Introduction to Mobile and Cloud Computing

Outline
• Syllabus and Overview
• Introduction to Cloud Computing
• Introduction to Mobile Computing

General Information
• Location and Time: M03-0204A, Tu & Th, 4:00 ~ 5:15pm
• Office: Science Center, S-3-075
• Email: shengbo@cs.umb.edu
• Office Hours: Tu & Th, 2 ~ 4pm
• Class Materials: http://www.cs.umb.edu/~shengbo/teaching/cs697.html
• Turn in homework via email (usually)
• Use “CS697” in subject line.
• If I receive your email, I will reply. If you do not get anything in 2-3 days, email again.

Why a class on mobile & cloud computing?
• Emerging areas that will be increasingly important
• Better job prospects, e.g., companies like Facebook, Twitter, Amazon, etc, are hiring
• Impact many different areas of research, such as networking, data mining, security, high performance computing, graphics, and so on
• Many mobile applications depend on the cloud, e.g., Windows mobile & Azure, iPhone & iCloud.

Goals for this class
• Introduce key technologies and open problems
  • How? Student presentations on recent papers from premier conferences and journals

  • Provide hands-on experience
  • How? Programming assignments, one on cloud, one on mobile phones, and one combining cloud and phones.

  • Explore research topics
  • How? Complete one research project during the entire semester

General Information
• Pre-requisites. None.
• Textbook. None.
• Your background
  – OS? Distributed OS?
  – Networks / Wireless networking?
  – Use Linux?
  – Programmed android/iPad/windows mobile before?
  – Access to laptop/PC?
General Information

• Grading Policy
  – Attendance & participation 10%
  – Paper presentations (2) 20%
  – Homework assignments (3) 30%
  – Class project (1) 40%

• University’s Policies
  – Plagiarism, Honor code
  – Emergency
  – Disability service

Paper Presentation

• Everyone will present 2 papers, one for cloud and the other for mobile computing
  • A list of papers can be found on course web page.

• Pick 4 papers total (2 cloud and 2 mobile) and email me.
  I will do the assignment.

• Do this by Monday, Sept 10 noon.

• May provide guidelines on presentations later

Class Project

• Either individual or in a group of 2 students
• Project considered complete if it has
  – Short report, 5-6 pages long, IEEE conference format
  – Source code and documentation
  – Presentation of project or demo (last 1 or 2 classes)
• Turn in 1 of everything per project. E.g., a group will only turn in 1 report with both names on it.
  Same grade for both people
• Team management

Class Project

• In general, your project should have an evaluation component.
• System implementation/prototype, can be combined on simulation (Matlab, NS2, etc).
• This means you have to think about issues like workload, trace data, experimental setup.
• No surprises. The expected output should be discussed with me in advance.
• It MUST work!

Project Topics

• Mobil phone Wi-Fi scanning
  – Find available Wi-Fi APs and test the link quality
  – Report to cloud and make it accessible to others
• Mobile phone Apps for drivers
  – Interactive speech-based navigation
  – Foreign road signs reorganization
• NFC-initialized communication between phones
  – Wi-Fi ad-hoc, Wi-Fi direct, or Bluetooth
• Cross device web caching/prefetching
  – Desktop, laptop, tablet, smartphone, etc
  – Cloud-based service

Project Topics

• Capacity planning on cloud service
  – Monitor the service load, analyze and predict the pattern
  – Dynamically allocate more resources when needed
• Job scheduling and resource bidding
  – Cloud service charge may vary, e.g., AWS’s ‘spot instance’
  – Non real-time jobs, but with deadlines
  – Given a limited budget
• Mobile bulletin board
  – Drop messages from phones to specific receivers
  – Valid only when receivers are in a certain area / within a certain time span
Class Project
• Choose a topic by Sept. 25’s class
• 10 min progress report on Oct. 23
• Final report due at the end of semester

Available Resources
• Smartphones
  – Windows phones (Samsung Focus)
  – Android phone (HTC, Samsung)

Available Resources
• Cloud service
  – 12 Azure passes
  – AWS

Compute • 1 hosted service, with 2 small compute instances
Storage • 1 storage account, with 3GB of storage and 250,000 storage transactions
Database • Two 1GB SQL Azure Web Edition databases
Data Transfers (per region) • 3 GB in • 3 GB out
Other • 100,000 Access Control transactions • 2 Service Bus connections

