ThinkAir: Dynamic Resource Allocation and Parallel Execution in Cloud for Mobile Code Offloading

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Prominent Related Works

- **MAUI(2010)**
  - Provides method level code offloading based on .NET framework.
  - Does not address the scaling of execution in cloud.

- **CloneCloud(2011)**
  - Provides offline static analysis of different running condition of the process binary, and build a database of pre-computed partitions.
  - Limited input/environment conditions, and needs to be bootstrapped for every new apps.
ThinkAir

- A framework that exploits the concept of smart phone virtualization in the cloud, and provides method-level computation offloading.
  - Parallelizing method execution using multiple VM images.
    - On-demand resource allocation.
  - Online method-level offloading.
Design Goals

- Dynamic adaptation to changing environment.
- Ease of use for developers.
- Performance improvement through cloud computing.
- Dynamic scaling of computation power.
Overview

- Annotate methods with `@Remote`. 
Execution Controller

- Make offloading decisions.
- Four policies:
  - Execution time
  - Energy
  - Execution time and energy
  - Execution time, energy, and cost.
Client Handler

- Code execution
  - Manage connection.
  - Execute code.
  - Return results.

- VM management
  - Add VM with more computing power or resources.
  - Distributes task among VMs, and collects results.
Cloud Infrastructure

- OS: customized version of Android x86.
- 6 types of VM.
- VM Resume latency:
  - Paused: 300ms
  - Up to 7s if too many VMs are resumed simultaneously.
  - Powered-off: 32s
Profilers

- **Hardware profiler**
  - CPU, Screen, WiFi, 3G

- **Software profiler**
  - Use Android Debug API to record information.

- **Network profiler**
Energy Estimation Model

- Modify the original PowerTutor model.
- **PowerTutor**\(^1\) model
  - CPU, LCD screen, GPS, WiFi, 3G, and audio interface.
  - HTC Dream phone.

\(^1\) Accurate online power estimation and automatic battery behavior based power model generation for smartphones, CODES/ISSS '10
Experiment Setup

- **BIV (boundary input value)**
  - The minimum value of the input parameter for which offloading would give a benefit.

- **Offloading policy:** execution time.

- **Different Scenarios:**
  - Phone
  - WiFi-Local (RTT 5ms)
    - router attached to cloud server.
  - WiFi-Internet (RTT 50ms)
  - 3G (RTT 100ms)
Micro-Benchmark[2] Results

TABLE II
Boundary input values of benchmark applications, with WiFi and 3G connectivity, and the complexity of algorithms.

<table>
<thead>
<tr>
<th>Benchmark</th>
<th>BIV WiFi</th>
<th>BIV 3G</th>
<th>Complexity</th>
<th>Data Tx (bytes)</th>
<th>Data Rx (bytes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fibonacci</td>
<td>18</td>
<td>19</td>
<td>$O(2^n)$</td>
<td>392</td>
<td>307</td>
</tr>
<tr>
<td>Hash</td>
<td>550</td>
<td>600</td>
<td>$O(n^2 \log(n))$</td>
<td>383</td>
<td>293</td>
</tr>
<tr>
<td>Methcall</td>
<td>2500</td>
<td>3100</td>
<td>$O(n)$</td>
<td>338</td>
<td>297</td>
</tr>
<tr>
<td>Nestedloop</td>
<td>7</td>
<td>8</td>
<td>$O(n^6)$</td>
<td>349</td>
<td>305</td>
</tr>
</tbody>
</table>

- Network latency clearly affects the BIV.

Fig. 2. Execution time and energy consumption of the $N$-queens puzzle, $N = \{4, 5, 6, 7, 8\}$.

- **BIV = 5**
N = 8

Different CPU energy consumed

- Due to bandwidth and latency of the links, and subsequently affected the time spent waiting for results and in transmission.
Face Detection Results

Counts the number of faces in a picture.
  - Photos are loaded in both device and cloud.

Fig. 4. Execution time and energy consumed for the face detection experiments.
Face Detection Results (Cont.)

- 100 pictures

Fig. 5. Energy consumed by each component for face detection with 100 pictures in different scenarios.
Virus Scanning Results

![Graphs showing execution time and energy consumption for different scenarios.]

Fig. 6. Execution time and energy consumption of the virus scanning in different scenarios.

- Total size of files: 10MB
- Number of files: ~3,500
  - CPU energy consumption is lower when offloading using 3G.
Parallelization with Multiple VM Clones

- Workloads are evenly distributed among VMs.
- Clones are resumed from pause state.

Fig. 7. Time taken and energy consumed on the phone executing 8-queens puzzle using $N = \{1, 2, 4, 8\}$ servers.

Fig. 8. Time taken and energy consumed for face detection on 100 pictures using $N = \{1, 2, 4, 8\}$ servers.

Fig. 9. Time taken and energy consumed for virus scanning using $N = \{1, 2, 4, 8\}$ servers.
Conclusion

- ThinkAir is a framework for offloading mobile computation to the cloud, with the ability of on-demand VM resource scaling.
- The authors will continue to work on improving programmer support for parallelizable applications, since they think it a key direction to use the capabilities of distributed computing of the cloud.