Using Wireless Data Collection Units as Point Detection Systems

Western States Rural Transportation Technology Implementers Forum

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Acknowledgements

- ODOT Research/OTREC
- ODOT ITS
- Technical Advisory Committee

Outline

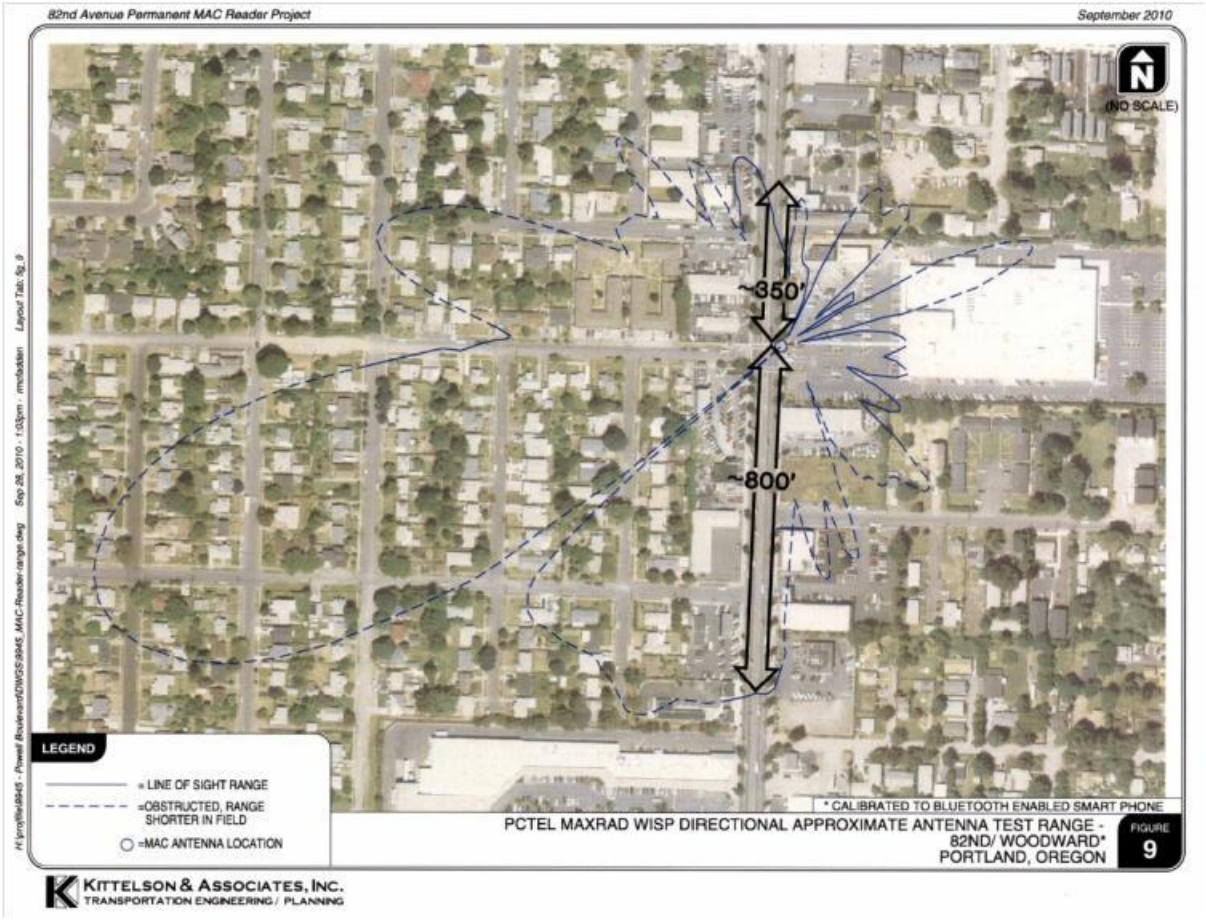
- Objectives
- Approach
- Overview of RSSI
- Tests and results
- Potential applications
- Discussion and Q & A

Objectives

- Utilize wireless data collection units to accurately identify when equipped vehicles just pass specific points on a road or highway
  - Original motivation was accurate travel time data collection on signalized arterials utilizing Bluetooth-based data collection units

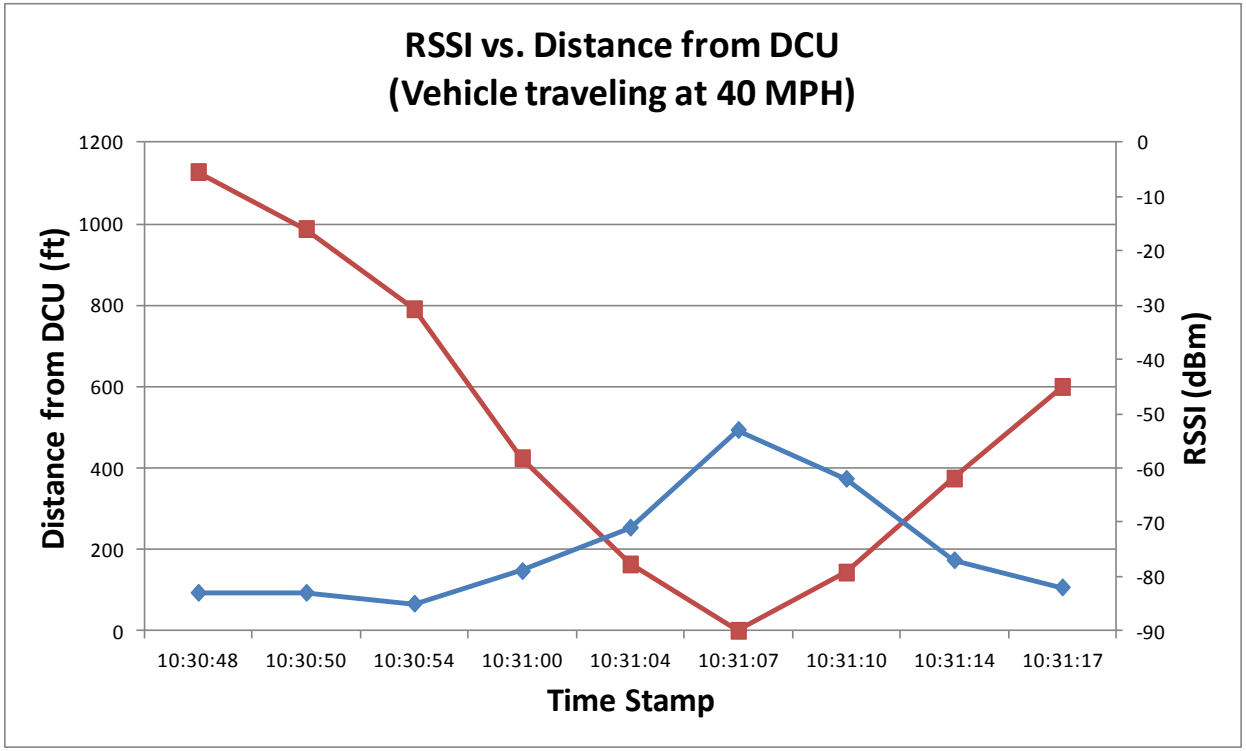
Antenna Coverage

- Example of antenna coverage pattern



Approach

- Utilize *Received Signal Strength Indicator* (RSSI) data
  - Larger RSSI value ➔ Vehicle closer to the DCU



Overview of RSSI

- *Received Signal Strength Indicator* (RSSI)
  - Value of the strength of a received radio frequency (RF) signal
  - Typically measured in units of decibels milliwatts (dBm)
    - 100 milliwatts → 20 dBm
    - 1000 milliwatts (1 watt) → 30 dBm
- Advantages
  - No additional hardware is needed to collect RSSI information in small wireless devices
- Disadvantages
  - Sensitive to variability in the transmitter, receiver and antenna orientation

Overview of RSSI (cont.)

