Mobile cloud computing

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Computer Sciences
Key Papers

- The case for cyber foraging
  - Balan et al, CMU
  - Sigops 2002

- Slingshot: Deploying stateful services in Wireless Hotspots
  - Su et al, University of Michigan
  - Mobisys 2005

- CloneCloud: Augmented smart phone applications
  - Chun et al, Intel Labs
  - HotOS 2009
What is cloud computing?

- I don’t understand what we would do differently in the light of Cloud Computing other than change the wordings of some of our ads

Larry Ellison, Oracle’s CEO

- I have not heard two people say the same thing about it [cloud]. There are multiple definitions out there of “the cloud”

Andy Isherwood, HP’s Vice President of European Software Sales

- It’s stupidity. It’s worse than stupidity: it’s a marketing hype campaign.

Richard Stallman, Free Software Foundation founder
What is cloud computing?

- Application is used as an **on demand service**. Often provided via the Internet
  - Think on-demand TV programs

- **Example:** Google App (online office)

- **Benefits to users**
  - Reduce expenses: multiple computers, multiple users
  - Ease of usage: easy installation, access everywhere

- **Benefits to providers**
  - Easier to maintain
  - Control usage (no illegal copies)
What is cloud computing?

- Computing resources are provided as on demand service
  - CPU hour
  - Memory
  - Network
  - Platform to run software

- Examples of cloud service providers: Amazon EC2, Google AppEngine …
Now to mobile computing ...
Mobile usage is growing rapidly!

More People: 1.7 Billion Internet Users by End 2009

More Places: Many of these are increasingly Mobile users

Spending More Time: Average User Spends 32 Hours per Month Online

Doing More Things: Over 85000 iPhone Applications, 2 Billion downloads
More collaborative and interactive than ever before

Consuming Tons of data: Predicted to touch 1 ZettaByte by 2015
HD audio/video; virtual worlds; online file servers, Telepresence

Anytime-anywhere access becoming expected
2 Broad class of applications

- Personal Productivity Applications
  - Email
  - Calendar
- Computationally Intensive Interactive Applications
  - Speech Recognition
  - Language Translation
  - Augmented Reality
Motivation: Handhelds are weak!

- Resource intensive App
- Huge Data Sets

2 GHz, 1 GB, 3-D graphics, 2 GB of data

200 MHz, 32 MB, no 3-D, no FPU, 32 MB Flash

Resource-poor wearable

Poor performance!
Solution: Cyber Foraging

- “To live off the land”
- Use resources in environment to augment device capabilities by using surrogates
- 2 methods
  - Data Staging
  - Remote Execution
The Big Picture

- **Data Staging**
  - Caching of large amounts of data
  - Handhelds with limited storage can access this data fast
  - Security and authentication

- **Remote Execution**
  - Uses remote servers to augment computational capabilities of handhelds
  - Enables computationally intensive applications
Roadmap

- Data Staging
- Remote Execution
  - Slingshot
  - Clonecloud
Data Staging: Motivation

- End-to-end latency across the Internet isn’t getting better
  - Physical limits
  - Routers, firewalls
  - Shows up in interactive file access delays
  - Crucial for small to medium files

- Can overcome this by caching & prefetching, but …
  - Handheld clients don’t have enough resources
  - Cache consistency

- Can untrusted and unmanaged computers help?

Yes!!
Data staging: Mechanism

- Coda clients speculatively prefetch data:
  - Nearby surrogate runs staging server
  - Used like a second level cache
  - Cache misses serviced by staging server

- Surrogates deployed in high-usage areas
Security

- Must provide level of security users expect
- *But surrogate is untrusted*

- Use end-to-end encryption
  - Only store encrypted data on surrogate
  - Client caches keys and checksums
  - Only need access control for keys
The “Gory” Details

Server

File Server

File data

Data Pump

Handheld client

Proxy

File System

Staged file traffic

File keys (via secure channel)

