

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

# Mobile Cloud Computing Architectures

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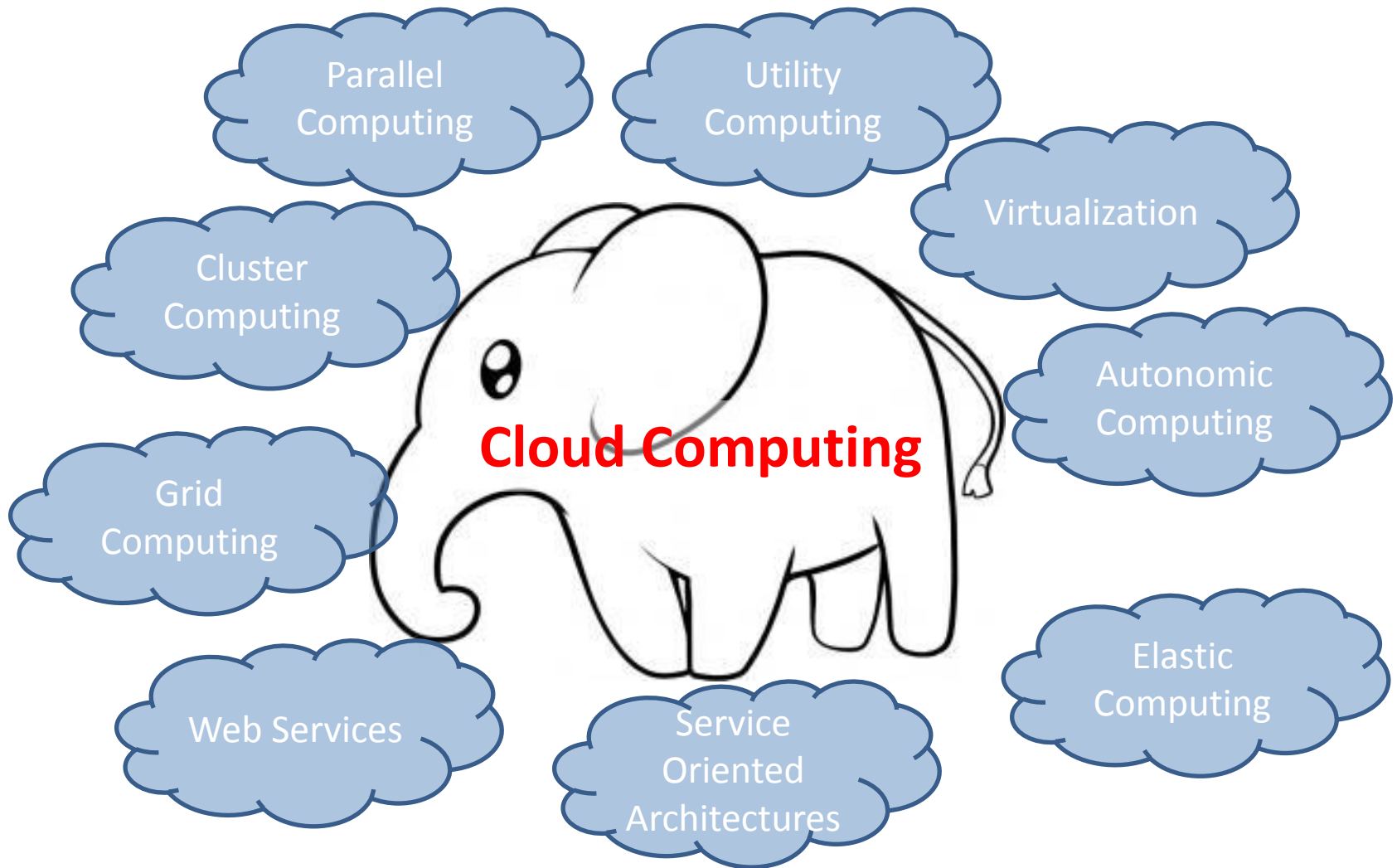
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# Cloud Computing