- RSSI
  - The basic circuit is designed to pick RF signals and generate an output equivalent to the signal strength
    - The ability of the receiver to pick the weakest of signals is referred to as *receiver sensitivity*
      - The higher the receiver sensitivity, the better
  - There are circuits which measure the signal strength based on the *output voltage*
    - If the signal strength is good, the output voltage is higher and the output voltage is poor if the signal strength is low

Overview of RSSI (cont.)

- Value of the strength of a received radio frequency (RF) signal
  - A theoretical RSSI can be calculated using known signal propagation models

$$P_r = P_t\left(\frac{\lambda}{4\pi d}\right)^n \quad \Rightarrow \quad PL_{dB} = 20\log\left(\frac{4\pi}{\lambda}\right) + 10n\log(d)$$

- Where

P_r = Power received (Watts)

P_t = Power transmitted (Watts)

n = Path loss exponent

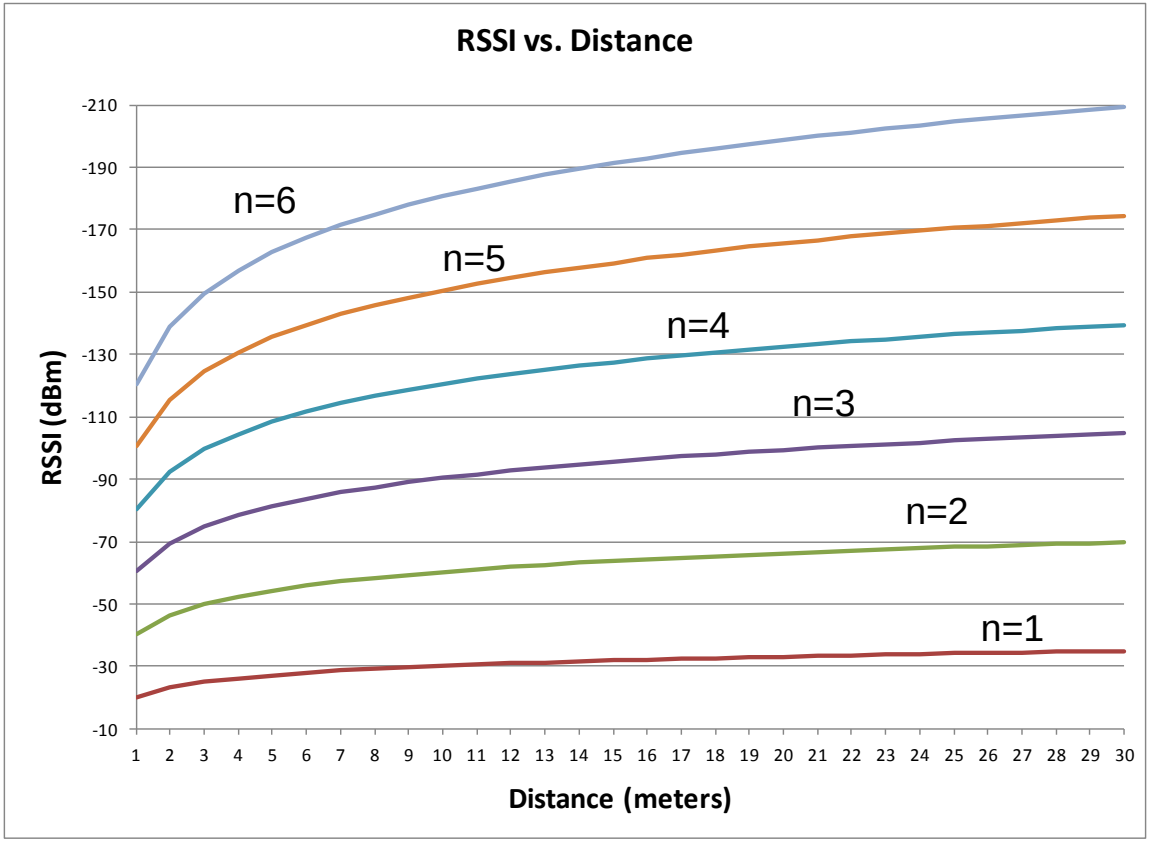
λ = Wavelength of the signal (meters)

d = distance between transmitter and receiver (meters)

PL_{dB} = Power loss in decibels

Overview of RSSI (cont.)

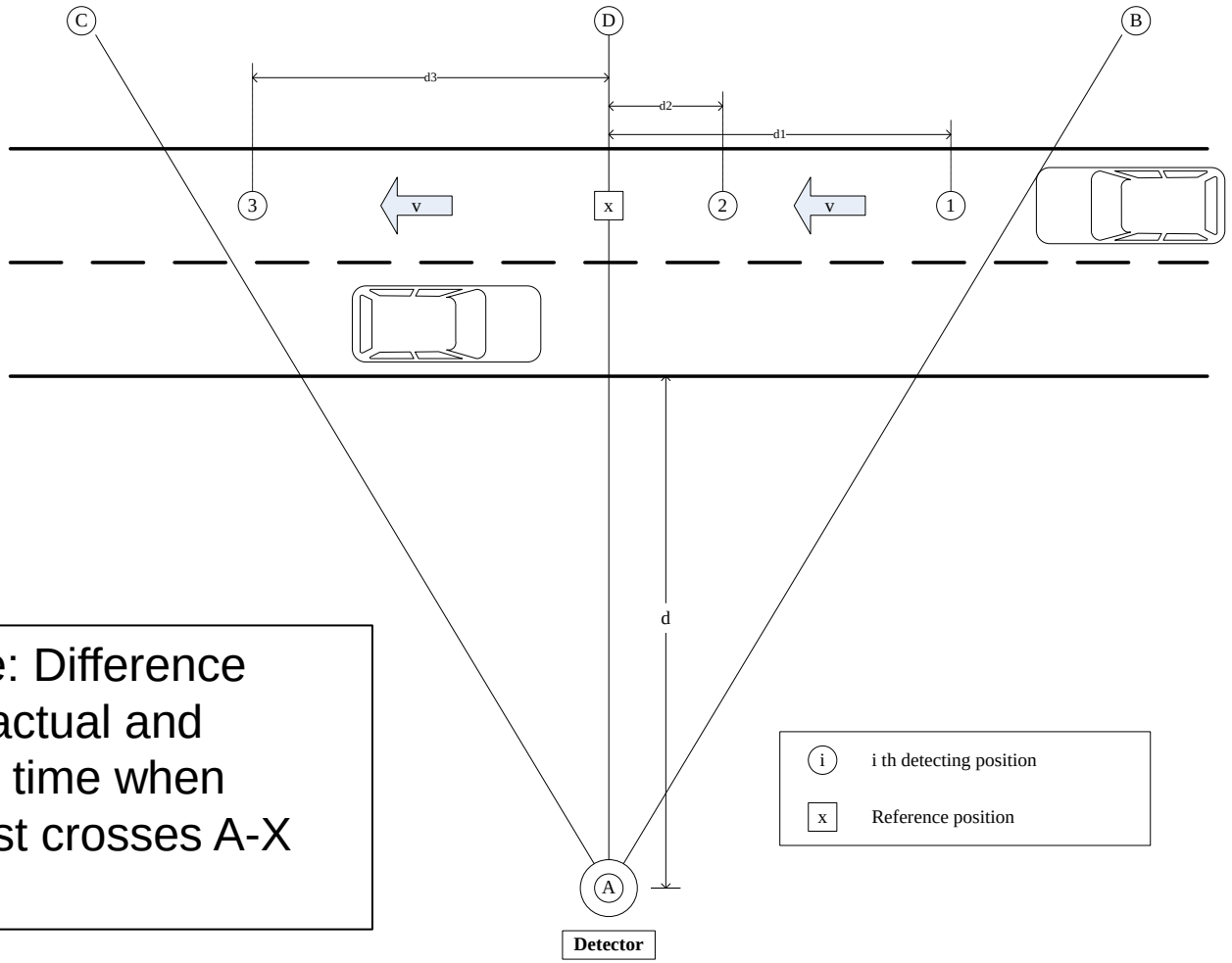
- RSSI vs. Distance for different values of *n*



