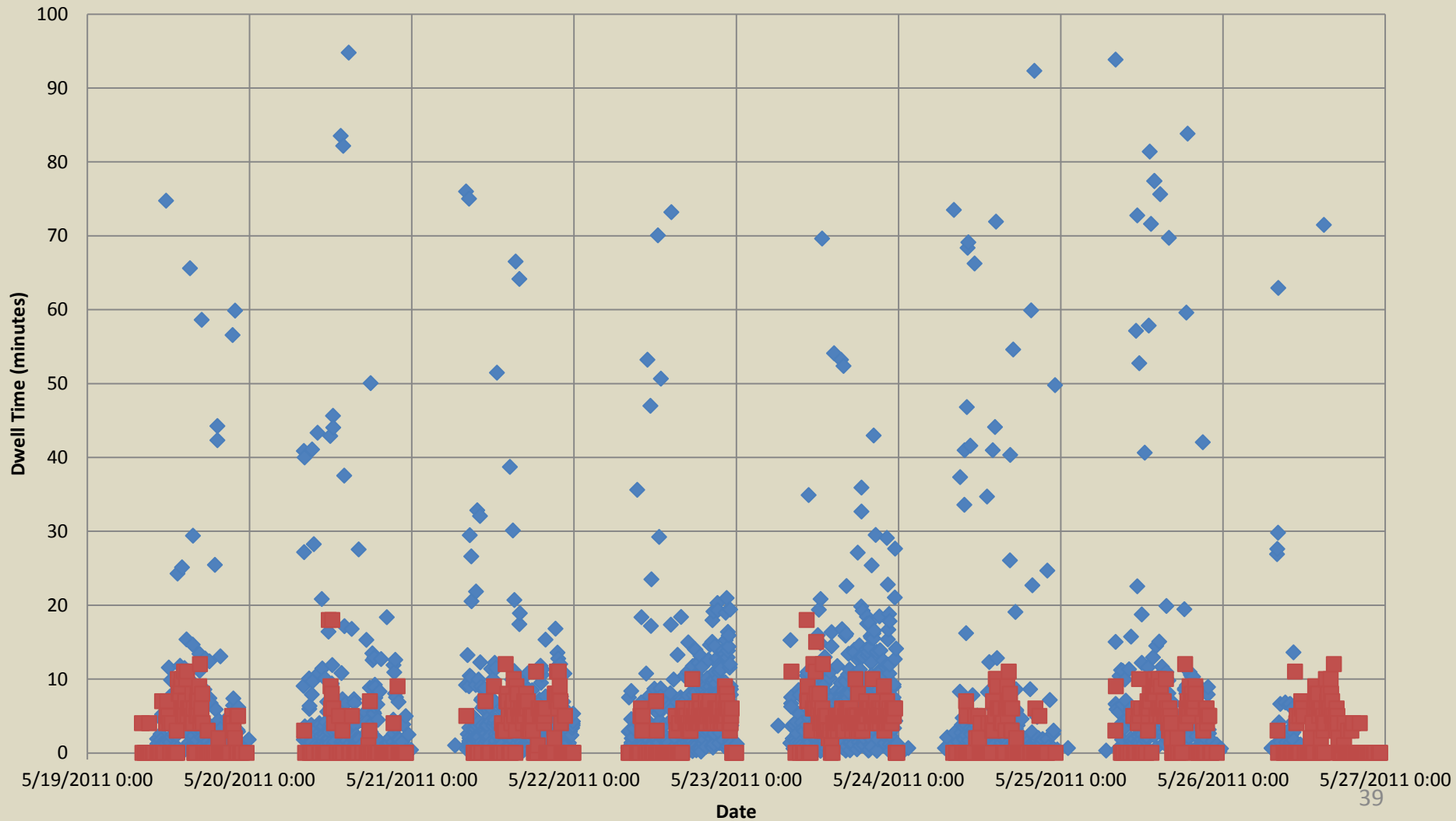Unfiltered Border Travel Times (To Canada)

