Using Wireless Data Collection Units as Point Detection Systems

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Acknowledgements

- ODOT Research/OTREC
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- 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 $\Rightarrow$ 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
- \( \lambda \) = 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
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

Histogram - Time Difference Between Highest RSSI Record and DCU (Camp Adair Road)
Camp Adair Road, Corvallis Tests

• Results

Highest RSSI - Manual Time Stamp
(Seconds)
Camp Adair Road 45 mph
Wallace Road, Salem Tests

• Location of test site

![Map showing the location of test site](image-url)
Wallace Road, Salem Tests

- Antenna height and DCU setup

Approximate Installation Height for Reader Unit and Antenna
Wallace Road, Salem Tests

- Results

![Histogram of Highest RSSI - Manual Time Stamp (Seconds) for Wallace Road - 40 Trials]
Highway 99W Tests

- Test setup diagram and pictures
Highway 99W Tests

• Results

Histogram - Time Difference Between Highest RSSI Record and DCU
(Highway 99W - Tigard, OR)
Max = 43 secs.
Highway 99W Tests

- Highest RSSI reading – Case 1

Vehicle with BT device - stationary

DCU
Highway 99W Tests

- Highest RSSI reading – Case 2

[Diagram of a vehicle with a BT device moving and a DCU marker]
Highway 99W Tests

RSSI vs. MAC Address Record
Vehicle Stopped Close to Intersection

-90
-80
-70
-60
-50
-40
-30
-20
-10
0
10
20
30
40
50
60
70
80
90
100

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

MAC Address Record

Cell 1
Cell 2
Highway 99W Tests

• Results

Histogram - Time Difference Between Highest RSSI Rate of Change Record and DCU (Highway 99W - Tigard, OR)
Max = 21 secs
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

Histogram - Time Difference Between Highest RSSI Rate of Change Record and DCU

Histogram - Time Difference Between Highest RSSI and DCU
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
## Distance Differences (feet)

<table>
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<th>Vehicle Speed Feet Per Second</th>
<th>Passing the DCU time difference - actual vs. detected (Seconds)</th>
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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