Testing Conducted With Bluetooth DCUs

- Outdoor testing conducted using two known BT devices within a vehicle
  - Local two-lane rural road in Corvallis – Three speeds tested
  - Wallace Road (four lanes) in Salem – One speed (45 MPH) tested
  - Highway 99W in Tigard – DCUs installed at five signalized intersections
  - Reser stadium parking lot – using two DCUs with overlapping coverage

General Test Setup



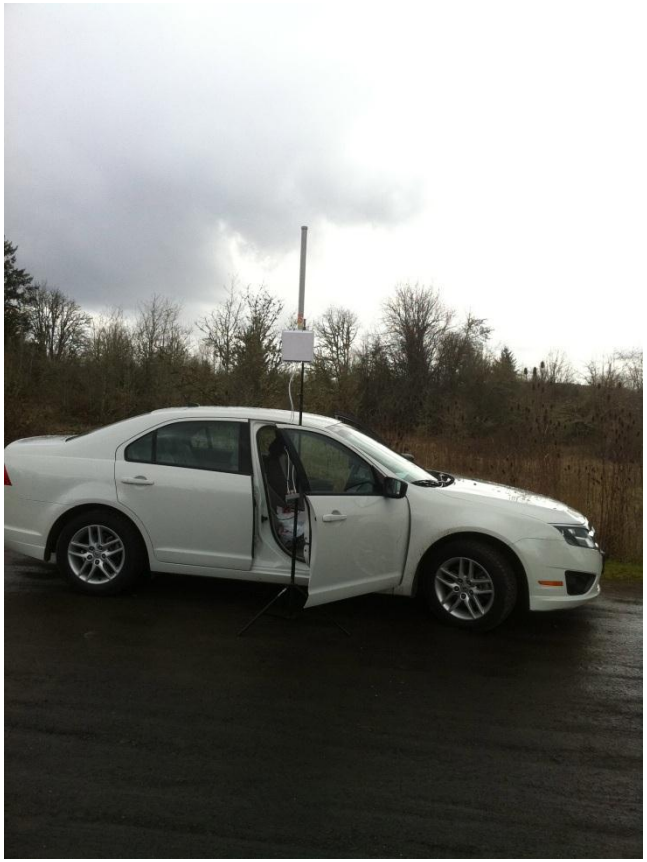
Response: Difference between actual and estimated time when vehicle just crosses A-X

Camp Adair Road, Corvallis Tests

- Antenna Height: 70”
- Distance between antenna’s location and the road: 437”
- Width of road: 270”
- Tested Speeds: 25, 35, and 45 mph
- Experiment Design: 30 observations per each travel speed