Border Dwell Times

Border Dwell Times (To Canada)
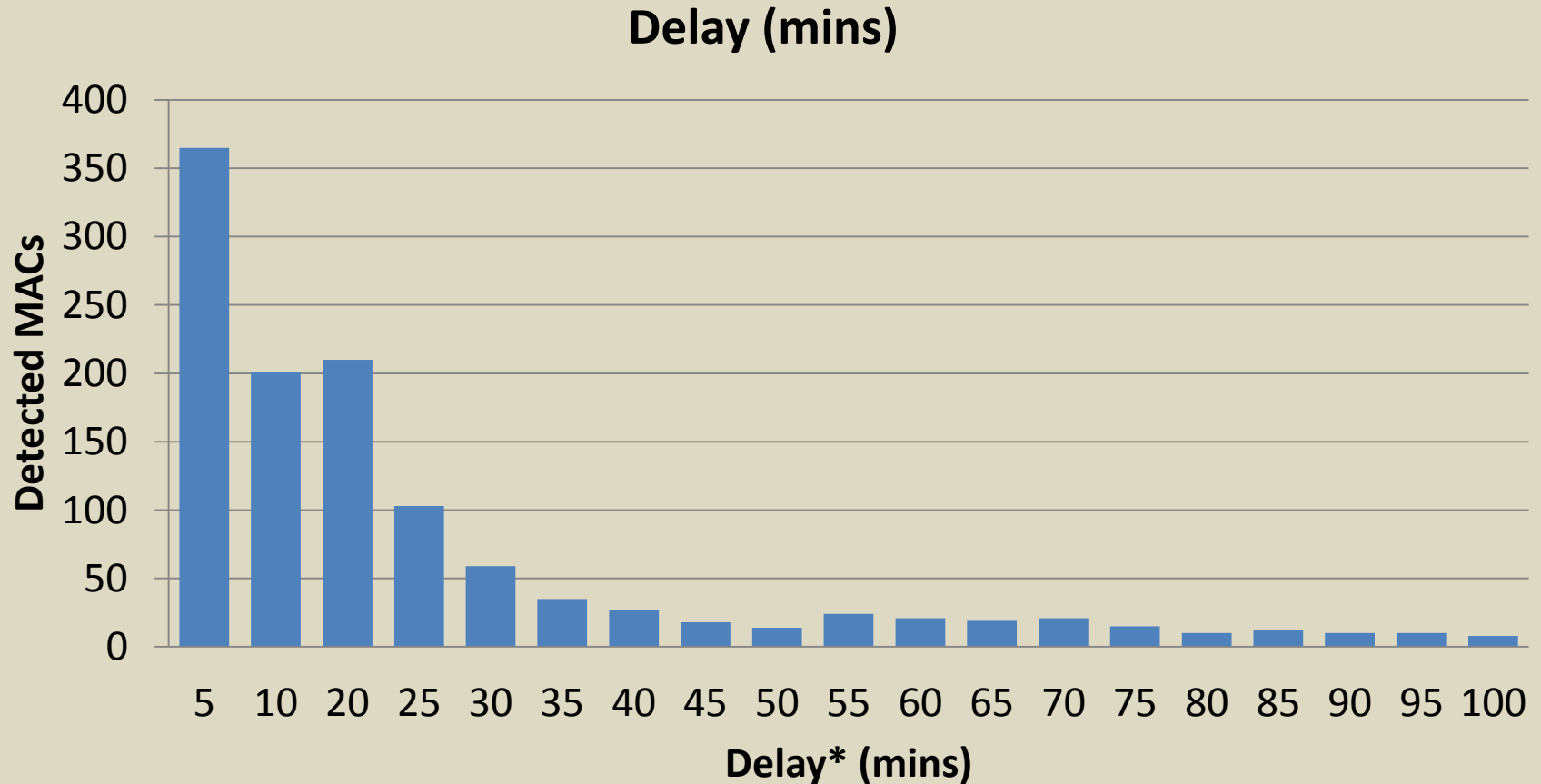
Border Dwell Times w/ Loops