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



# Cloud Computing

## Old Wine in New Bottle ?

### Grid Computing

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

### Utility Computing

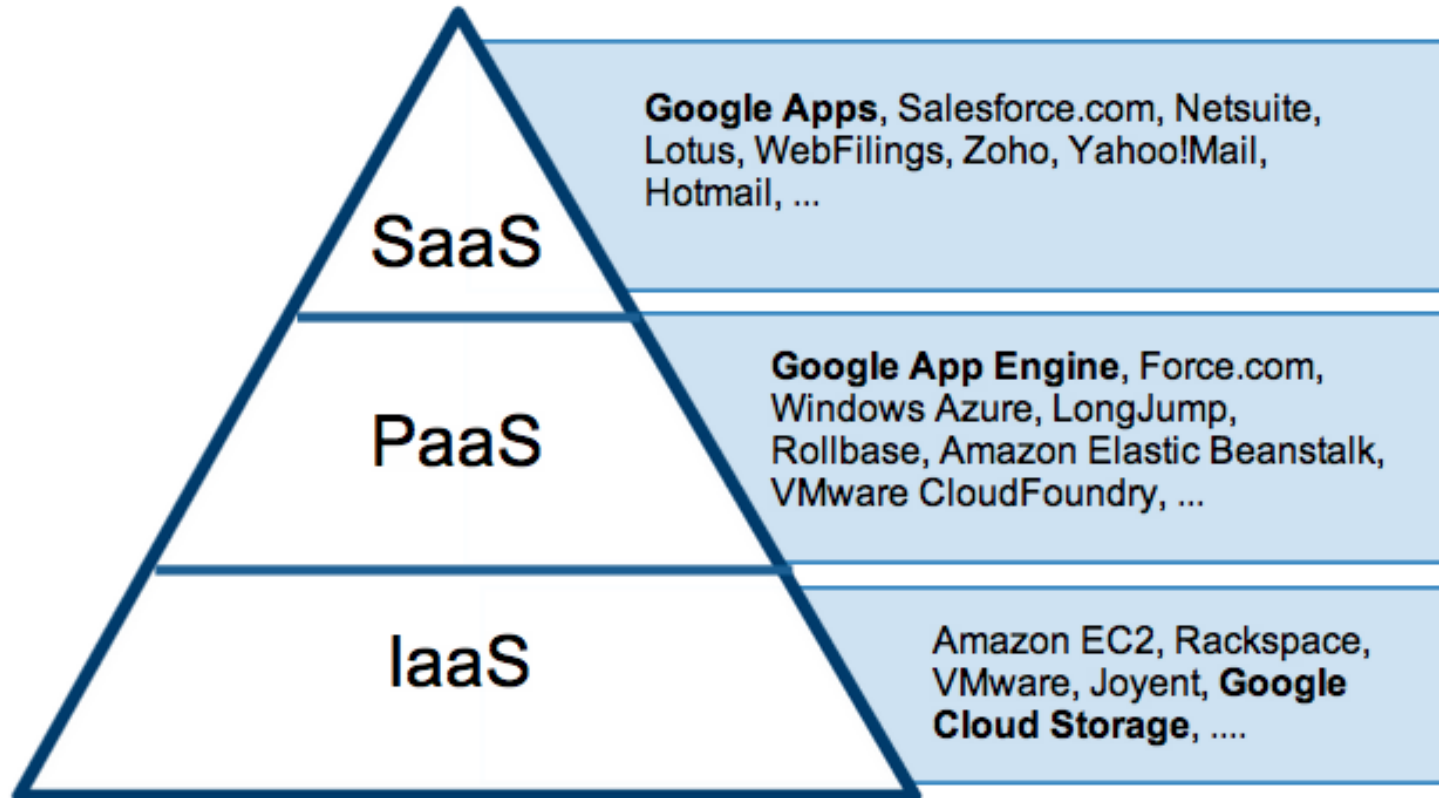
A business model to charge for resource  
Use a time on a supercomputer and pay for usage