Camp Adair Road, Corvallis Tests

- Test vehicle and DCU setup

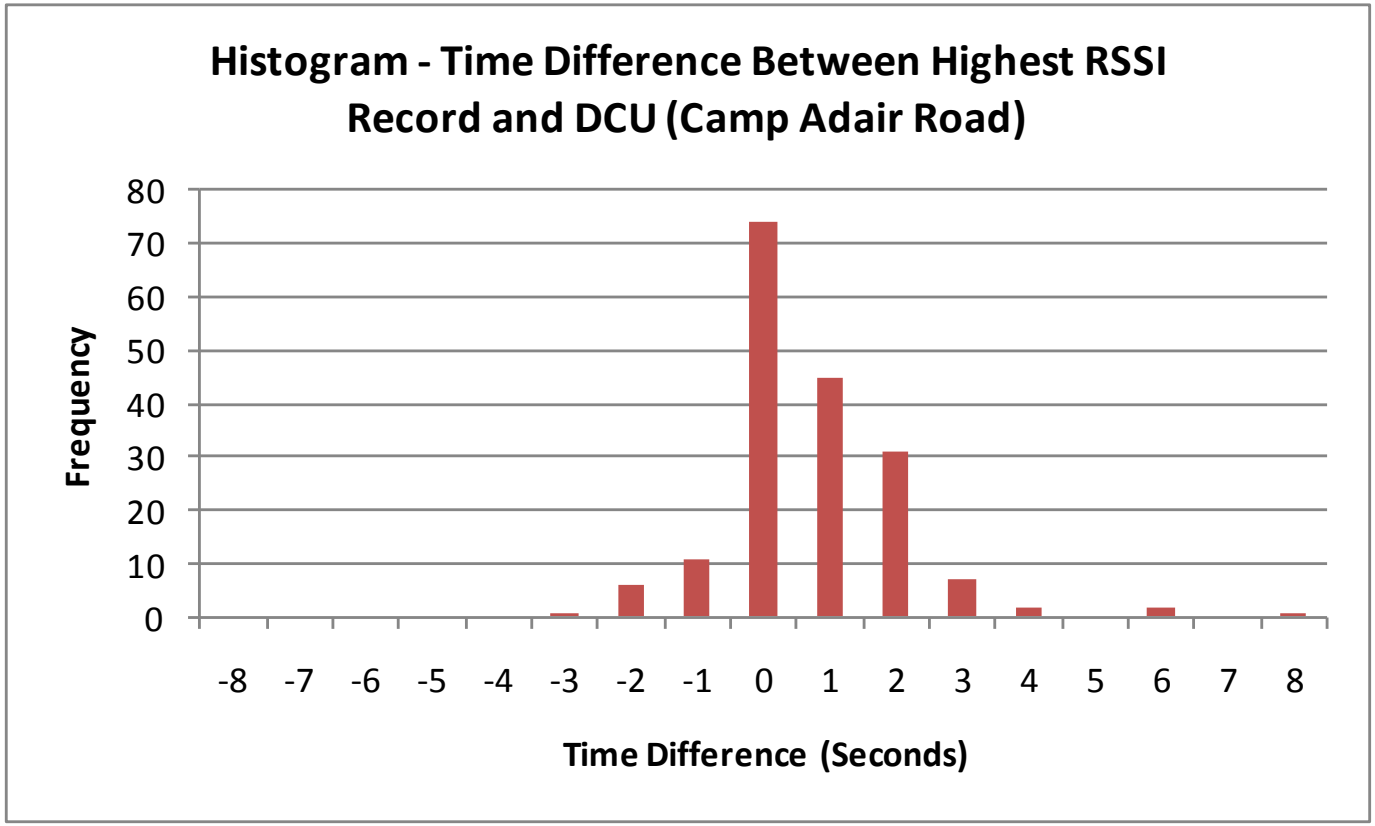


Camp Adair Road, Corvallis Tests

- Camp Adair Road

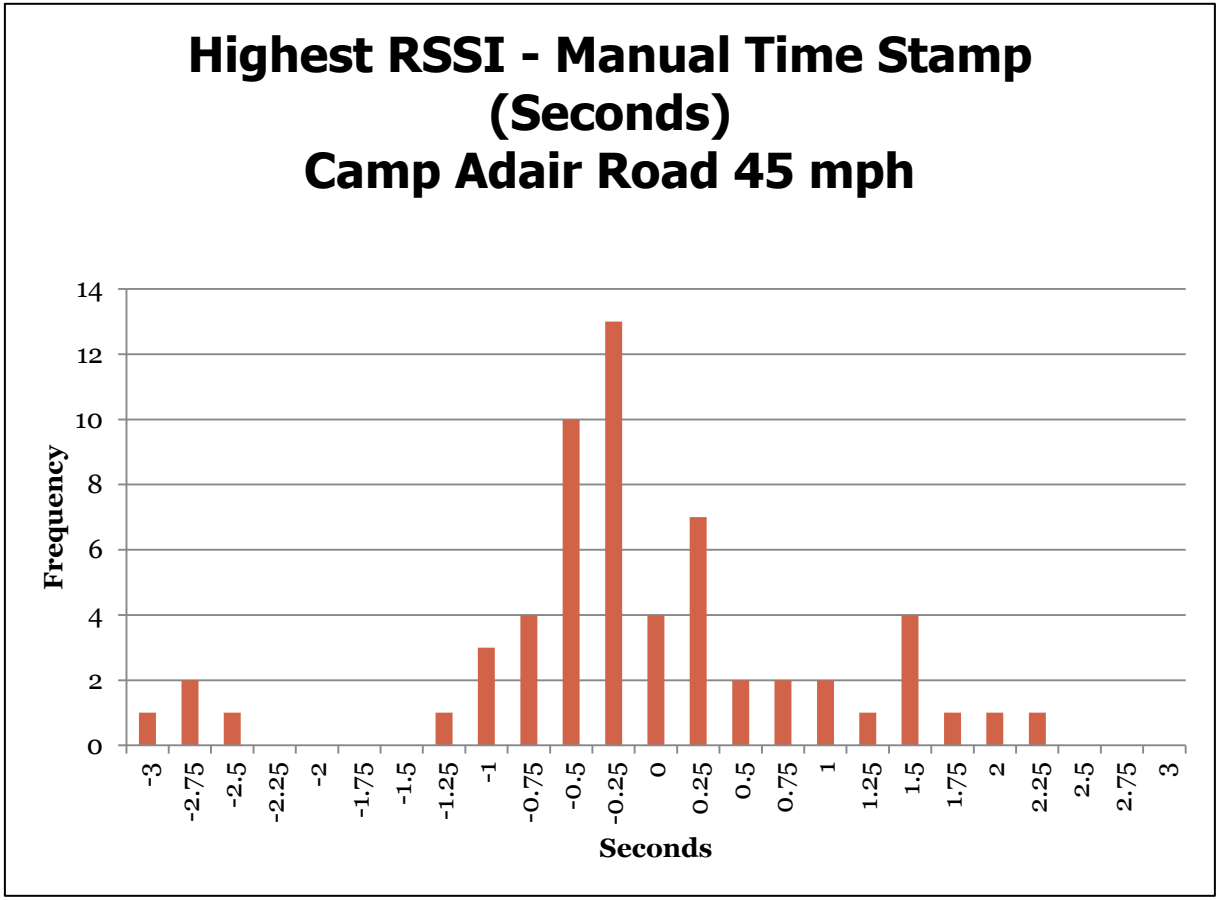
Camp Adair Road, Corvallis Tests

- Results



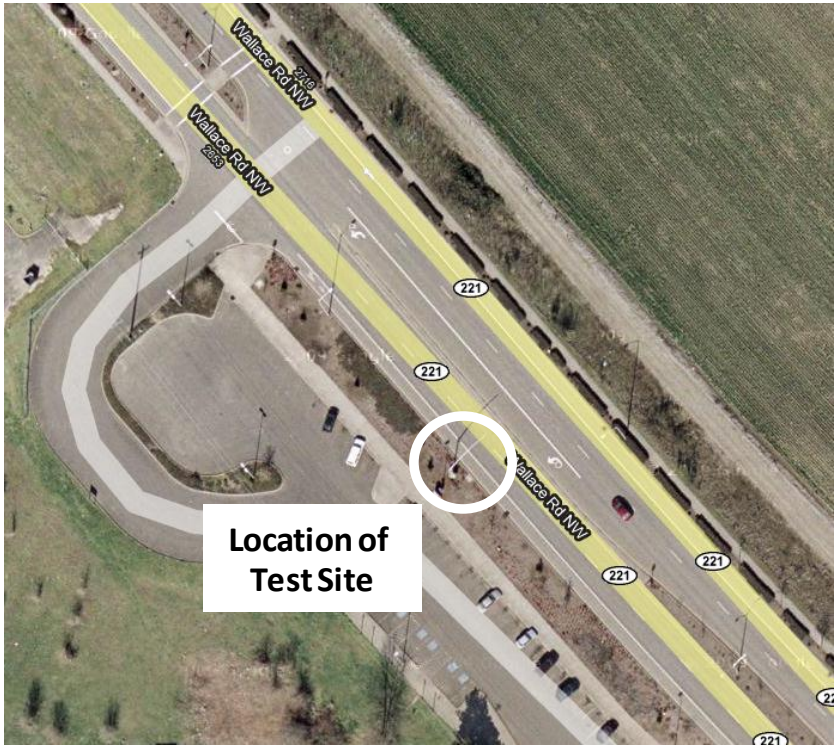
Camp Adair Road, Corvallis Tests