Border Dwell Times (To Canada)
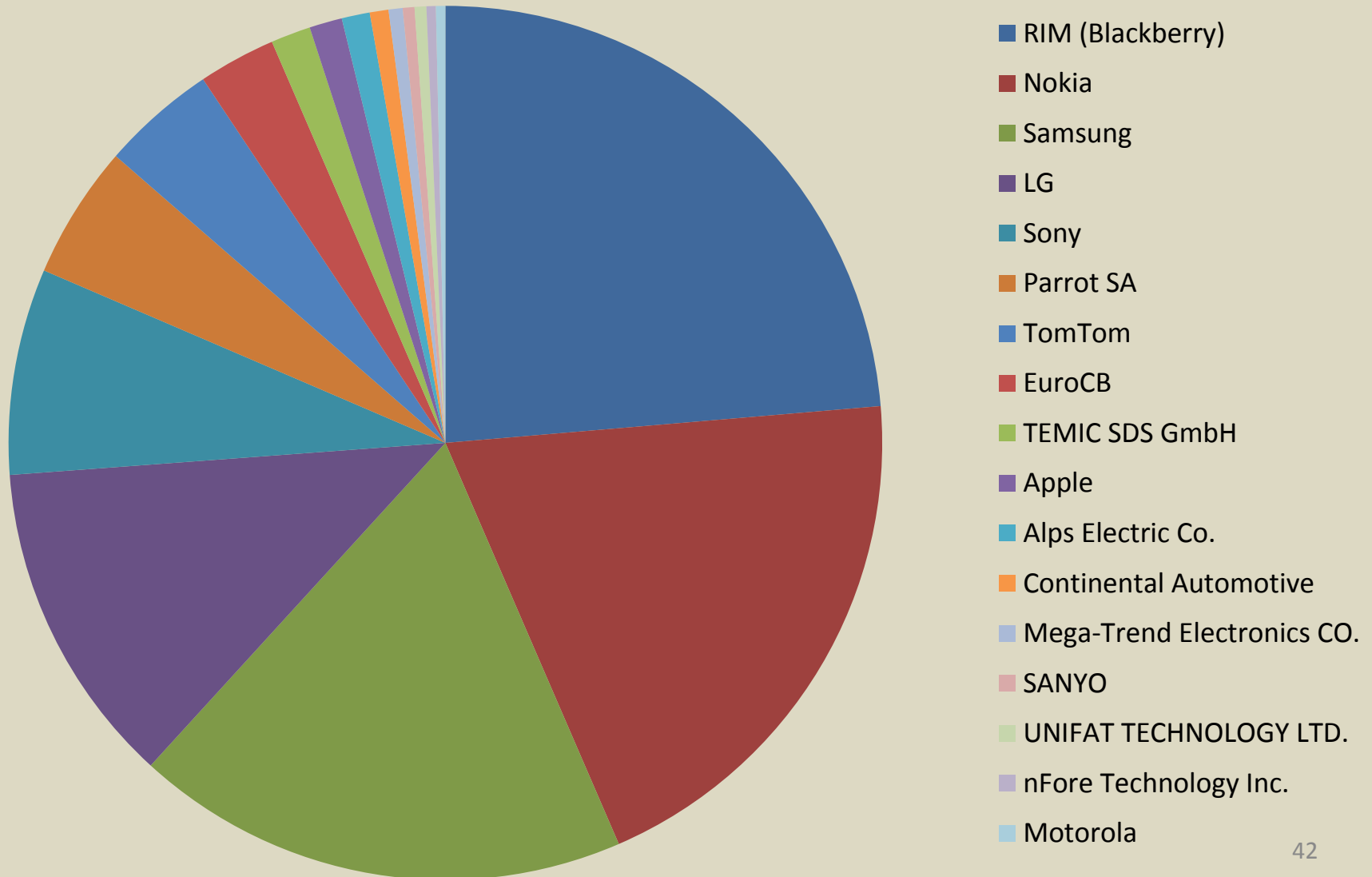
SR-539 Delay Comparison

