HOT Topics in Computer Science (HOT-T-CS)

Mobile Cloud Computing
Architectures

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A quote from Oracle CEO Larry Ellison

“The interesting thing about cloud computing is that we’ve **redefined cloud computing to include everything that we already do**…. I don’t understand what we would do differently in the light of cloud computing other than **change the wording of some of our ads.**”
Cloud Computing

- Parallel Computing
- Utility Computing
- Virtualization
- Autonomic Computing
- Elastic Computing
- Grid Computing
- Web Services
- Service Oriented Architectures
- Cluster Computing
- Cloud Computing

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Cloud Computing
Old Wine in New Bottle?

**Grid Computing**
Harness the compute power of geographically distributed heterogeneous machines which are sitting idle

**Utility Computing**
A business model to charge for resource
Use a time on a supercomputer and pay for usage

**Cloud Computing**
A superset of functionalities
Offers a complete environment starting from low-level infrastructure to managed applications
Uses similar charging concepts like Utility computing, but with greater variations
Service Models

Cloud Computing as Gartner Sees It

- **SaaS**
  - Google Apps, Salesforce.com, NetSuite, Lotus, WebFilings, Zoho, Yahoo!Mail, Hotmail, ...

- **PaaS**
  - Google App Engine, Force.com, Windows Azure, LongJump, Rollbase, Amazon Elastic Beanstalk, VMware CloudFoundry, ...

- **IaaS**
  - Amazon EC2, Rackspace, VMware, Joyent, Google Cloud Storage, ....

Source: Gartner AADI Summit Dec 2009
Management Model

IaaS
- API / GUI
- Application
- Solution Stack
- Virtual Machine
- Hypervisor
- Compute & Storage
- Network
- Facility

PaaS
- API / GUI
- Application
- Solution Stack
- Virtual Machine
- Hypervisor
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SaaS
- API / GUI
- Application
- Solution Stack
- VM
- Hypervisor
- Compute & Storage
- Network
- Facility

Tenant
Provider
# Mobile Backend as a Service

<table>
<thead>
<tr>
<th>What</th>
<th>Provides mobile application developers a way to connect their application to backend cloud storage and processing</th>
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| Why  | Abstract away complexities of launching and managing own infrastructure  
       | Focus more on front-end development instead of backend functions |
| When | Multiple Apps, Multiple Backends, Multiple Developers  
       | Multiple Mobile Platforms, Multiple Integration, Multiple 3rd Party Systems & Tools |
| How  | Meaningful resources for app development acceleration – 3rd party API, Device SDK’s, Enterprise Connectors, Social integration, Cloud storage |

Source: http://rapidvaluesolutions.com/whitepapers/How-MBaaS-is-Shaping-up-Enterprise-Mobility-Space.html
Mobile Backend as a Service

• Amazon Silk browser
  – Split browser

• Apple Siri
  – Speech recognition in cloud

• Apple iCloud
  – Unlimited storage and sync capabilities

• Image recognition apps on smartphones useful in developing augmented reality apps on mobile devices
  – Augmented reality app using Google Glass
Developing applications for mobile platforms is challenging

- Heterogeneity: form factors, hardware platforms, limitations on connectivity, battery, resources

MBaaS aims to hide the heterogeneity

- **Native Apps**: Build for specific platforms, like Android, iOS, Blackberry
- **Web-based**: Mobile optimized websites that currently uses HTML5 ➔ cross-platform mobile applications
  - HTML5 provides access to some native device features, like GeoLocation, camera, calendar, etc.)
- **Hybrid Apps**: embed HTML5 apps within native containers ➔ some benefits of both worlds
Comparison of App Models

- **Native**
  - Full Capability
  - Advanced UI Interaction
  - Access to all native APIs
  - App store distribution
  - Single Platform

- **Hybrid**
  - Web Developer Skills
  - Access to native APIs
  - App store distribution
  - Multiple Platforms

- **HTML5**
  - Web Developer Skills
  - Instant Updates
  - Unrestricted distribution
  - Partial Capability

Source: [www.dotnet-tricks.com](http://www.dotnet-tricks.com)
What is still missing?

