Bluetooth-Low-Energy based System for Automatic Public-Transport passengers' Movement data collection

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The Research Project

Outline

• Objectives and motivation
• The research project
• Technology
• Preliminary results
• Benefits
OBJECTIVES AND MOTIVATION
Full Definition of infer

inferred  inferring

transitive verb

1  : to derive as a conclusion from facts or premises <we see smoke and infer fire — L. A. White> — compare imply

2  : GUESS, SURMISE <your letter ... allows me to infer that you are as well as ever — O. W. Holmes †1935>

3  a : to involve as a normal outcome of thought
   b : to point out : INDICATE <this doth infer the zeal I had to see him — Shakespeare> <another survey...inferences that two-thirds of all present computer installations are not paying for themselves — H. R. Chellman>

4  : SUGGEST, HINT <are you inferring I'm incompetent?>
Objective

• Developing a prototype for data collection system for tracking PT passengers movement based on BLE technology
# Tracking Technologies and Passengers Trackability

<table>
<thead>
<tr>
<th>Event</th>
<th>AVL</th>
<th>APC</th>
<th>AFC</th>
<th>GNSS</th>
<th>BLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arrival at a stop</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Partial</td>
<td>Yes, accurate</td>
</tr>
<tr>
<td>Boarding</td>
<td>No</td>
<td>Yes (aggregate)</td>
<td>Partial</td>
<td>Yes (with AVL)</td>
<td>Yes</td>
</tr>
<tr>
<td>In-vehicle positioning</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Alighting</td>
<td>No</td>
<td>Yes (aggregate)</td>
<td>Partial</td>
<td>Yes (with AVL)</td>
<td>Yes</td>
</tr>
<tr>
<td>Transferring</td>
<td>No</td>
<td>No</td>
<td>Partial (time/location)</td>
<td>Partial</td>
<td>Yes (with IMU)</td>
</tr>
<tr>
<td>Remarks</td>
<td></td>
<td>Trip OD not possible</td>
<td>Given complete swipe in/swipe out</td>
<td>High energy consumption, less accurate</td>
<td>low energy consumption, accurate</td>
</tr>
</tbody>
</table>

Remarks:
- Trip OD not possible
- Given complete swipe in/swipe out
- High energy consumption, less accurate
- Low energy consumption, accurate
THE RESEARCH PROJECT
Architecture
Tasks

- Modeling
  - PT
  - BLE
  - IT
- Small scale demonstration (BIU campus)
- Field test (with a PT operator)
PT modeling

- Data fusion from different sources
  - Passengers’ location
  - Vehicles’ location
  - PT routes
  - Stop to route association
- Event reporting (arrival, waiting, boarding, riding, alighting)
- Event status (provisional, permanent)
- Challenges:
  - Participants VS total patronage
  - “Near” real-time estimation
Data collection

- Data accumulation (smartphone)
- Data transmission to the server (periodically)
- Data upload to the DB
- Data structure:

<table>
<thead>
<tr>
<th>Time</th>
<th>Lat</th>
<th>Lon</th>
<th>Speed</th>
<th>MAC</th>
<th>RSSI</th>
<th>OBJ</th>
</tr>
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<tbody>
<tr>
<td>1465540958180</td>
<td>32.0727863</td>
<td>34.8496547</td>
<td>7.0318217C:EC:79:FD:58:37</td>
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<td></td>
<td></td>
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<td>34.8497126</td>
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<tr>
<td>1465540959420</td>
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<td>34.8497626</td>
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<td></td>
</tr>
<tr>
<td>1465540962156</td>
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<td>34.8498201</td>
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<td></td>
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<td></td>
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<tr>
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<tr>
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<td></td>
<td></td>
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<tr>
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<td>34.8499945</td>
<td>3.160063568:9E:19:03:1A:0D</td>
<td>-81500-20</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
TECHNOLOGY
Bluetooth Low Energy (BLE)

- Also known as Bluetooth 4.0
- Most smartphones have Bluetooth capability - new ones come with 4.0 (iBeacon in Apple iOS7, Android 4.3+)
- Highly-efficient energy consumption characteristics
- Range of 50 meters
- Sufficient accuracy potential in diverse environments
- Cost-effective deployment model (IoT)
- Unlicensed Band – wireless communication compatibility
# Power Consumption of Positioning Sensors

