Investigating the management of IoT cloud systems by means of simulation

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IoT – Internet of Things

New trend

- Connection between objects
  - Things/Devices/Sensors/Actors
  - Smart Environment

- Like the internet revolution
  - Connection between people
  - Unprecedented scale and pace (200 billion devices by 2020)

- Dynamic global network infrastructure
- Self-configuring capabilities
- Standard and interoperable communication protocols
Cloud Computing

- Commercial providers
  - Amazon
  - IBM
  - Microsoft

- Private Clouds - OpenStack

- Elastic construction of virtual infrastructures

- Wide range
  - From infrastructures to application-level
IoT Cloud systems

- Cloud
  - Manage resources
  - Scalability
  - Handle big data
  - Access from everywhere

- IoT Cloud features
  - Connect devices
  - Store the data
  - Process
  - Visualize
Simulators

- Related ones: e.g. OMNet++, CloudSim
- DISSECT-CF: DIScrete event baSed Energy Consumption simulaTor for Clouds and Federations

A. Markus, A. Kertesz, G. Kecskemeti, Cost-Aware IoT Extension of DISSECT-CF. Future Internet 2017, 9, 47.
Simulating IoT sensors

- Cloud system
- Extension:
  - IoT sensors
  - Data generation
  - Message handling
- Case study:
  - Weather prediction

```xml
<Application tasksize='250000'>
  <Station>
    <name count='1'>Szeged</name>
    <freq>60000</freq>
    <snumber size='200'>10</snumber>
    <time starttime='500' stoptime='1000'>
      1000
    </time>
    <maxinbw>100</maxinbw>
    <maxoutbw>100</maxoutbw>
    <storagebw>100</storagebw>
    <sterepo>sztakilpdsceph</sterepo>
    <storage>60000</storage>
    <ratio>1</ratio>
  </Station>
</Application>
```
Weather prediction: Idokep.hu

- Crowdsourced meteorological service of Hungary
- Established in 2004, since 2008 weather information on Croatia and Germany
- System architecture: more than 400 stations, sensors for temperature, humidity, barometric pressure, rainfall and wind properties
- Refreshed every 10 minutes, forecasts up to a week.
# Pricing Schemes of providers

<table>
<thead>
<tr>
<th>Provider</th>
<th>MS Azure</th>
<th>IBM Bluemix</th>
<th>Amazon</th>
<th>Oracle</th>
</tr>
</thead>
<tbody>
<tr>
<td>IoT fix prices and device side</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pay as you go</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Extras at start</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>In tiers</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Device price / month</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Price / message pricing</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Messages/month pricing</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Data exchanged (in MB)</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Message size limit</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td><strong>Cloud side</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Instance price</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>GB hour price</td>
<td>+</td>
<td>+</td>
<td>(+)</td>
<td></td>
</tr>
</tbody>
</table>
Applied cost model for IoT

<iotproviders>
  <bluemix calculate="false">
    <price-per-MB mbfrom="1" mbto="499999">0.00097</price-per-MB>
    <price-per-MB mbfrom="450000" mbto="699999">0.00068</price-per-MB>
    <price-per-MB mbfrom="700000" mbto="1">0.00014</price-per-MB>
  </bluemix>
  <amazon price="5" messagecount="1000000" exchangerate="0.95" calculate="true">512</amazon>
  <oracle calculate="false" period="31">
    <messages-per-month-per-device>15000</messages-per-month-per-device>
    <deviceprice per month>0.93</deviceprice per month>
    <am-messages-per-month-per-device>1000</am-messages-per-month-per-device>
    <am-deviceprice-per-month>0.02344</am-deviceprice-per-month>
  </oracle>
  <azure calculate="false" period="1">
    <price-per-month>421.65</price-per-month>
    <messages-per-day>6000000</messages-per-day>
    <messagesize-per-KB>4</messagesize-per-KB>
  </azure>
</iotproviders>
Simulator extensions
Execution

- Set up Cloud
- Set up Devices (Stations)
- Start app
- Start Cost metering
- Start sensors, VMs
- Receive messages
- Process data
Evaluation scenarios

1. 1 day, 478 stations (8 sensors)
   - varying message data size

2. 744 stations
   - varying sensor number and data size

3. 600 stations
   - varying data generation frequency

4. 200, 487, 600 stations
   - varying task creation frequency

5. 200 -> 300 -> 500 -> 200 stations
   - VM scaling as changing num. of stations
Scenario 1: Results

- Bigger messages require more tasks/VMs

![Graph showing the relationship between message size and number of tasks/VMs over time.]
Scenario 1: costs

![Costs of IoT and Cloud sides for different message sizes]
Scenario 3: Results

- More frequent data generation needs more tasks
Scenario 3: costs

![Bar chart showing the number of virtual machines by category and interval](chart)

<table>
<thead>
<tr>
<th>VM Category</th>
<th>Interval 1 min</th>
<th>5 min</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Azure cloud cost</strong></td>
<td>32.538</td>
<td>5.45</td>
</tr>
<tr>
<td><strong>IoT provider</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bluemix</td>
<td>0.31948</td>
<td>0.06371</td>
</tr>
<tr>
<td>Amazon</td>
<td>32.80</td>
<td>6.5436</td>
</tr>
<tr>
<td>Oracle</td>
<td>4464.00</td>
<td>4464.00</td>
</tr>
<tr>
<td>Azure</td>
<td>4215.5</td>
<td>4215.5</td>
</tr>
<tr>
<td><strong>IoT side cost</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bluemix</td>
<td>0.31948</td>
<td>0.06371</td>
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</tr>
<tr>
<td>Azure</td>
<td>4215.5</td>
<td>4215.5</td>
</tr>
<tr>
<td><strong>Sum</strong></td>
<td>32.85748</td>
<td>5.51371</td>
</tr>
</tbody>
</table>
Scen. 4: Number of tasks and VMs

- Varying task generation frequency

![Graph showing number of tasks and VMs varying with task generation frequency.](image)
Scen. 4: IoT-side costs

- Bluemix is the cheapest
Scenacio 5: Effects of VM shutdown

![Graph showing number of tasks over time with and without turnOff function]

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<th>Oracle</th>
<th>Azure</th>
</tr>
</thead>
<tbody>
<tr>
<td>IoT side cost</td>
<td>0.18</td>
<td>18.92</td>
<td>14136.00</td>
<td>421.65</td>
</tr>
<tr>
<td>VM function</td>
<td>ON</td>
<td>OFF</td>
<td>ON</td>
<td>OFF</td>
</tr>
<tr>
<td>Bluemix cloud cost</td>
<td>51.80</td>
<td>89.39</td>
<td>51.80</td>
<td>89.39</td>
</tr>
<tr>
<td>Sum</td>
<td>51.98</td>
<td>89.58</td>
<td>108.31</td>
<td>473.45</td>
</tr>
</tbody>
</table>
Conclusions

- Distributed systems simulators are not generic enough for IoT Cloud simulation

- We proposed:
  - Modelling generic IoT sensors with an XML based, declarative modelling language
  - Modelling provider costs
  - Weather prediction case study
  - Validation with 5 different scenarios

- Our future work will address:
  - non-frequency based sensor data production
  - additional case studies
Thank You for Your Attention!

Questions?

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