- Battery capacity on smartphones is limited
  - Applications are not designed with the objective of optimal power consumption
- Smartphone processors are not fast → time to compute can be high → bad user experience

- How can we use Cloud Computing to overcome these limitations?
Mobile Cloud Computing is a framework to augment a resource constrained mobile device to execute parts of the program on cloud based servers.

**Pros:**
- Saves battery power
- Makes execution faster

**Cons:**
- Must send the program states (data) to the cloud server ➔ consumes battery
- Network latency can lead to execution delay

Typical MCC workflow

Key challenges?

- MCC requires dynamic partitioning of an application to optimize
  - Energy saving
  - Execution time

- Requires a software (middleware) that decides at app launch which parts of the application must execute on the mobile device, and which parts must execute on cloud
  - This is a classic optimization problem
MAUI server is the cloud component. The framework has the necessary software modules required in the workflow.

- MAUI enables the programmer to produce an initial partition of the program
  - Programmer marks each method as “remoteable” or not
  - Native methods cannot be remoteable
- MAUI framework uses the annotation to decide whether a method should be executed on cloud server to save energy and time to execute
• Smartphone processors are ARM based, cloud servers are x86 ➔ How to run same program code on different architectures
  – Uses Microsoft .NET Common Language Runtime
  – MAUI apps are written in C#
  – MAUI server has copies of the executable
    • Only program states must be sent to server to execute a method
CloneCloud system does not require the developer to annotate the methods as remoteable → it can work on unmodified applications (or binaries).

- CloneCloud transforms a single machine execution into a distributed execution optimized for various factors (network connection, processing speeds, application computing patterns).

CloneCloud uses static analysis of the code, and partitions at the thread level.
COMET: Code Offload by Migrating Execution Transparently

- Works on unmodified applications (no source code required)
- Allows threads to migrate between machines depending on workload
- It implements a Distributed Shared Memory (DSM) model for the runtime engine
  - DSM allows transparent movement of threads across machines
  - In computer architecture, **distributed shared memory** (DSM) is a form of **memory** architecture where the (physically separate) memories can be addressed as one (logically **shared**) address space

Requires only program binaries
Execute multi-threaded programs correctly
Improve speed of computation

Further improvements to data traffic during migration is also possible by sending only the parts of the heap that has been modified
Alternative Architectures

• Micro-cloud for offloading
  – Form a transient cloud using mobile devices in the vicinity

• Edge Cloud for offloading
  – Use the routers and/or other nearby servers to act as the compute resource

• Fog Computing (Mobile Fog)
  – Use ubiquitous sensor devices (Internet of Things) to act as a platform for unlimited computing power
Assumption is that a mobile device can only connect to other devices in the vicinity. Computation offloading can be performed among a set of mobile devices $\Rightarrow$ Mobile Device Cloud.

Goal is to maximize the lifetime of the collection of the mobile devices.

- Ported MapReduce framework to execute on Mobile Device Cloud.
- Has been shown to be useful for other latency sensitive applications.
Goal is to reduce the latency in reaching the cloud servers
Use servers that are closer to the mobile devices ➔ use cloudlet
A **cloudlet** is a new architectural element that arises from the convergence of mobile computing and cloud computing. It represents the middle tier of a 3-tier hierarchy: mobile device --- **cloudlet** --- cloud

Use remote cloud

Use cloudlet
Fog Computing

- **Fog computing** is an architecture that uses one or a collaborative multitude of end-user clients or near-user edge devices to carry out a substantial amount of storage, communication, control, configuration, measurement and management.

- Fog computing is a non-trivial extension of the cloud computing.
Summary

• The service oriented framework, like MBaaS, is focused mainly on application developers, less on user experience

• MCC focuses more on user experience
  – Lower battery consumption
  – Faster application execution

• MCC architectures designs the middleware to partition an application execution transparently between mobile device and cloud servers

• Alternative architectures focus on efficient use of computing resources in the user’s environment