Border Results

Delay (mins)
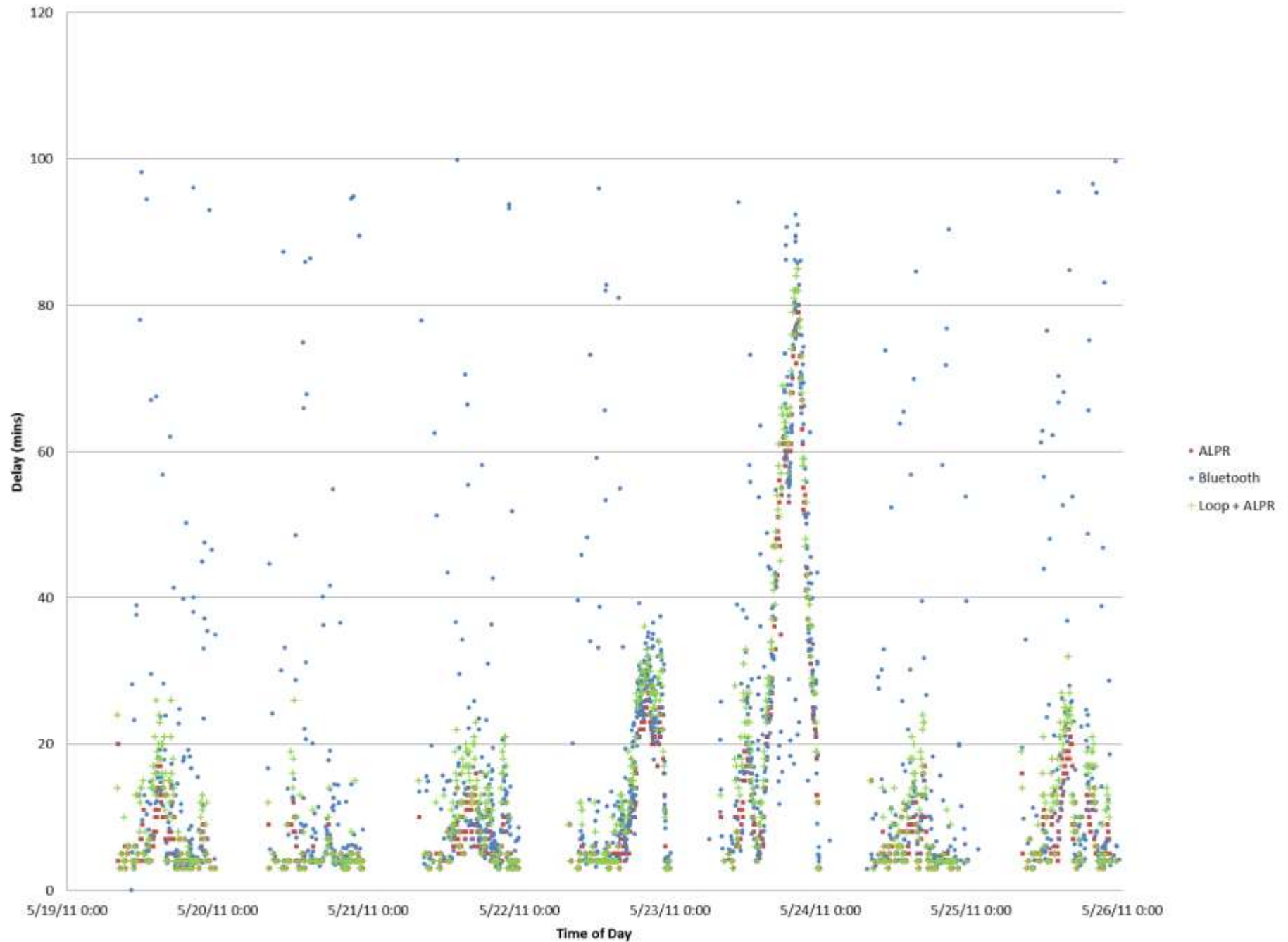
*After subtracting free-flow travel time of 3.96 minutes.
(73 devices detected with no delay, 243 with over 100 mins)

What are the Devices?