- Results



Wallace Road, Salem Tests

- Location of test site

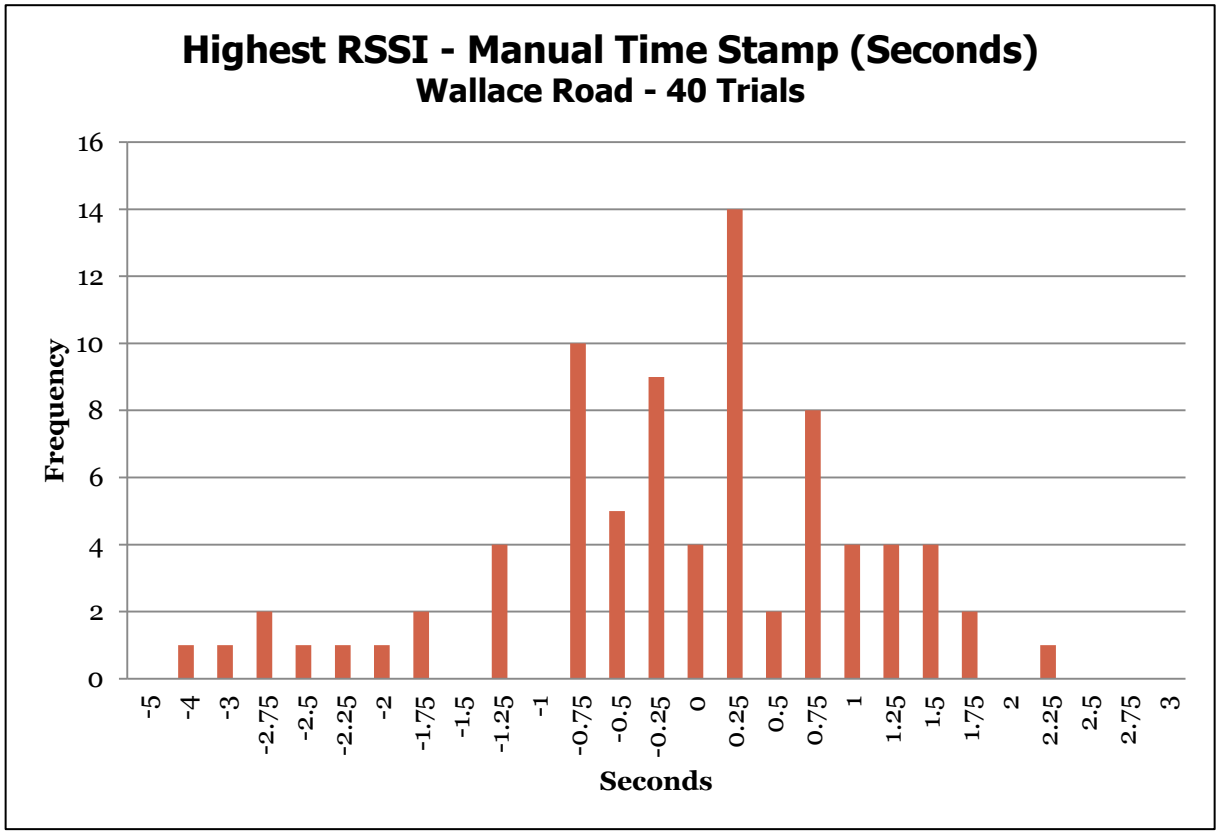


Wallace Road, Salem Tests

- Antenna height and DCU setup

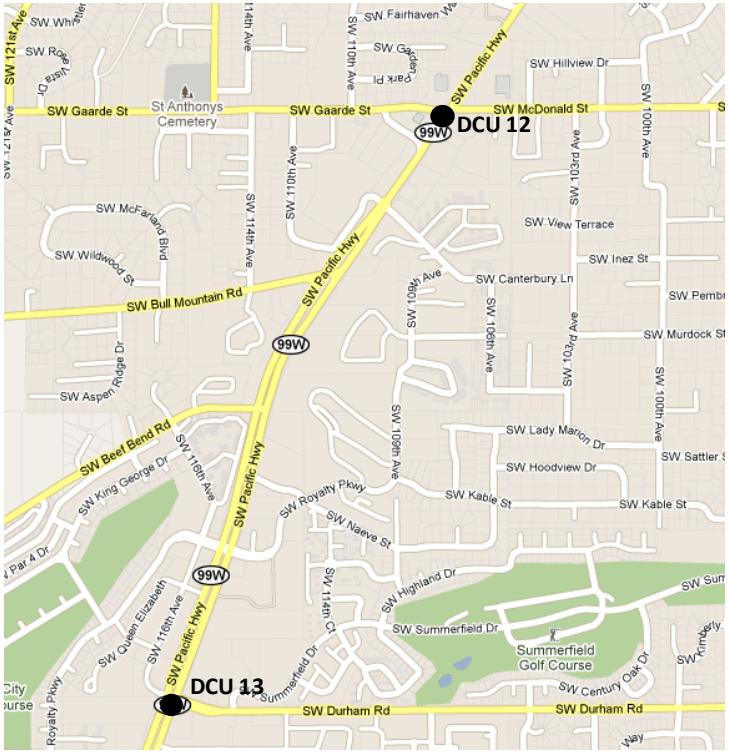
Wallace Road, Salem Tests

- Results



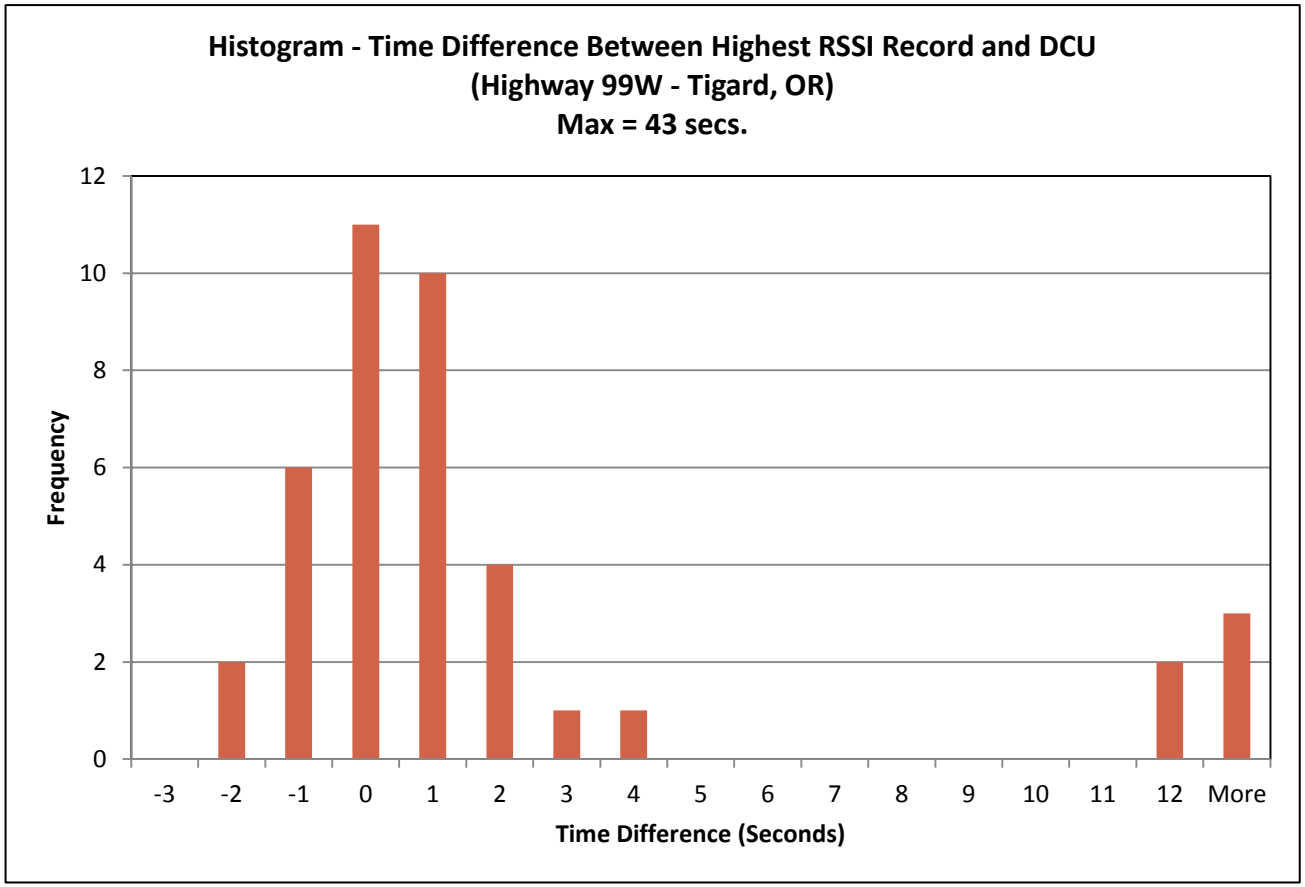
