Bonsai in the Fog: an Active Learning Lab with Fog Computing

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Life on the edge

The era of the cloud’s total dominance is drawing to a close

The rise of the “internet of things” is one reason why computing is emerging from the centralised cloud and moving to an “edge” of networks and intelligent devices.

Blowing away the cloud

Connected devices, worldwide, bn

- Internet of things*
- Mobile phones
- PC, laptop & tablet
- Fixed phones

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<td>20</td>
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Source: Ericsson

*Everyday objects connected to the internet
Deployment Models

IoT+Edge
- Low latencies, but
- Limited capabilities,
- Difficulties in sharing data

IoT+Cloud
- Huge computing power, but
- Mandatory connectivity,
- High latencies,
- Bandwidth bottleneck.

- Not sufficient *per se* to support the IoT momentum alone.
- There is a need for **filtering** and **processing** before the Cloud.
- Processing should occur wherever it is **best-placed** for any given IoT application
Deployment Models

IoT+Edge
- Low latencies, but
- Limited capabilities,
- Difficulties in sharing data.

Fog computing is a system-level horizontal architecture that distributes resources and services of computing, storage, control and networking anywhere along the continuum from Cloud to Things, thereby accelerating the velocity of decision making.

Fog-centric architecture serves a specific subset of business problems that cannot be successfully implemented using only traditional cloud based architectures or solely intelligent edge devices.

- Huge computing power, but
- Mandatory connectivity,
- High latencies,
- Bandwidth bottleneck.

[OpenFog Reference Architecture, 2016.]
Fog Characteristics

- Context- & location-awareness
- Low latency & bandwidth savings
- Pervasiveness & geo-distribution
- Fog & Things Mobility
- Heterogeneity of devices
Fog Computing in Education?

- OpenFog is calling for design of courses that include Fog computing in higher education programs.
- We introduced Fog computing in our Advanced Software Engineering course (2 hours lecture and 2 hours active learning lab).
Our goals

• Design an active learning lab that had to:

  First **hands-on experience** and **active learning**
  
  **Quick learning curve** and **two-hours** time
  
  **Limited costs** and **cross-platform**
Use Case
Multi(functional)Lab

BYOD  Wi-fi  Projector
micro:bits

• Programmable with an online editor either with blocks or in JavaScript.
• Cross-platform.
• Cost around €20 😊...
The ingredients
Activity Plan

- **Set-up of an IoT testbed** and simple Edge application (IoT+Edge)
- **Coding of a gateway module** to stream/visualise data to the Cloud (IoT+Cloud)
- **Extensions** to the gateway module to perform more computation (Fog)
BonsaiFog App

Collector ➔ Radio Dashboard ➔ Gateway ➔ Internet

(serial)

https://github.com/di-unipi-socc/bonsaifog
Collector v1

- Measure **moisture** of one bonsai.
- Plots the **histogram** to the micro:bit LEDs.
- When A pressed: shows **measurement**.
IoT+Edge
Collector v2

- Measure moisture of one bonsai.
- Plots the histogram to the micro:bit LEDs.
- When A pressed: shows measurement.
- Streams data to the radio dashboard at the instructor’s laptop every second.
- (Streams data to serial port at students’ laptop.)
Radio Dashboard

- Every time a client connects, a LED is turned on.
- Brightness of the LEDs depends on soil moisture of the associated bonsai.
- Receives data from Collector clients.
- Streams data to the serial port of the instructor’s laptop.
Gateway v1

- Receives and parse data from serial.
- Streams data to ThingSpeak.
ThingSpeak

• A Cloud service featuring MATLAB analytics and data visualisation for IoT data.
• Playtime 😊
<table>
<thead>
<tr>
<th>Feature</th>
<th>FREE</th>
<th>STANDARD</th>
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</thead>
<tbody>
<tr>
<td>Scalability for larger projects</td>
<td>✗ No. Annual usage is capped.</td>
<td>✓</td>
</tr>
<tr>
<td>Number of messages</td>
<td>3 million/year (~8,200/day)</td>
<td>33 million/year per unit (~90,000/day per unit)</td>
</tr>
<tr>
<td>Message update interval limit</td>
<td>Every 15 seconds</td>
<td>Every second</td>
</tr>
<tr>
<td>MATLAB Compute Timeout</td>
<td>20 seconds</td>
<td>60 seconds</td>
</tr>
<tr>
<td>Number of simultaneous MQTT subscriptions</td>
<td>Limited to 3</td>
<td>50 per unit</td>
</tr>
<tr>
<td>Private channel sharing</td>
<td>Limited to 3 shares</td>
<td>Unlimited</td>
</tr>
<tr>
<td>Technical Support</td>
<td>Forum</td>
<td>Standard MathWorks support</td>
</tr>
</tbody>
</table>
Problem or opportunity?
Where is the Fog?
What can we make foggy?
Idea #1

Aggregate data and send an average every 10 seconds.
Idea #2

Send data only if the difference between previous average is greater than a threshold.
Idea #3

Send data only if the difference between previous average is greater than a threshold. Send it anyhow, if no data hasn’t been sent for 1 hour.
Related Work

• Literature focus either on
  - IoT+Edge
    e.g., (Shultz et al., 2015),
    (Abraham, 2016),
    (Wu and Zeng, 2016),
    (Jang et al., 2017)

  - IoT+Cloud
    e.g., (Kortuem et al., 2013),
    (Patil et al., 2016).

Our goal was to showcase Fog computing and highlight the differences with respect to other deployment models for the IoT.
Concluding Remarks

First *hands-on experience* and *active learning*

- Practically understand Fog computing.
- Show differences with alternative deployment models.
Concluding Remarks

• Use of high-level language.
• JavaScript everywhere.
• Very good online docs.

Quick learning curve and two-hours time

All students successfully completed the activity within the two hours.
Concluding Remarks

• Cost is around €30 euro per table.
• All platforms supported.
• We borrowed micro:bits from pisa.coderdojo.it
Future Work

Extend the testbed, increase heterogeneity of devices and protocols.

Test scalability and measure effectiveness of the lab session.

Perform quantitative measurements of bandwidth savings.
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