Improving QoE via context prediction: A case study of using WiFi radiomaps to predict network disconnection

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Outline

• Scope
• WiFi radiomap-based Indoor Positioning Systems
• Platform Design and Implementation
• Case study-based evaluation
• Conclusions & Future Work
Scope

• Work in Progress
• Main goal: Develop an open platform for studying, analyzing and utilizing context for improving QoE
• This paper: focus on prediction of position using WiFi radiomaps
• Prototype implemented (on Android) and evaluated with simulated data (with Python script)
Fingerprinting Positioning (1)

- Based on the real-time comparison of received radio parameters (traditionally RSS) with pre-measured position-stamped signal signatures (called fingerprints) which are stored in a database.

- It consists of two phases:
  - *Offline phase (or training phase)*: The collection of the fingerprints to be stored in a database
  - *Online phase (or positioning phase)*: the instantaneous measurement is correlated with the database to estimate the most likely position.
Fingerprinting Positioning (2)

Offline phase / Training

```json
"lat": 35.0083700,
"lng": 33.6965000,
"measurements": [
  {"macAddress": "0", "ssid": -65 },
  {"macAddress": "1", "ssid": -66 },
  {"macAddress": "2", "ssid": -80 },
  {"macAddress": "3", "ssid": -85 }
]

"lat": 35.0083800,
"lng": 33.6967000,
"measurements": [
  {"macAddress": "0", "ssid": -75 },
  {"macAddress": "1", "ssid": -76 },
  {"macAddress": "2", "ssid": -60 },
  {"macAddress": "3", "ssid": -58 }
]
```
Fingerprinting Positioning (3)