- RIM (Blackberry)
- Nokia
- Samsung
- LG
- Sony
- Parrot SA
- TomTom
- EuroCB
- TEMIC SDS GmbH
- Apple
- Alps Electric Co.
- Continental Automotive
- Mega-Trend Electronics CO.
- SANYO
- UNIFAT TECHNOLOGY LTD.
- nFore Technology Inc.
- Motorola

Tests Summary

- "Gateways" often create delay
- Delay is generally predictable
- Data is comparable to ALPR + Loops
- Delay can be quantified quickly using MAC address sensors
- Additional info from MAC sensors, such as device type can help make data more useful

Recommendations

- Mounting
  - Depending on antenna, higher may be better
  - Avoid shielding signs/wall, etc.

- Location
  - Understand impact of intersection delay if mounting at intersections
  - Midblock is not affected by intersection delay, but will reduce sample size – faster vehicles
  - Understand impact of range and use range as filtering tool

- Device Types
  - Use MAC brand for further filtering
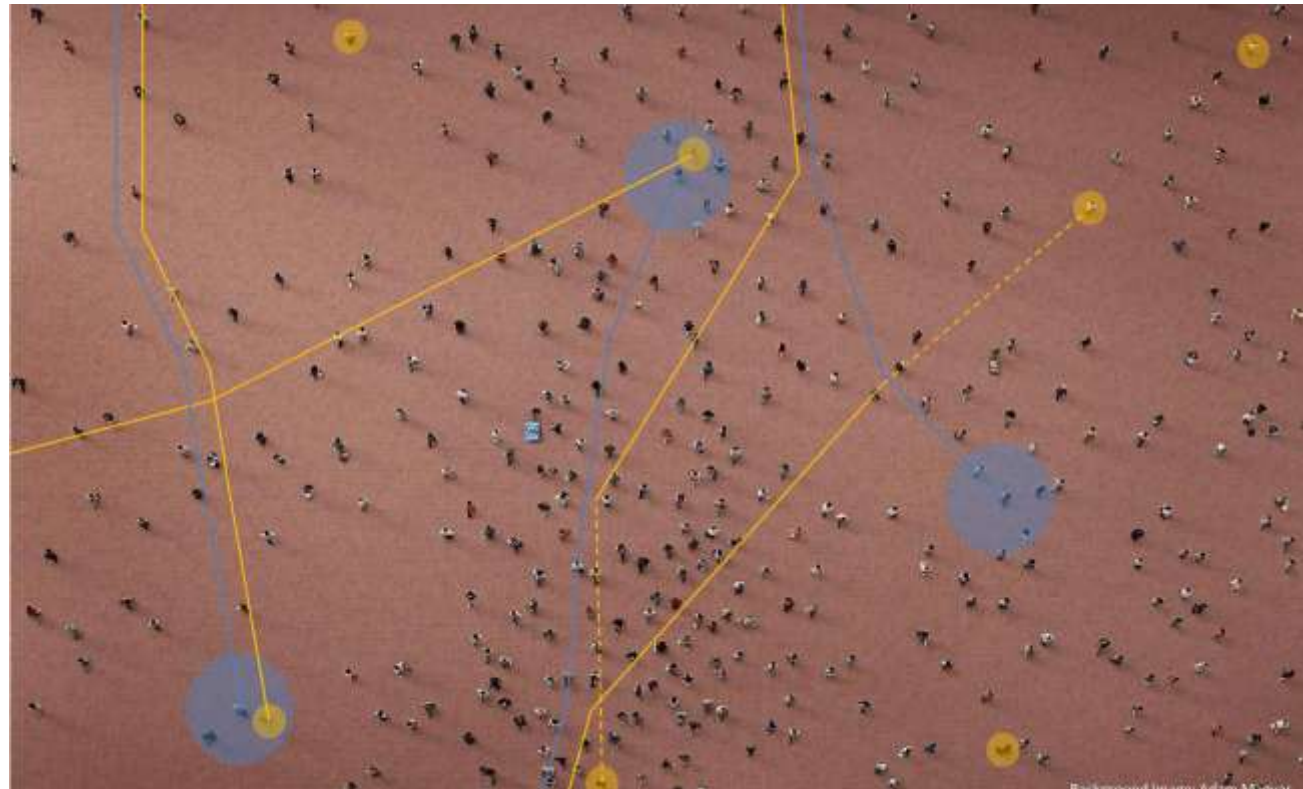
Additional Relevant Research