### 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

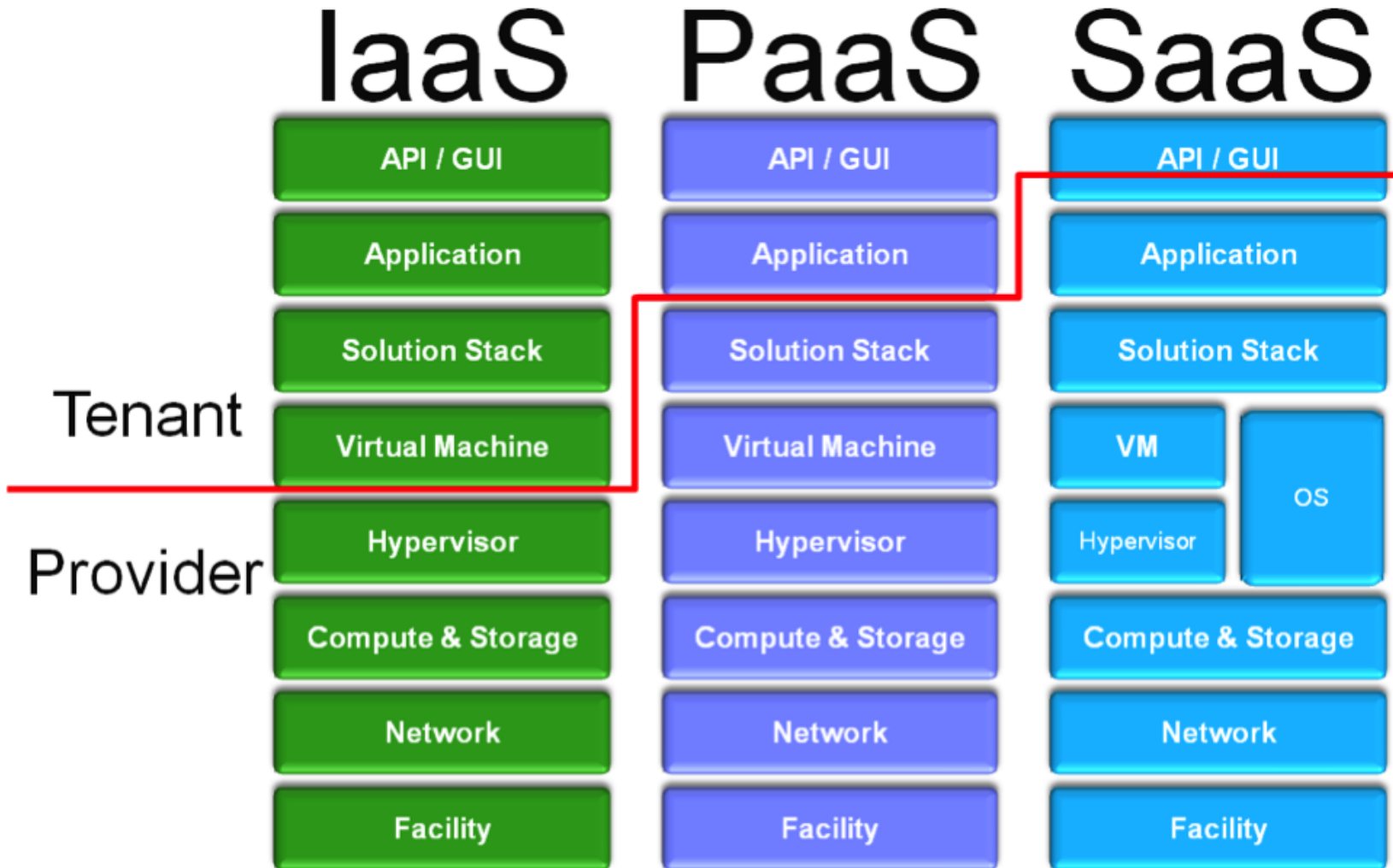
# Service Models

## Cloud Computing as Gartner Sees It



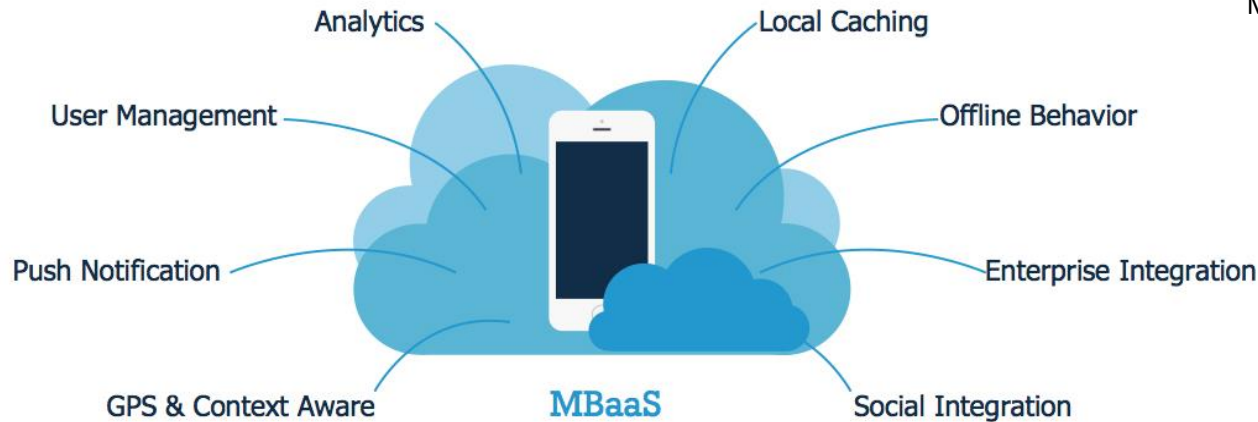
Source: Gartner AADI Summit Dec 2009

# Management Model



# Mobile Backend as a Service

Source: <http://rapidvaluesolutions.com/whitepapers/How-MBaaS-is-Shaping-up-Enterprise-Mobility-Space.html>



What	<ul style="list-style-type: none"><li>• Provides mobile application developers a way to connect their application to backend cloud storage and processing</li></ul>
Why	<ul style="list-style-type: none"><li>• Abstract away complexities of launching and managing own infrastructure</li><li>• Focus more on front-end development instead of backend functions</li></ul>
When	<ul style="list-style-type: none"><li>• Multiple Apps, Multiple Backends, Multiple Developers</li><li>• Multiple Mobile Platforms, Multiple Integration, Multiple 3rd Party Systems &amp; Tools</li></ul>
How	<ul style="list-style-type: none"><li>• Meaningful resources for app development acceleration – 3rd party API, Device SDK's, Enterprise Connectors, Social integration, Cloud storage</li></ul>