Highway 99W Tests

- Test setup diagram and pictures



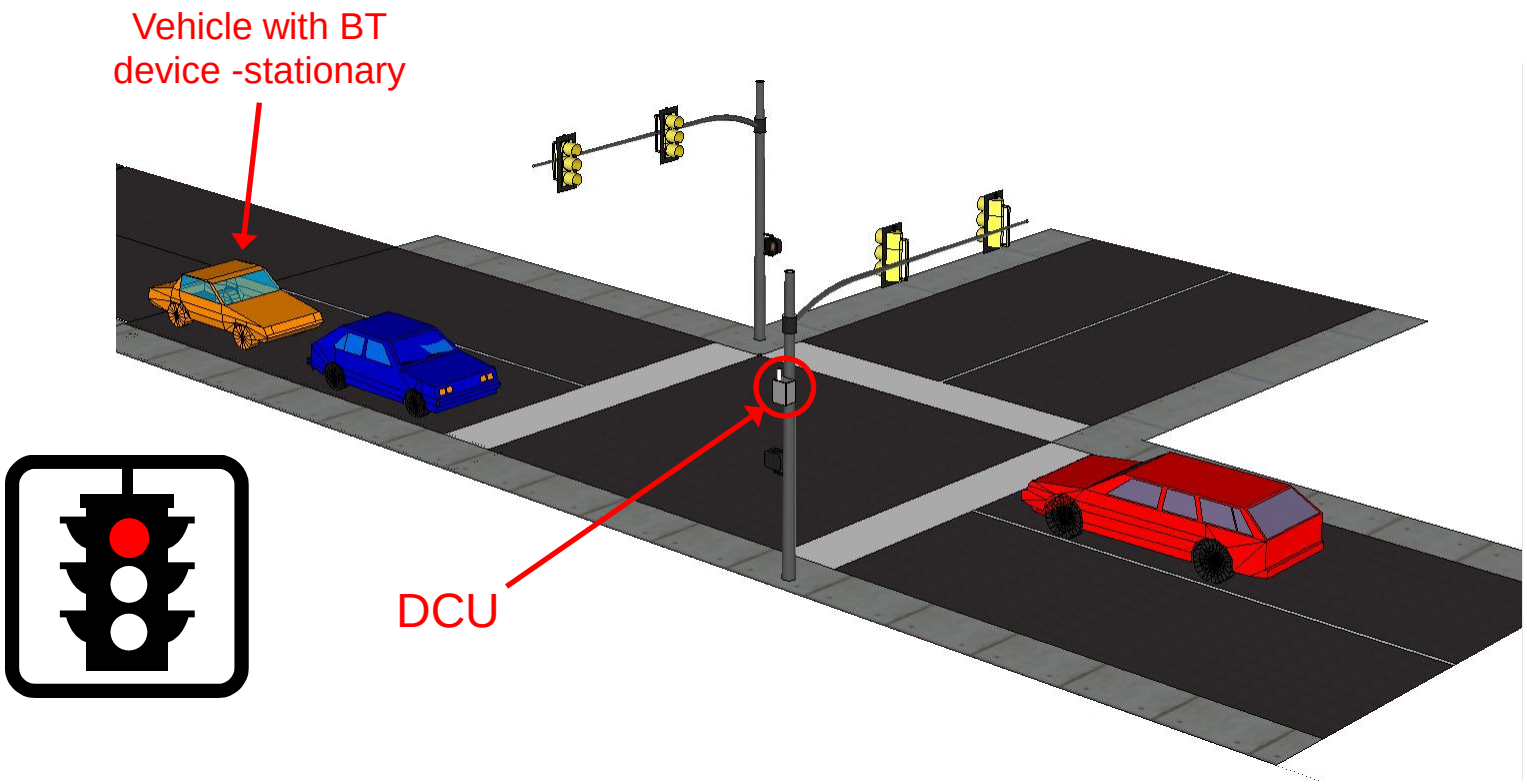
Highway 99W Tests

- Results



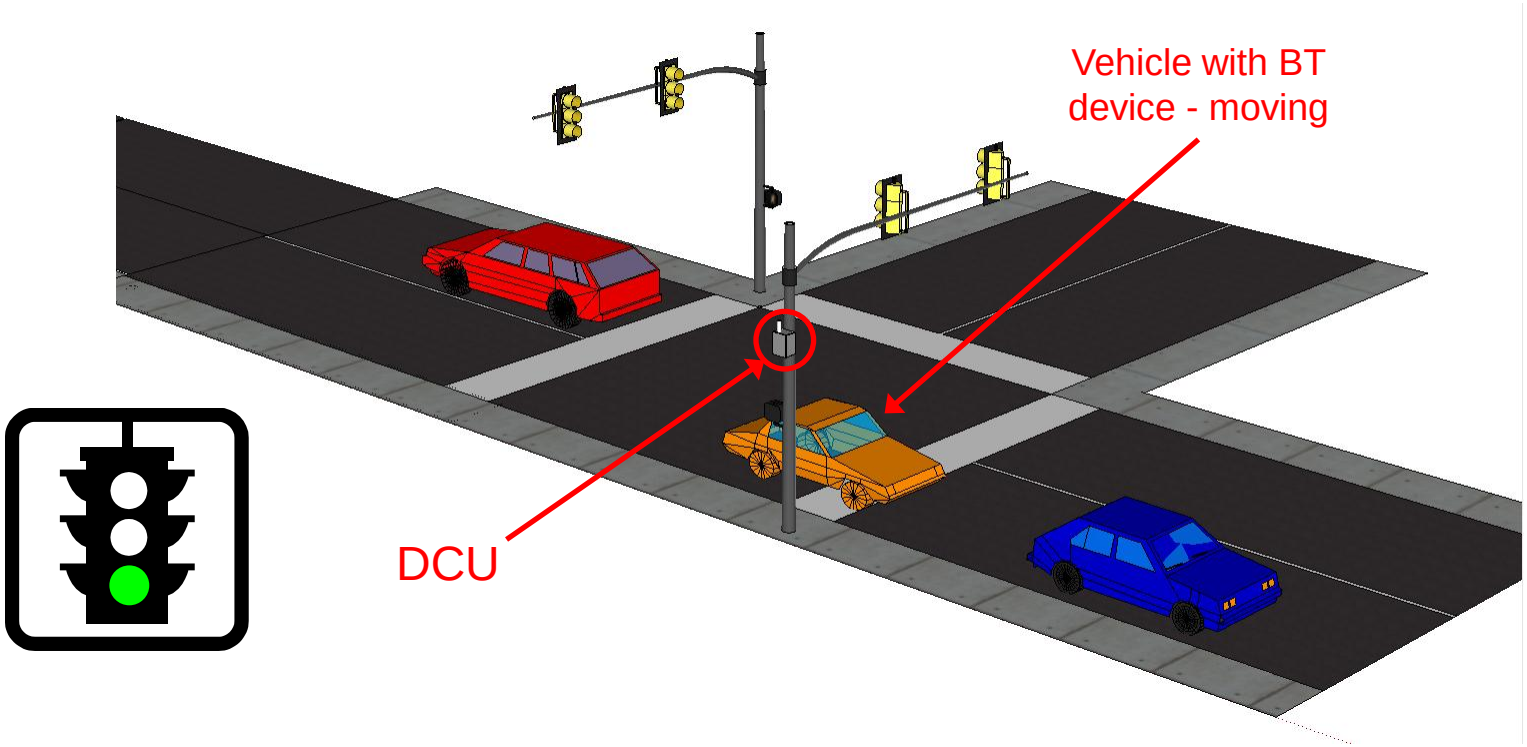
Highway 99W Tests

- Highest RSSI reading – Case 1

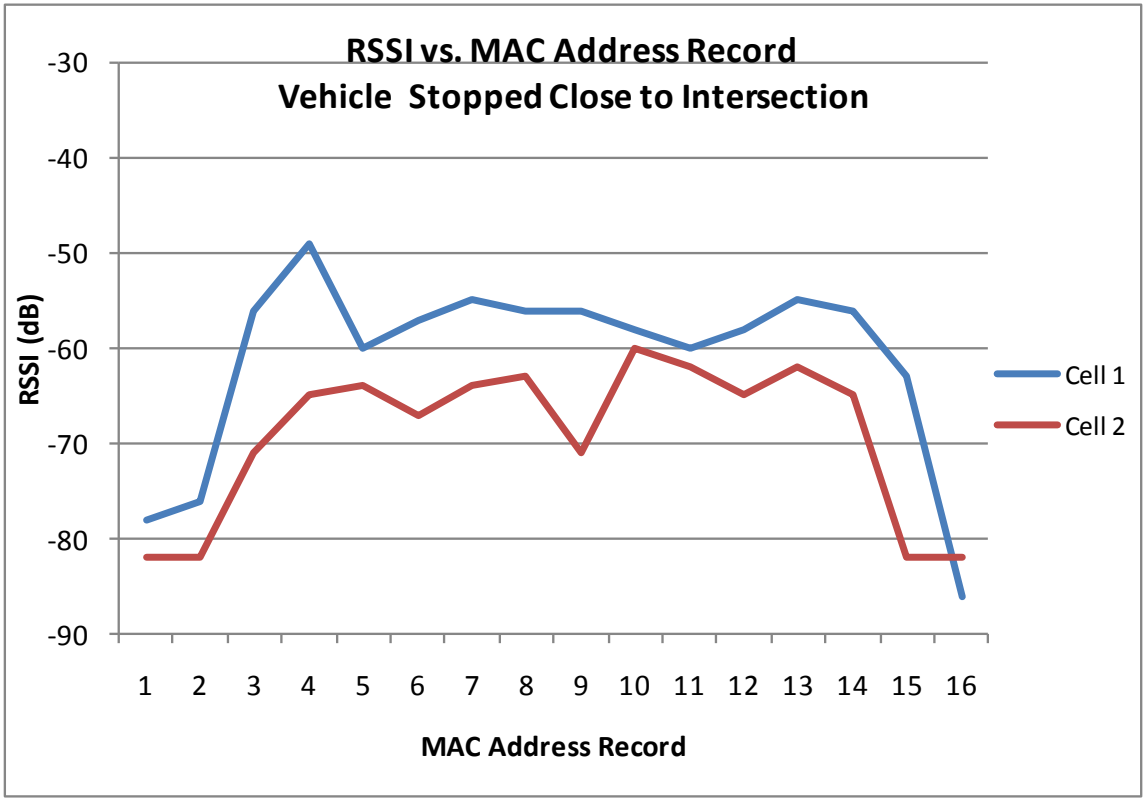


Highway 99W Tests

- Highest RSSI reading – Case 2