Online phase / Positioning

```
"lat": 35.0083700,
"lng": 33.6965000,
"measurements": [
  {"macAddress": "0", "ssid": -65 },
  {"macAddress": "1", "ssid": -66 },
  {"macAddress": "2", "ssid": -80 },
  {"macAddress": "3", "ssid": -85 }
]
```

```
"lat": 35.0083700,
"lng": 33.6967000,
"measurements": [
  {"macAddress": "0", "ssid": -75 },
  {"macAddress": "1", "ssid": -76 },
  {"macAddress": "2", "ssid": -60 },
  {"macAddress": "3", "ssid": -58 }
]
```

```
"lat": ?,
"lng": ?,
"measurements": [
  {"macAddress": "0", "ssid": -62 },
  {"macAddress": "1", "ssid": -67 },
  {"macAddress": "2", "ssid": -81 },
  {"macAddress": "3", "ssid": -87 }
]`
Platform Design and Implementation

https://github.com/nearchos/CAIPS
Case study-based evaluation

• **Aims**
  • Assess the potential of WiFi-based indoor positioning as a means of predicting network disconnection

• **Method**
  • Identify and map Points of Interest (POIs)
  • Measure network connectivity at POIs
  • Create simulated motion paths (recurring, on a weekly basis)
  • Run pattern-matching algorithm to *predict* the next POI, and thus the predicted network quality
Points of Interest (POIs) and Network connectivity

<table>
<thead>
<tr>
<th>POI</th>
<th>WiFi strength (dB)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>-81</td>
<td>Edge of building</td>
</tr>
<tr>
<td>B</td>
<td>-61</td>
<td>Entrance/Exit</td>
</tr>
<tr>
<td>C</td>
<td>$-\infty$</td>
<td>Stairwell (weak signal)</td>
</tr>
<tr>
<td>D</td>
<td>-62</td>
<td>Transition point</td>
</tr>
<tr>
<td>E</td>
<td>-54</td>
<td>Transition point</td>
</tr>
<tr>
<td>F</td>
<td>-67</td>
<td>Edge of stairwell</td>
</tr>
<tr>
<td>G</td>
<td>-59</td>
<td>Edge of stairwell</td>
</tr>
<tr>
<td>H</td>
<td>$-\infty$</td>
<td>Stairwell (weak signal)</td>
</tr>
<tr>
<td>I</td>
<td>-43</td>
<td>Office (frequent use)</td>
</tr>
<tr>
<td>J</td>
<td>-51</td>
<td>Transition point</td>
</tr>
<tr>
<td>K</td>
<td>-74</td>
<td>Entrance/Exit</td>
</tr>
<tr>
<td>L</td>
<td>-60</td>
<td>Edge of building</td>
</tr>
<tr>
<td>M</td>
<td>-64</td>
<td>Transition area</td>
</tr>
<tr>
<td>N</td>
<td>-53</td>
<td>Admin office (frequent use)</td>
</tr>
<tr>
<td>O</td>
<td>-59</td>
<td>Entrance/Exit</td>
</tr>
<tr>
<td>P</td>
<td>-56</td>
<td>Transition point</td>
</tr>
<tr>
<td>Q</td>
<td>-63</td>
<td>Edge of stairwell</td>
</tr>
<tr>
<td>R</td>
<td>$-\infty$</td>
<td>Stairwell (weak signal)</td>
</tr>
<tr>
<td>S</td>
<td>-66</td>
<td>Edge of stairwell</td>
</tr>
<tr>
<td>T</td>
<td>-47</td>
<td>Lab (frequent use)</td>
</tr>
<tr>
<td>U</td>
<td>-70</td>
<td>Transition point</td>
</tr>
<tr>
<td>V</td>
<td>-62</td>
<td>Transition point</td>
</tr>
<tr>
<td>W</td>
<td>-56</td>
<td>Library (frequent use)</td>
</tr>
<tr>
<td>X</td>
<td>-52</td>
<td>Cafeteria (frequent use)</td>
</tr>
</tbody>
</table>

Table 1: Points of Interest (POIs) with annotations
Simulated motion paths

<table>
<thead>
<tr>
<th>Id</th>
<th>Time</th>
<th>Motion path</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>08:00</td>
<td>B C A D F J I</td>
<td>Arriving to the building</td>
</tr>
<tr>
<td>ii</td>
<td>09:00</td>
<td>I J M Q R S T</td>
<td>Going to a timetabled class</td>
</tr>
<tr>
<td>iii</td>
<td>12:00</td>
<td>T S R Q M J I</td>
<td>Returning to office</td>
</tr>
<tr>
<td>iv</td>
<td>13:00</td>
<td>I J M Q R S V X</td>
<td>Going for lunch</td>
</tr>
<tr>
<td>v</td>
<td>13:30</td>
<td>X V S R Q M J I</td>
<td>Returning to office</td>
</tr>
<tr>
<td>vi</td>
<td>14:30</td>
<td>I J M Q U W W</td>
<td>Going to the library</td>
</tr>
<tr>
<td>vii</td>
<td>14:45</td>
<td>W U Q M J I</td>
<td>Returning to office</td>
</tr>
<tr>
<td>viii</td>
<td>17:00</td>
<td>I J F D A C B</td>
<td>Leaving the building</td>
</tr>
</tbody>
</table>

Table 2: Fabricated model illustrating user’s most common motion patterns in the building
Pattern matching algorithm

Algorithm 1 Simple pattern matching algorithm

1: procedure PREDICTNEXTPOINT(PATTERNS, PATH, TIME)
2:   result ← MatchWithAllCharacters
3:   if result == 1 then
4:     print 'Found a match'
5:   else
6:     if result == 0 then
7:       PredictNextPoint(path - firstCharacter, time)
8:     else
9:       nextPoint ← getClosestMatchInTime()
10:  procedure MATCHALLCHARACTERS(PATTERNS, PATH)
11:    list result ← Ø
12:    for item in PATTERNS do
13:      if item in PATH then
14:        result ← result + item
15:    return result

Based on the algorithm by Karp:
Conclusions

• A work-in-progress paper
  • Assessed the potential of indoor positioning for predicting context (network quality in particular) and its ability to help optimize the QoE

• Future work
  • Collect real-world traces for multiple users over a period of time (automatic POI identification)
  • Test different algorithms and assess their ability to predict user motion patterns and user context in general (besides simple string pattern matching)
  • More ambitious: use neural networks to directly infer QoE-sensitive properties (e.g. network quality) from WiFi radiomaps
Questions?

• Thank you!

• While we are at this...
  ...why not submit/attend **ISD2017 @ Larnaca, Cyprus**?
  (track 5 – Mobility and Context-awareness in ISD)

http://isd2017.uclancyprus.ac.cy – Papers due April 29\textsuperscript{th} – Conference on September 6-8th