# 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

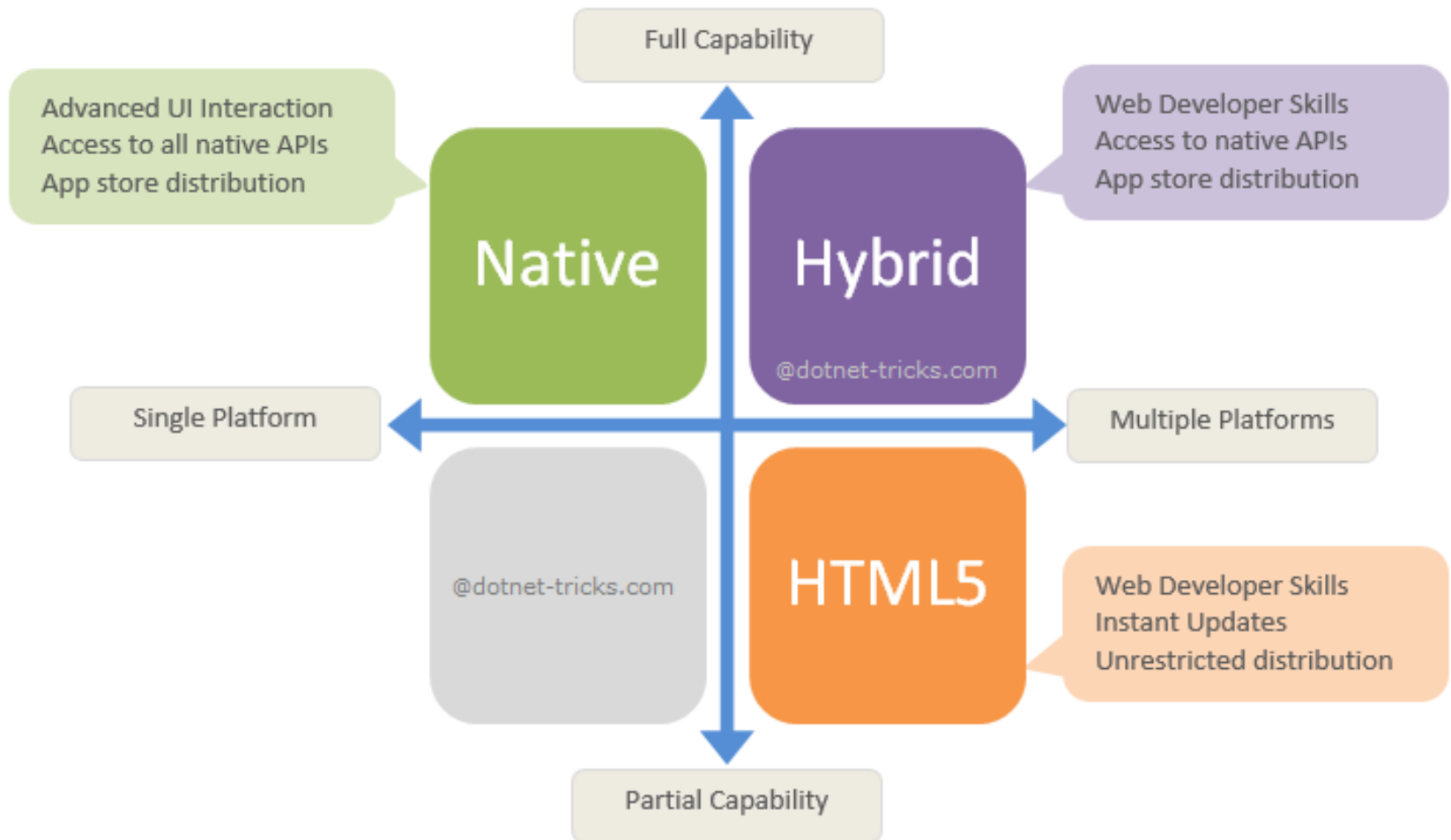


# App Models: Native, Web-based, Hybrid

- 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

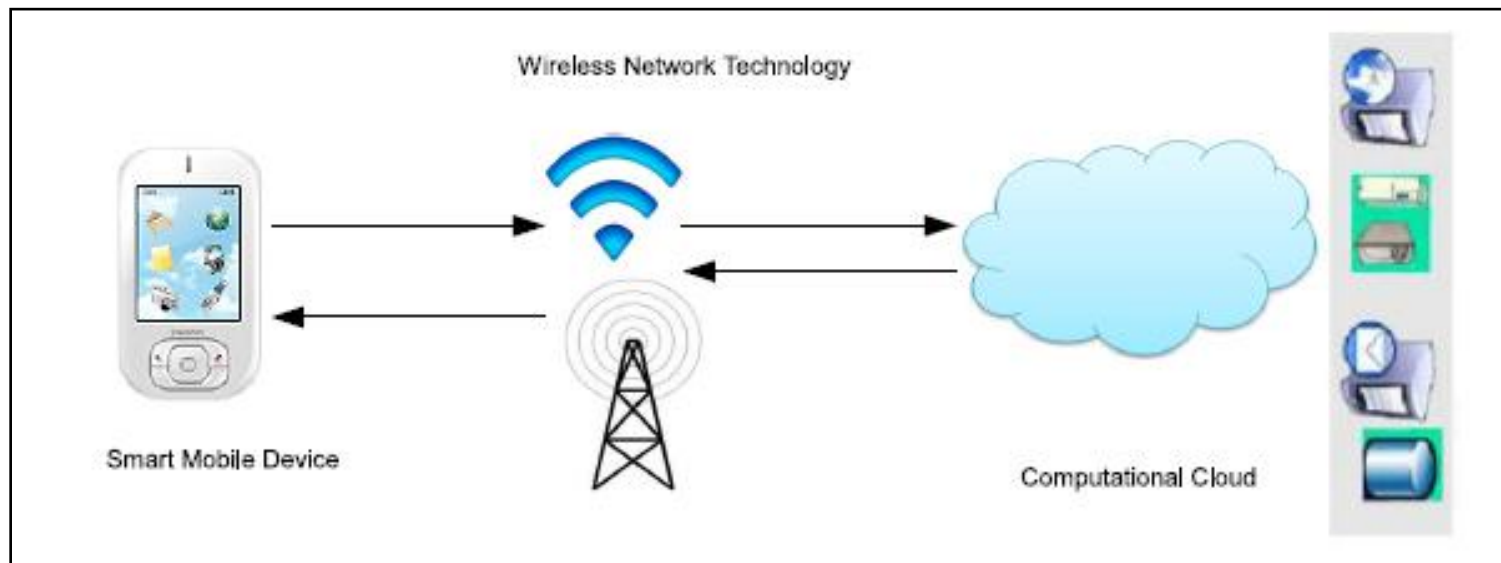


Source: [www.dotnet-tricks.com](http://www.dotnet-tricks.com)

# 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



Source: Shiraz, Muhammad, et al. "A review on distributed application processing frameworks in smart mobile devices for mobile cloud computing." Communications Surveys & Tutorials, IEEE 15.3 (2013): 1294-1313.