Surrogate

Staging Server

Normal file traffic

Encrypted file data
Data staging reduces cumulative delay up to 64%
Roadmap

- Data Staging
- Remote Execution
  - Clonecloud
  - Slingshot
Motivation: mobile interactive applications

- speech recognition, language translation, augmented reality, …
  - Resource-heavy, but need bounded response time
Solution: Remote Execution

- Augment capabilities of handhelds by using nearby servers

- But how do you make legacy applications use remote execution?
- And get good performance as well?
Strawman Mechanism

- Heavily modify each application to use remote execution
  - Tweak every last drop of performance

- Requires ~3-4 grad student months per reasonably sized application
  - Grad students have nothing else to do anyway right?? 😊

- Method does not scale and is not agile
Mechanism: CloudClone

Computation migration – for enhanced productivity
CloneCloud (Chun et al.)

- Developers write applications once for their Smartphone platforms
  - CloneCloud morphs applications automatically
  - Clones software of the Smartphone
  - Synchronizes image incrementally and offloads execution in clone
  - Merges results back retroactively or not
Augmentation types

Cloud

Smart Phone

Primary  Background  Mainline  Hardware  Multiplicity
Primary functionality outsourcing
Primary functionality outsourcing

Schedule heavy computations sync
- Video/audio processing
- Floating point computation
Background augmentation
Background augmentation

Schedule background processes async
- Back ground virus scans
- Security checks

Cloud

Smart Phone
Hardware augmentation

Cloud

Smart Phone
Hardware augmentation

Cloud

Capability inflation: CPU clock rate, the number of virtual CPU cores, memory size
• File system scanning app.
  • HTC G1 – 3953 s
  • QEMU* VM on a Dell Desktop – 336 s

Smart Phone
Augmentation through multiplicity
Augmentation through multiplicity

Choosing between multiple execution paths
• Energy conservation path
• Fault diagnosis

Cloud

Smart Phone
Cloudclone: Key challenges

- When to augment?
  - Applicability is application dependent
- Which part to augment?
  - Consider local computation power
  - Resource usage such as power
- Where to augment?
  - Choose remote location intelligently
  - Network latency
Cloudclone: Key challenges

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Remote execution

Internet

Wireless Hotspot

Limited bandwidth

AP

VNC Server

VNC client

High latency

Limited bandwidth

High latency
Slingshot: Smart Remote execution

Wireless Hotspot

AP

Surrogate

VNC client

Internet

VNC
VM

Home Server
Slingshot: Smart Remote Execution

AP
Wireless Hotspot
VNC client
Surrogate
Internet

Home Server
VNC VM

Problems:
1. No service during migration
2. Loss state on surrogate failure
Slingshot: Smart Remote Execution

- Home replica always available
- No state loss on surrogate failure
Ease of Management

- **Slingshot**
  - Minimizes the surrogate computing base
  - Uses a heavyweight virtual machine
  - Places no hard state on surrogates
Slingshot Overview

- Slingshot applications
  - Remote desktop: VNC
  - Speech recognition: IBM ViaVoice
Network Topology

- Workload: open Word, insert text, save document and close Word
Benefit of Slingshot

- Slingshot: 2.6 times faster than remote execution
Instantiating the First Replica

- Slingshot executes 2.6 times faster than remote execution
How about energy savings?

The Energy Consumption of Wi-Fi vs. 3G for Connectivity to the Cloud
Energy consumption is function of RTT

The Energy Consumed by Offloading 10KB and 100KB of Code to the Cloud as the RTT Increases
How do we conserve energy then?

- Use close-by surrogates for offloading computation
- Choose between modes of transfer (3G vs WiFi)
  - Profile WiFi/3G/DSL links
  - Choose the one with the best RTT
  - See work like “Context for wireless”
Energy savings from smart offloading

A comparison of energy consumption for image recognition software
Energy savings from smart offloading

A comparison of energy consumption for image recognition software
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A comparison of energy consumption for image recognition software
Conclusions

- Mobile cloud computing extends limits of mobile devices
- Presented some key mechanisms to facilitate such mobile computing in the cloud
  - Cloudclone
  - Slingshot