<table>
<thead>
<tr>
<th></th>
<th>BLE</th>
<th>BT 2.1</th>
<th>WLAN</th>
<th>IMU</th>
<th>GPS (GNSS)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Current (in data sheet)</strong></td>
<td>0.01-0.1 (mA)</td>
<td>1-3 (mA)</td>
<td>10-20 (mA)</td>
<td>5-10 (mA)</td>
<td>100-250 (mA)</td>
</tr>
<tr>
<td><strong>Expected battery life</strong></td>
<td>100 days</td>
<td>3-10 days</td>
<td>6-12 hours</td>
<td>12-24 hours</td>
<td>1-2.5 hours</td>
</tr>
<tr>
<td><strong>Tested consumption</strong></td>
<td>0.5 (mA)</td>
<td>3 (mA)</td>
<td>20 (mA)</td>
<td>12 (mA)</td>
<td>300 (mA)</td>
</tr>
</tbody>
</table>

We are interested in overall energy consumption.
Tags Used

AprilBeacon based on TI CC254X

The AprilBeacon is developed and produced including hardware and firmware all provide by AprilBrother LLC. It can work as a standalone system. The AprilBeacon previous version is based on TI CC254X BLE 4.0 module.

Models

<table>
<thead>
<tr>
<th>Available</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Model</th>
<th>101</th>
<th>202</th>
<th>241</th>
<th>242</th>
<th>227A</th>
<th>302</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core Chip</td>
<td>CC2541</td>
<td>CC2540</td>
<td>CC2541</td>
<td>CC2541</td>
<td>CC2540</td>
<td>CC2540</td>
</tr>
<tr>
<td>Battery</td>
<td>CR2032</td>
<td>CR2450</td>
<td>CR2450</td>
<td>CR2477</td>
<td>AAA Battery x 2</td>
<td>USB</td>
</tr>
<tr>
<td>Range (m)</td>
<td>10m</td>
<td>30m</td>
<td>25m</td>
<td>25m</td>
<td>30m</td>
<td>15m</td>
</tr>
<tr>
<td>Antenna</td>
<td>PCB</td>
<td>PCB</td>
<td>PCB</td>
<td>PCB</td>
<td>External</td>
<td>PCB</td>
</tr>
<tr>
<td>Size (mm)</td>
<td>24.8 * 24.8 * 7.5</td>
<td>31 * 31 * 9</td>
<td>31 * 31 * 9</td>
<td>31 * 31 * 11.7</td>
<td>66 * 36 * 22</td>
<td>21.6 * 14.3 * 5.4</td>
</tr>
<tr>
<td>Firmware</td>
<td>BlueBeacon</td>
<td>AprilBeacon</td>
<td>AprilBeacon</td>
<td>AprilBeacon</td>
<td>AprilBeacon</td>
<td>ZeroBeacon</td>
</tr>
<tr>
<td>Advantages</td>
<td>Small size and easy to deploy</td>
<td>With certification, stable signal, with reset button</td>
<td>20% power saving, With barcode, good for deployment.</td>
<td>2 times the power of a CR2450 battery, longer battery life.</td>
<td>Longer battery life saving maintenance cost</td>
<td>Mini USB interface, small size, AprilBeacon name changeable</td>
</tr>
</tbody>
</table>
Signal strength (static)

Many SNR samples are combined into a smooth signal / distance approximation
Signal Strength (dynamic)

The signal from BLE_TAG6 as received on the way to BLE_TAG5
In-Bus positioning

- Two BLE tags were positioned at the front and the rear of a bus
- A passenger was monitored walking in the bus
- Signals are relatively noisy due to the bus structure and materials composition
- Yet, front/mid/rear positioning is possible
Indoor Positioning

A Walking path in an indoor space (up) with corresponding Signal Strength in db (down)
SOME RESULTS
Tags’ deployment

- 16 stops
- 6 vehicles
Preliminary results #1

Single passenger tracking

Passengers waiting at stop 3
Preliminary results #2
Preliminary results #3
Benefits

• Improving the quality of data collection
• Enabling the implementation of advanced PT models
• Anonymous monitoring
• Zone based ticket validation
• VMS obsolete?
• Multi-language interface
• Smart card/e-wallet integration
• Better accessibility for disabled and mobility impaired passengers
Thanks!

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