Mobile Cloud Computing is a framework to augment a resource constrained mobile device to execute parts of the program on cloud based servers

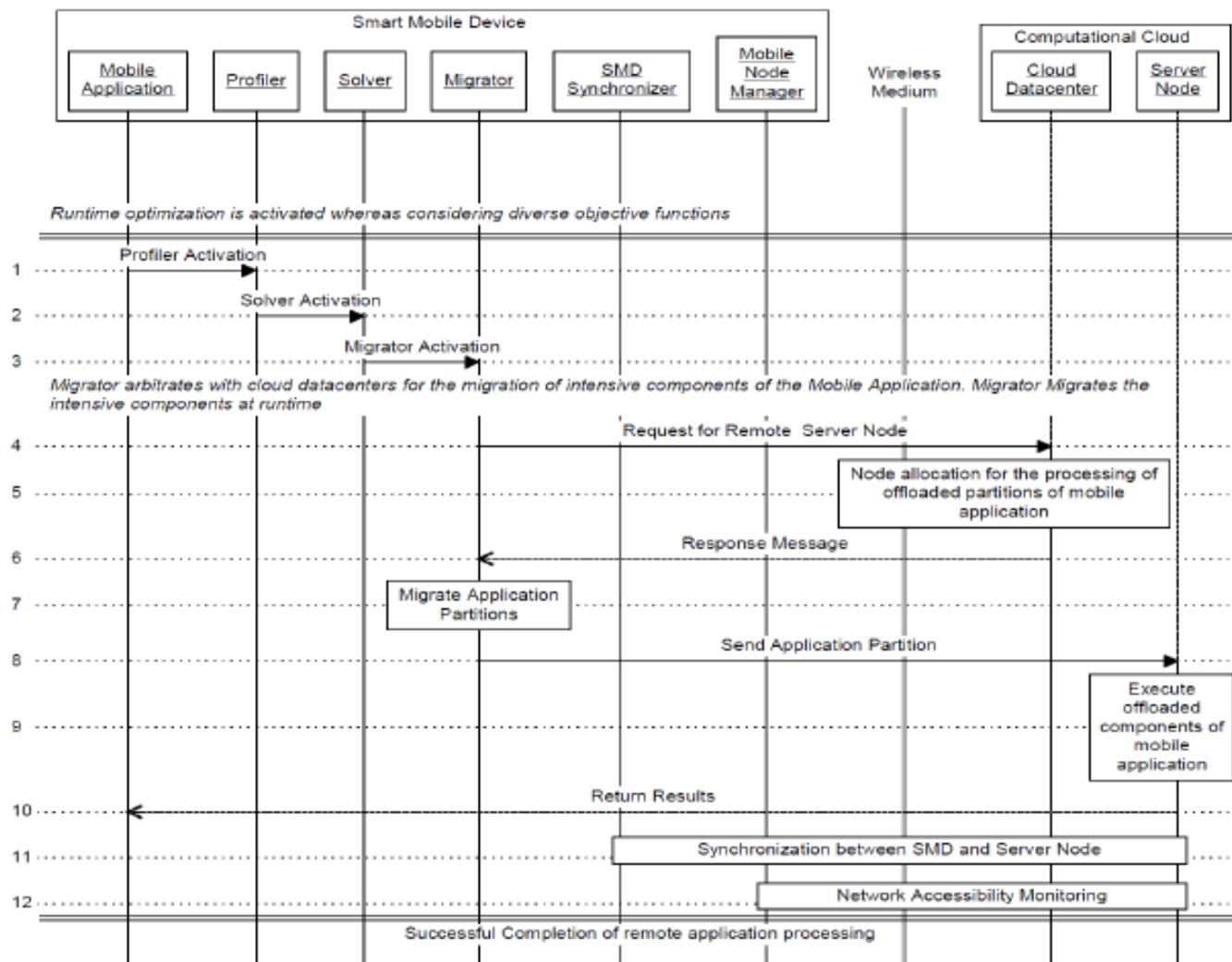
## Pros:

