Basestation Position Solving Using Timing Advance Measurements

ICSIP

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Outline

· Background

· GSM range measurements

· Base station position solving

· Conclusions
Motivation and objective

- Base station positions and coverage areas are not in public domain
- These are needed for positioning of phones without GPS
- In this work we estimate base station position using range measurements from GPS-equipped mobile phones
Range measurements in GSM

- Timing advance (TA) is used to compensate the propagation delay of transmission due to distance between BS and GSM terminal.
- Transmission time of one GSM bit is $3.69 \mu s$.
- Radiowave propagates $\approx 1100$ m.
- TA granularity is 550 m.
- LTE (4G) networks similar, granularity 78 m.
Measured TA values

- TA=0
- TA=1
- TA=2
- TA=3
- TA=4

550 m
**TA measurement modelling**

- **Simple model:**
  \[ \text{Range} = TA \times 550m + N(\mu, \sigma^2) \]

- **Alternative:**
  
  separate error parameters
  
  \[ \text{Range} = TA_i \times 550m + N(\mu_i, \sigma^2_i) \]
Measured TA distribution

- TA = 0
- TA = 1
- TA = 2
- TA = 3
- TA = 4

Distance from BS [m]

Cumulative probability

0 550 1100 1650 2200 2750
Single normal distribution
Multiple normal distributions

- Cumulative probability
- Distance from BS [m]
- TA = 0
- TA = 1
- TA = 2
- TA = 3
- TA = 4
Basestation position estimation

We compare two recursive Bayesian methods:

- Point Mass Filter (PMF)
- Gaussian Mixture Filter (GMF)
Point Mass Filter

- The probability density is approximated using a grid of points
- Optimal when number of grid points tends to infinity
- Easy to implement, but needs lots of computational resources
Gaussian Mixture Filter

- The probability density is approximated using a weighted sum of Gaussians
- Measurements are linearized for each of Gaussian component in the estimation
- Components are merged or deleted during the estimation
- Much faster than PMF
Real world examples

10 measurements

PMF:

30 measurements

GMF:

550m
## Simulated BS position results

- PMF uses exact measurement error model
- PMF is used as a reference

<table>
<thead>
<tr>
<th>Filter</th>
<th>Mean error [m]</th>
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<tbody>
<tr>
<td>GMF assuming ideal measurements</td>
<td>442</td>
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<tr>
<td>GMF using single error model</td>
<td>349</td>
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<tr>
<td>GMF using multiple error models</td>
<td>160</td>
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<tr>
<td>PMF</td>
<td>141</td>
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Conclusions

- TA measurements can be used to solve the BS position.
- Accuracy can be enhanced by TA modeling and TA measurement error separately for different TA values.
- GMF performs fast and well in estimation.