- Bus Stop Waiting Times
  - Measure average user wait time
  - Determine arrival patterns

- Mobile Sensing
  - Discover pedestrian travel patterns

Bus Wait Times
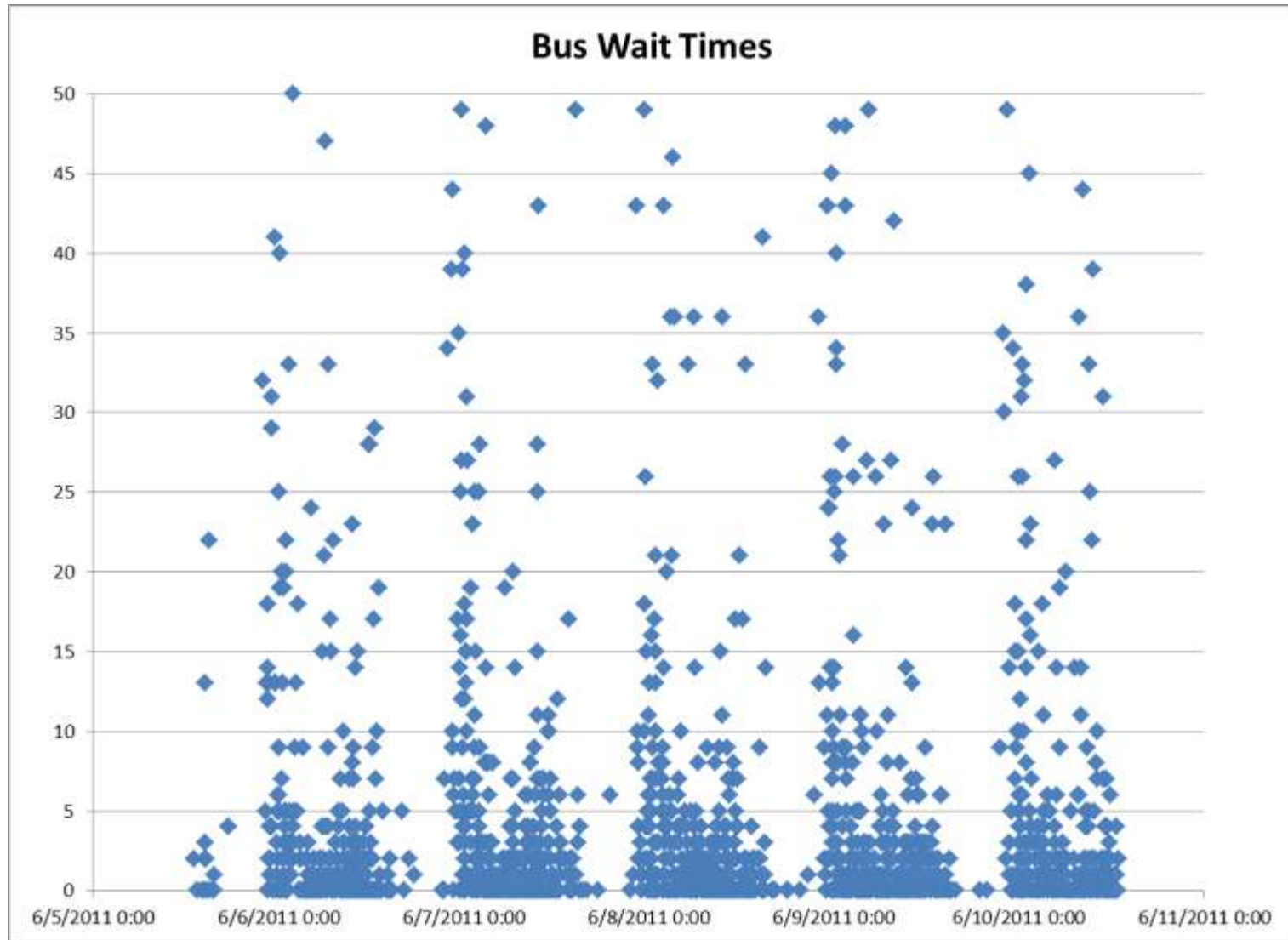
Mining Device Communications

