Using Bluetooth Low Energy (BLE) Technology to Trigger In-Vehicle Messages at Work Zones

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Outline

• Background & Objectives
• Our Approach
• Design and Development
• Experiments and Results
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• Summary & Conclusion
Background

• According to FHWA in 2015, there were an estimated 96,626 crashes in work zones (a 42% increase since 2013), resulting in 700 deaths and 47,758 injuries in the US.

• More than 20,000 workers are injured in work zones each year, with 12% of those due to traffic incidents.

• Many ITS tools and applications have been developed and implemented to effectively mitigate traffic impacts caused by construction.

• In recent years, challenges to work zone safety and mobility have been exacerbated by the growing issue of distracted driving.

Objectives

• Investigate Bluetooth Low Energy (BLE) tags that can be deployed in or ahead of work zones to provide in-vehicle warning messages.

• Investigate the effectiveness of using in-vehicle spoken messages to measure the drivers’ understanding of the work zone in order to reduce risky behavior, associated with distraction.

• Deploy a BLE based system in or ahead of work zones that can trigger spoken and contextual messages in existing smartphones located in vehicles passing by.

• Such messages can be updated remotely in real time and as such may provide significantly improved situational awareness about dynamic conditions at the work zones.
Two Concurrent Research Projects

- Capturing Driver Attention and Reducing Speed in Work Zones
  - Investigate BLE to Trigger In-Vehicle WZ Messages
  - Driver Behavior & Distraction Study and In-Vehicle WZ Message Design
    - This presentation
  - Engineering Study

Human Factors Study

Roadway Safety Institute
Methodology

• Program Bluetooth long-range modules

• Develop a data acquisition and testing program on the smartphone to collect BLE ID and signal strength

• Design test scenarios to evaluate the communication range, latency, and power consumption under a variety of conditions and when the smartphone user is travelling at different speeds

• Develop an in-vehicle app to demonstrate the system capability and performance under a variety of conditions
System Architecture

- Geo-fencing
- Customized Bluetooth firmware
- Automatic Bluetooth scanning
- Auditory feedback through smartphone speaker / car audio system
Bluetooth Low Energy (BLE) Modules

- **Model #1**
  - (3.0” x 2.75” x 0.25”)

- **Enclosure & Battery**
  - (4.5” x 3.5” x 2.25”)

- **Module #2**
  - (1.5” x 1.25” x 0.25”)

Bluetooth Programming Interface
Software Development

- Customized firmware for Bluetooth modules
- Geospatial database for Bluetooth location and message
- A local copy of DB on the smartphone
- Geo-fencing and auto scanning
- Smartphone app for in-vehicle application
- Smartphone app for engineers in a work zone
Work Zone Alert App

**Settings**
- Enter scanning period (sec): 100
- RSSI Threshold (-20 to -128): -128
- Vibration: ON
- Warning Sound: ON
- Enable incoming/outgoing calls: ON
- Enable Data Collection: ON
- Display Visual Alert: OFF

Warning

WORK ZONE
App for Work Zone Engineers
Experiment and Data Collection

- City Street / County Road / MnROAD
- Minivan / Sedan
- Traffic Barrel / Lamp Post
- Speed 30 ~ 70 mph

Bluetooth LE Module Attached to a Lamp Post (8-ft above ground)

Bluetooth LE Module Placed on a Traffic Barrel / Barricade
Experiment Setup

Bluetooth Module

Work Zone Alert App
Geo-fencing Example
WZ-002 @ 70 MPH

125 m (410 ft)

Travel Direction

MnROAD
Work Zone at I-35E and Co. Rd E East in Vadnais Heights, MN

battery powered Bluetooth beacon
Work Zone at I-35E & County Rd. E East

- Geo Fence
- BLE Beacon
- Start BLE Scanning
- Travel Direction

160 m (525 ft)
Discussions

• Crowdsourcing based solution (e.g., Waze)
  ✓ Inconsistent on information availability & description,
  ✓ No information quality check and validation,
  ✓ May cause distraction

• Rural application

• Cell service coverage

• Cloud-based solution

• Geo-fencing vs. beacon based solution
Benefits and Impacts

• A smartphone app runs as a background service
• Provide dynamic work zone information
• Provide guidelines (based on results from human factors study) for engineers and operational staff to determine the placement of tagged landmarks at work zones for triggering in-vehicle messages.
• The app can potentially be integrated with 511 or other navigation Apps to receive work zone information
Limitations & Next Step

Limitations

• Line of sight
• BLE module placed at least 1m above ground

Next Step

• Placement of phones in a vehicle
• Incorporate results from human factors study
• Pilot implementation and deployment to evaluate system performance
Summary & Conclusion

• We have developed a Bluetooth Low Energy (BLE) system to provide in-vehicle warning messages to a driver.

• A smartphone app was developed to perform Bluetooth scanning and to announce the appropriate message corresponding to a Bluetooth tag when it is detected.

• A continuous Bluetooth scan is initiated when a vehicle enters a geo-fenced work zone.

• The final message structure and content will be determined from the results of the human factors study.
Another smartphone app was developed for work zone deployment contractors to request message updates.

Our system is capable of providing in-vehicle messages for motorists approaching a work zone using the Bluetooth low energy technology.

Our experiment results indicated that communication between a smartphone and BLE tags at highway speed is feasible.

Our future effort will focus on validation of the proposed system in a real work zone environment under different traffic conditions.
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Questions?

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