- 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

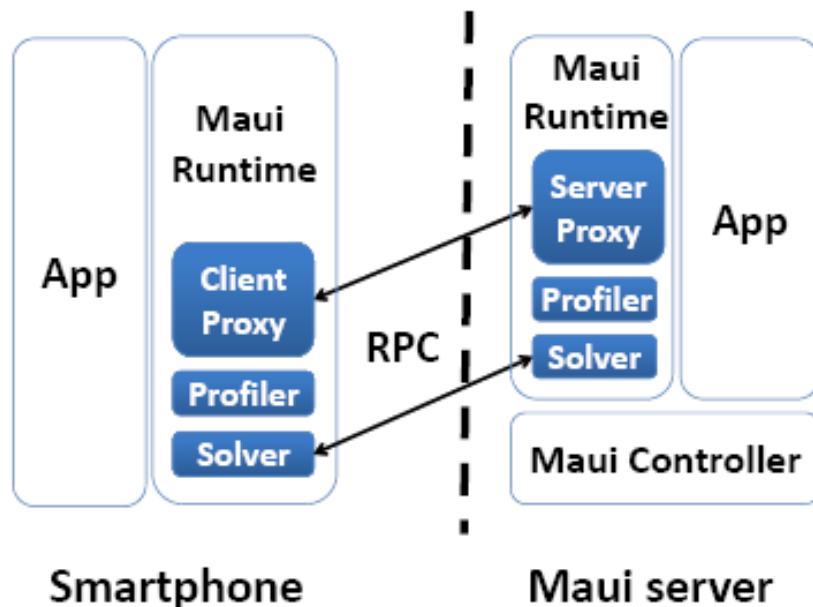


Source: Shiraz, Muhammad, et al. "A review on distributed application processing frameworks in smart mobile devices for mobile cloud computing." Communications Surveys & Tutorials, IEEE 15.3 (2013): 1294-1313.