- Mobile Sensors – as apps on smartphones

Mobile Monitor app running (left) and approach concept (right)
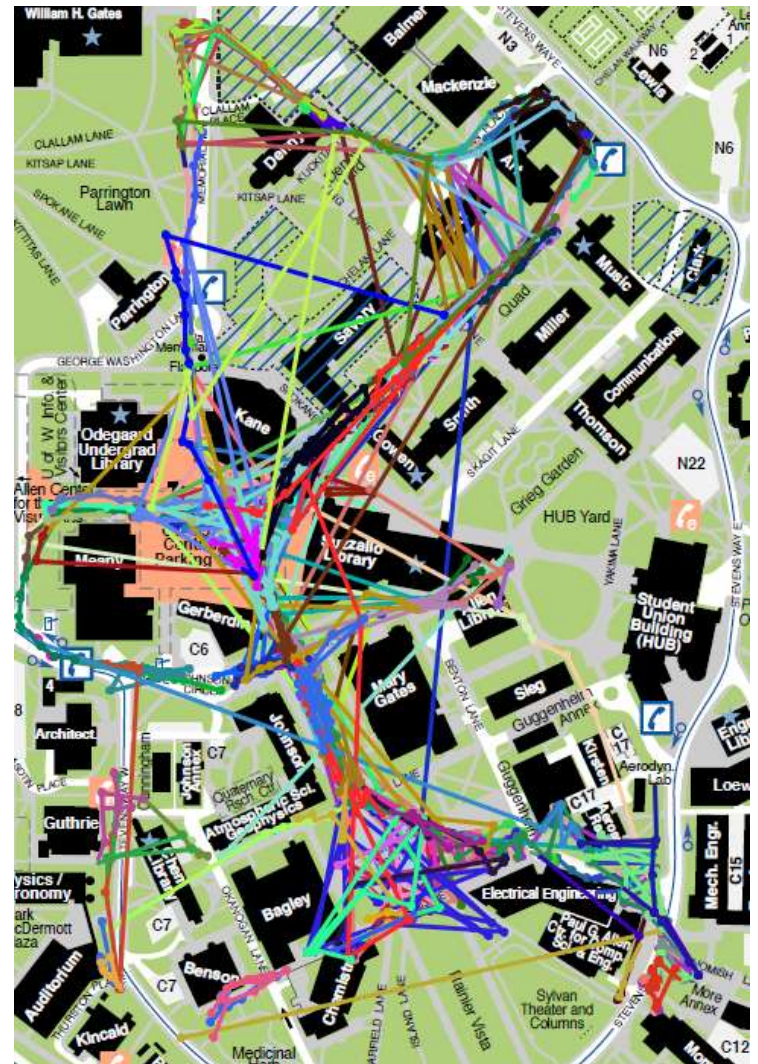
Mining Device Communications

- Concept verification
  - 4/20 1:10pm to 2:00pm
  - 4 participants
  - Loop routes

- Data
  - Travel Times/Distances
  - Routes
  - Origin/Destination

	Duration	Day	Devices Found	Trajectories Found
Mobile App Based Test	1 hr	April 20th	546	226
Static Sensor Test	24 hrs	May 4th, 5th	638	261

Bluetooth traces discovered on campus

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