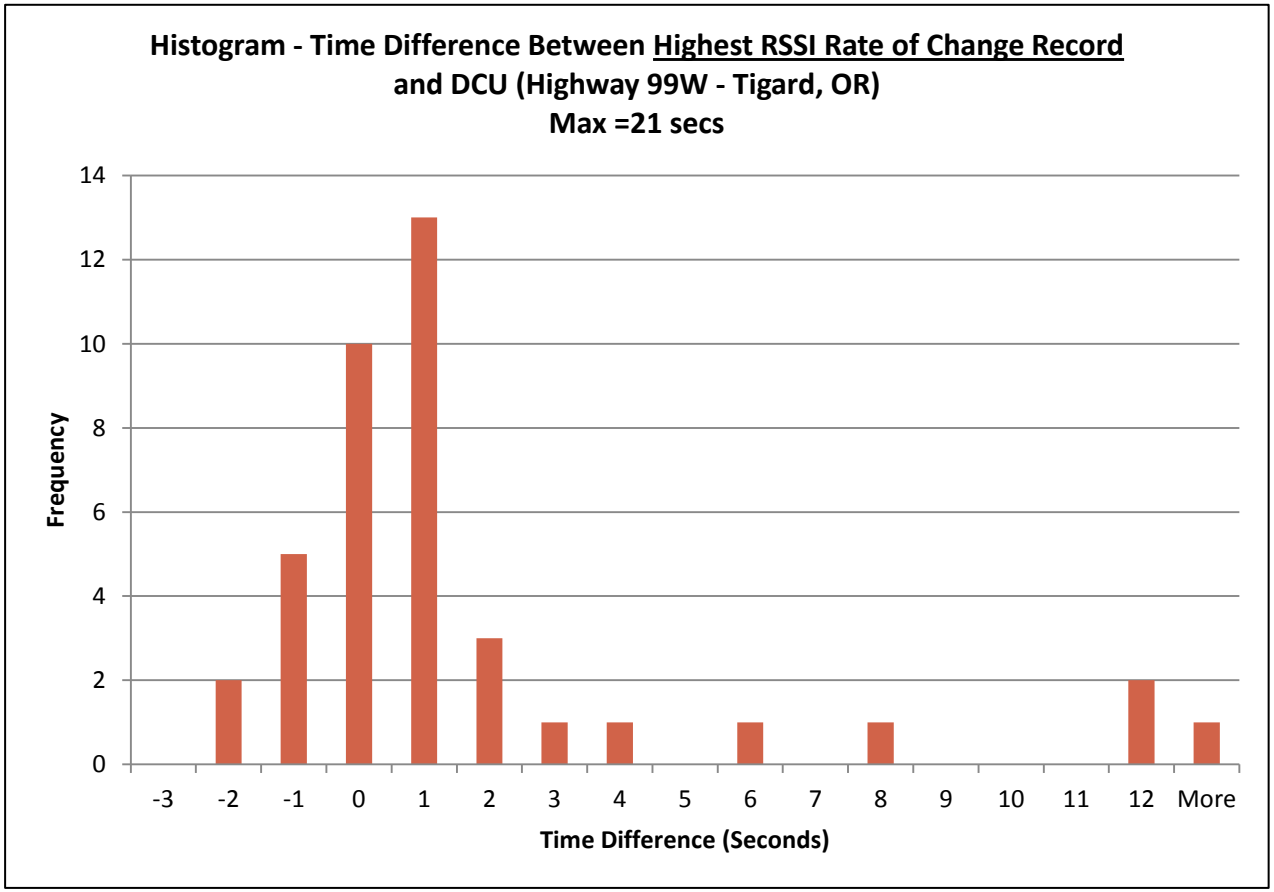


Highway 99W Tests



Highway 99W Tests

- Results



Reser Stadium Tests

- Two DCUs
  - One DCU at a "signal"
  - One DCU 100 feet from the signal
- 120 vehicle passes
  - 60 West
  - 60 East
  - In some passes, the vehicle stopped at the "intersection".

