Leveraging Applications Performance with Fog Computing

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Outline

• Overview of Fog Computing
• Problems
• Evaluation
  – Mobile Fog
  – U-Fall
• Summary
Fog Computing

• Fog computing is a new cloud computing paradigm that allows computation at the edge of the network (Yi et al, 2015).
  – Different from centralized cloud where computation happens in data centers that are located far from mobile devices

• Fog computing enables a new class of applications that require:
  – Mobility, geo-distribution, location-awareness, and low latency
  – Sometimes called future internet applications or Internet-of-Things (IoT) applications
Problems

- Fog networking
  - Network function virtualization (NFV) and software-defined networking (SDN) interesting new approaches for large heterogenous networks.

- Quality of service
  - Connectivity, reliability, capacity, delay (latency)

- Programming model
  - Orchestrating dynamic, hierarchical, and heterogenous resources is hard

- Computation offloading
  - Wireless networking makes it hard because the links are unreliable
Mobile Fog

- Mobile Fog is a PaaS programming model for developing IoT applications that provides a simplified programming model (Hong et al, 2013).
  - High-level programming model for developing applications that run on heterogenous devices that are geographically spread over a large area
  - Dynamic scaling using on-demand resources on both fog nodes and the cloud
  - Currently limited to simulated devices and lacks a runtime system that runs on real hardware
Mobile Fog Hierarchy

Data Center 1

Fog-Enabled Router

Smartphone

Vehicle

Camera

Data Center 2

Fog-Enabled Router

Smartphone

Vehicle

Camera
Mobile Fog Evaluation

• Vehicle-to-vehicle video streaming
  – A vehicle randomly selects another vehicle within a query range and streams video to it.
  – Fog-based system always outperforms cloud-based system in latency because video stream rarely needs to go through the cloud (only when target vehicle is far away).

• Mobile CEP
  – A vehicle requests processing sensor data from a query range.
  – Cloud-based system outperforms fog-based system in latency when the query range is very large because fog system has to wait to aggregate data from multiple sources.
Mobile Fog Evaluation

- Tree structure does not work well when devices move around (Yi et al, 2013)
- The performance evaluation is done using simulation which makes the results inconclusive (e.g. no power usage measurement).
U-Fall

- U-Fall is a real-time fall detection system that detects and predicts abnormal events for stroke patients (Cao et al, 2015).

- Previous attempts using wearable computers have not been successful because they have limited computing capacity.

- U-Fall uses fog computing to perform computation in two phases
  - Root-sum-of-squares (RSS) and activities of daily livings (ADL) using smart device accelerometer
  - Machine learning analytics on the cloud
U-Fall Design

Front-end Module

Accelerometer → RSS Detector → ADL Filter

Alarm

Back-end Module

Data Preprocessor → Non-linear Analyzer

Mobile Device

Server on the cloud
## U-Fall Evaluation

<table>
<thead>
<tr>
<th></th>
<th>T-System</th>
<th>P-System</th>
<th>U-Fall</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ADL response time (ms)</strong></td>
<td>33.39</td>
<td>58.45</td>
<td>34.32</td>
</tr>
<tr>
<td><strong>Fall response time (ms)</strong></td>
<td>35.38</td>
<td>47.85</td>
<td>35.67</td>
</tr>
<tr>
<td><strong>Fall energy consumption (joule)</strong></td>
<td>1.33</td>
<td>2.26</td>
<td>1.63</td>
</tr>
<tr>
<td><strong>Fall detection sensitivity (i.e. real falls)</strong></td>
<td>90%</td>
<td>78%</td>
<td>88%</td>
</tr>
<tr>
<td><strong>Fall detection specificity (i.e. only real falls)</strong></td>
<td>61.1%</td>
<td>75.2%</td>
<td>74.6%</td>
</tr>
</tbody>
</table>
U-Fall Evaluation

• T-System (threshold-based) performs the best for all other metrics except in specificity, where P-System (pattern matching) performs best.

• U-Fall has similar performance for specificity (74.6%) as P-System (75.2%) and otherwise it's very close to T-System, which is the leader.
Summary

- Fog computing is an extension to cloud computing that enables future internet applications
  - Mobility, geo-distribution, location-awareness, and low latency
- There are no standardized fog computing runtimes available at this time
  - Required for wide-spread adoption of fog computing
- Performance evaluation scenarios are either simple (e.g. U-Fall) or based on simulation (Mobile Fog) which makes them inconclusive
  - More work needed to evaluate the effectiveness of fog computing
Thank you! Questions?
U-Fall Detection Accuracy

- Sensitivity measures the ability to detect real falls which is calculated as $\frac{TP}{TP+FN}$
  - TP is true positives (i.e. a fall occurs and it is detected) and FN is false negatives (i.e. fall occurs and it is not detected)
- Specificity measures the ability to detect only real falls (i.e. avoid false positives) which is calculated as $\frac{TN}{TN+FP}$
  - TN is true negatives (i.e. fall did not occur nor was one detected) and FP is false positives (i.e. fall did not occur but once was detected).