# 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

# [1] MCC Systems: MAUI



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

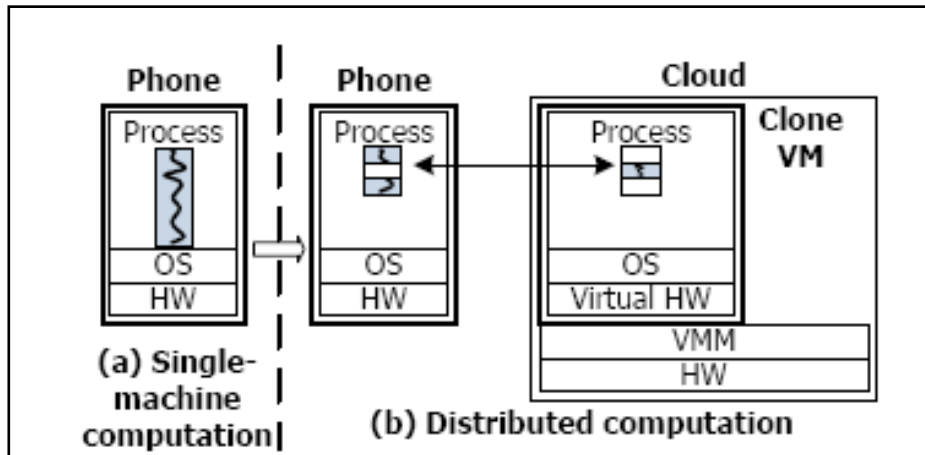
# [2] MCC Systems: MAUI

- 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

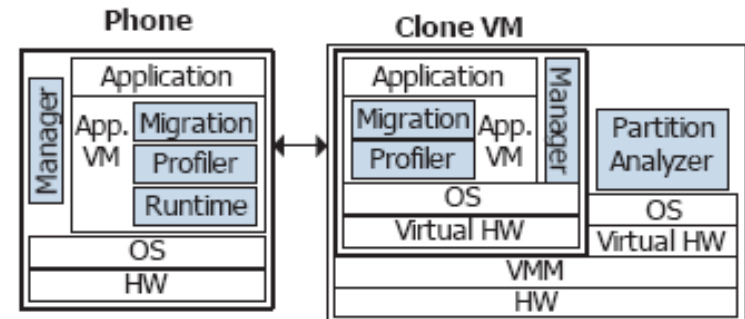


# MCC Systems: CloneCloud

- 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 Model



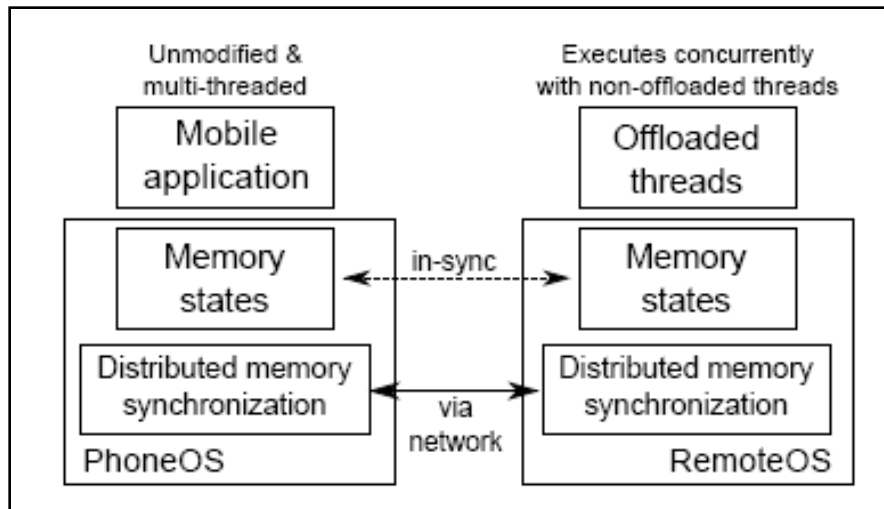
CloneCloud Architecture

CloneCloud uses static analysis of the code, and partitions at the thread level

# MCC Systems: COMET

## 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

# Micro-Cloud Architecture

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 → Mobile Device Cloud

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



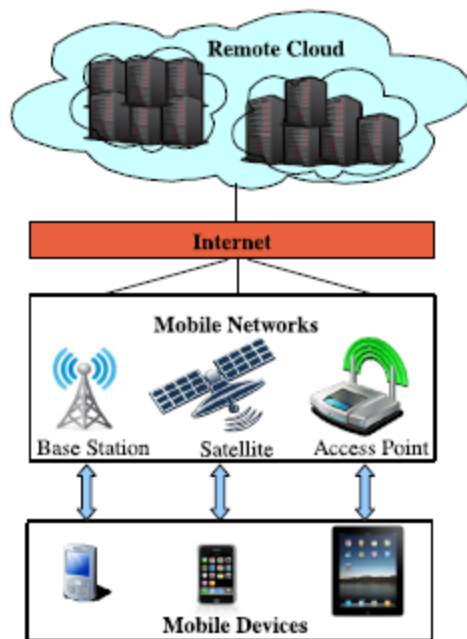
- Ported MapReduce framework to execute on Mobile Device Cloud
- Has been shown to be useful for other latency sensitive applications

# Edge Cloud or Cloudlet

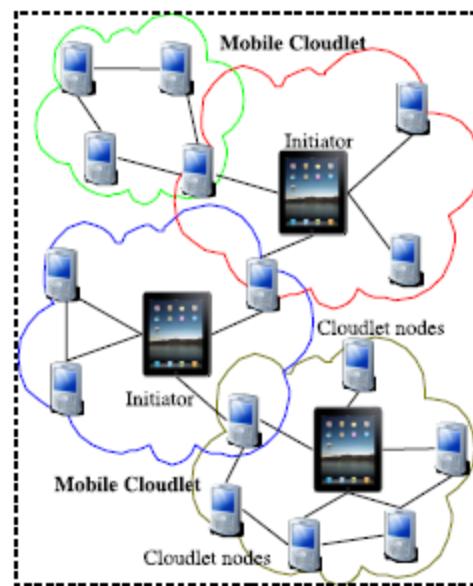
Goal is to reduce the latency in reaching the cloud servers

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

# References

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