Reser Stadium Tests

- Antenna setup 1

Reser Stadium Tests

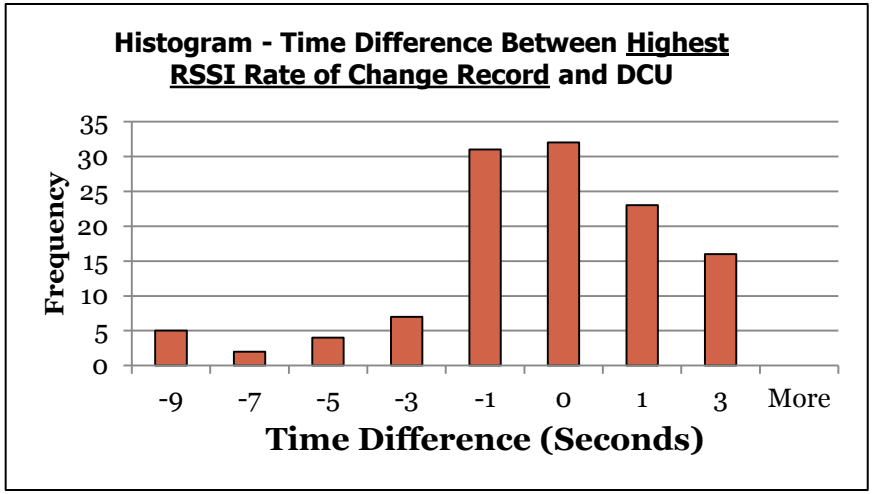
- Antenna setup 2

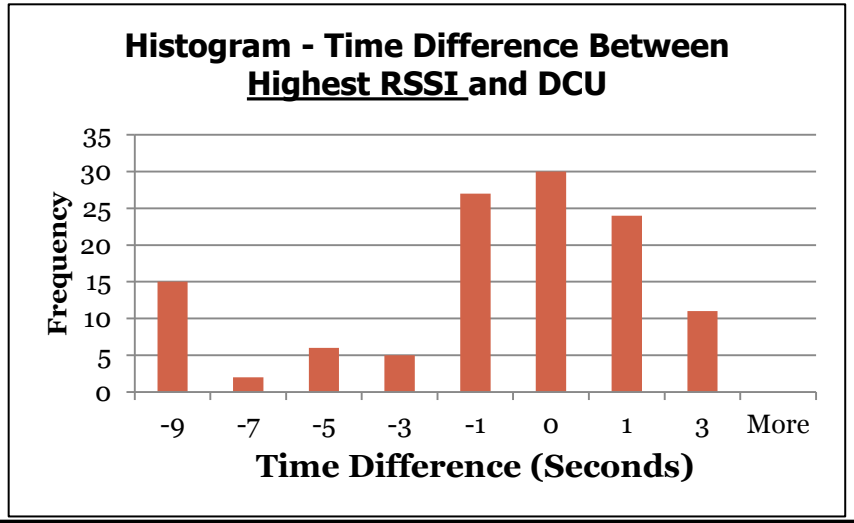
Reser Stadium Tests

- Pictures

Reser Stadium Tests

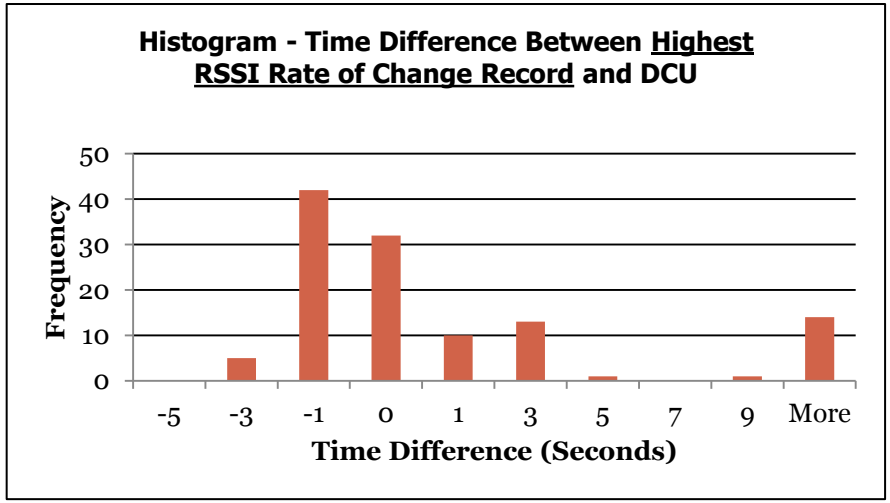
- Intersection
  - Includes stops and through passes

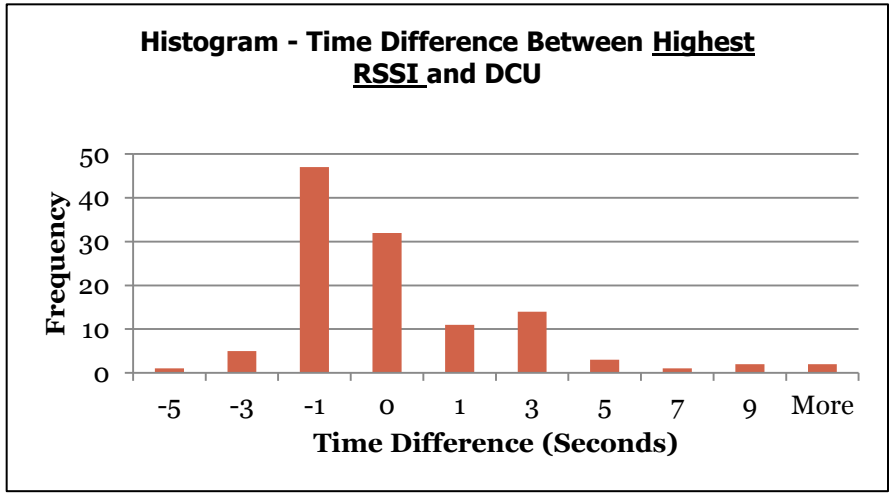




Reser Stadium Tests

- Before Intersection





On-Going Research

- Better methods for identifying when the vehicle passes the DCU
  - Better results have been obtained
- Testing the use of two DCUs to more accurately (in distance) identifying when the vehicle passes the DCU
  - Adjacent
  - On opposite sides of the road

On-Going Research

Distance Differences (feet) 5280 ft/mile

Vehicle Speed	Vehicle Speed	Passing the DCU time difference - actual vs. detected (Seconds)					
Speed (MPH)	Feet Per Second	1	2	3	4	5	6
1	1.47	1.47	2.93	4.40	5.87	7.33	8.80
2	2.93	2.93	5.87	8.80	11.73	14.67	17.60
3	4.40	4.40	8.80	13.20	17.60	22.00	26.40
4	5.87	5.87	11.73	17.60	23.47	29.33	35.20
5	7.33	7.33	14.67	22.00	29.33	36.67	44.00
6	8.80	8.80	17.60	26.40	35.20	44.00	52.80
7	10.27	10.27	20.53	30.80	41.07	51.33	61.60
8	11.73	11.73	23.47	35.20	46.93	58.67	70.40
9	13.20	13.20	26.40	39.60	52.80	66.00	79.20
10	14.67	14.67	29.33	44.00	58.67	73.33	88.00
11	16.13	16.13	32.27	48.40	64.53	80.67	96.80
12	17.60	17.60	35.20	52.80	70.40	88.00	105.60
13	19.07	19.07	38.13	57.20	76.27	95.33	114.40
14	20.53	20.53	41.07	61.60	82.13	102.67	123.20
15	22.00	22.00	44.00	66.00	88.00	110.00	132.00
16	23.47	23.47	46.93	70.40	93.87	117.33	140.80
17	24.93	24.93	49.87	74.80	99.73	124.67	149.60
18	26.40	26.40	52.80	79.20	105.60	132.00	158.40
19	27.87	27.87	55.73	83.60	111.47	139.33	167.20
20	29.33	29.33	58.67	88.00	117.33	146.67	176.00
21	30.80	30.80	61.60	92.40	123.20	154.00	184.80
22	32.27	32.27	64.53	96.80	129.07	161.33	193.60
23	33.73	33.73	67.47	101.20	134.93	168.67	202.40
24	35.20	35.20	70.40	105.60	140.80	176.00	211.20
25	36.67	36.67	73.33	110.00	146.67	183.33	220.00
26	38.13	38.13	76.27	114.40	152.53	190.67	228.80
27	39.60	39.60	79.20	118.80	158.40	198.00	237.60
28	41.07	41.07	82.13	123.20	164.27	205.33	246.40
29	42.53	42.53	85.07	127.60	170.13	212.67	255.20
30	44.00	44.00	88.00	132.00	176.00	220.00	264.00
31	45.47	45.47	90.93	136.40	181.87	227.33	272.80
32	46.93	46.93	93.87	140.80	187.73	234.67	281.60
33	48.40	48.40	96.80	145.20	193.60	242.00	290.40
34	49.87	49.87	99.73	149.60	199.47	249.33	299.20
35	51.33	51.33	102.67	154.00	205.33	256.67	308.00
36	52.80	52.80	105.60	158.40	211.20	264.00	316.80
37	54.27	54.27	108.53	162.80	217.07	271.33	325.60
38	55.73	55.73	111.47	167.20	222.93	278.67	334.40
39	57.20	57.20	114.40	171.60	228.80	286.00	343.20
40	58.67	58.67	117.33	176.00	234.67	293.33	352.00

Applications

- Intersection performance data collection
  - Average control delay
  - Average total time at intersection
- Work zone data collection
  - Average time in work zone
- Acceleration/deceleration data
  - Need to evaluate accuracy obtainable

DISCUSSION
&
QUESTIONS