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What is cloud computing
“The interesting thing about Cloud Computing is that we’ve redefined Cloud Computing to include everything that we already do.”
Larry Ellison, Oracle CEO

“It’s stupidity. It’s worse than stupidity: it’s a marketing hype campaign.”
Richard Stallman, Founder of GNU

Views from NIST
• National Institute of Standards and Technology
  Responsible for developing standards and guidelines for government operations and assets (excluding national security)
  A model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction.
In the Beginning was the Mainframe and Terminals

Users did individual work by connecting to central computer

Next came PCs

Users did individual work on their own desktops

Then the PCs Got Tied Together

Users could talk to each other’s PCs

Then came the Web

Users did individual work by connecting to web servers

Then the Web got big

Server had to become cluster of PCs

Then the Web got REALLY big, and really important

Server PCs had to live in expensive data center

Microsoft Data Center in Dublin, 27,000 m², 22 MW, US$ 500 M
Data Centers

- Need lots of electric power (1.5% of all US electricity, EPA 2007)
- Long lead time to build
- Inflexible investment of capital
- Need specialized skills (security, failover, load balancing, etc.)
- Takes time away from core competencies
- Hard for all but largest companies to own/run

Solution: Outsource Data Center

- Can reap economies of scale
- Because of scale, can afford specialized skills
- Web developers can concentrate on their core competencies that give them market advantage
- Shorter lead times
- Lower capital requirements
- Computing power becomes a commodity, as did electric power in early 20th century

Similar to Electrification in Early 20th Century

See The Big Switch: Rewiring the World, from Edison to Google, by Nicholas Carr, Norton, 2008, from which this chart is taken

5 Key Characteristics of Cloud

- On demand self-service. User can provision computing capabilities without human interaction with service provider
- Broad network access. Computing facilities available over network using standard mechanisms
- Resource pooling. Service provider resources are pooled to support multi-tenant model, with resources (physical & virtual) dynamically assigned

5 Key Characteristics of Cloud

- Rapid elasticity. Computing capabilities can be elastically provisioned and released. Appears to be unlimited to the user.
- Measured service. Resource (e.g. storage, processing, bandwidth, etc) monitored and reported.

Types of Cloud Service Models

- Software as a service (SaaS)
  - Cloud provides application.
  - Customer uses the application.
- Platform as a service (PaaS)
  - Cloud provides programming lang., libraries, services, tools.
  - Customer creates their own applications.
Types of Cloud Service Models

• **Infrastructure as a service (IaaS)**
  - Cloud provides processing, storage, networks, and other fundamental computing resources.
  - Customer runs own software, including OS.

• **Private Cloud (On-Premise)**

**View from Berkeley**

- Applications delivered as services over the Internet, and the hardware and systems software in the datacenters that provide those services.
- Services are referred to **Software as a Service**
- Datacenter hardware and software is known as **the cloud**
- Service being sold is known as **utility computing**

**New aspects from hardware perspective**

- Appearance of infinite computing resources. Planning less important
- Eliminate up-front commitment
- Pay-as-you-go, release resources when not needed.

**Why should you use the cloud?**

- **Question.** If your company needs 500 servers in the day (peak period) and 100 servers at night (off-peak period). How many servers should you buy?

  - Average is 300 servers. What happens if we just get 300?

- Real world estimates of server utilization is 5% to 20%.
- Peak work load exceeds average factors by 2 to 10.
Why should you use the cloud?

- Animoto is a video sharing site
- When added Facebook, load increased from 50 servers to 3500 servers in 3 days

Is it cheaper?

<table>
<thead>
<tr>
<th>Internet</th>
<th>WAN bandwidth/traffic</th>
<th>CPU (core) (all extra)</th>
<th>Disk storage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bill to 2005</td>
<td>1 Mbps WAND link</td>
<td>4 GHz CPU, 1 GB DRAM</td>
<td>500 GB disk, 16 MB MMU</td>
</tr>
<tr>
<td>Bill to 2005</td>
<td>$500/mo.</td>
<td>$5/GB</td>
<td>$500</td>
</tr>
<tr>
<td>Bill to 2005</td>
<td>1 GB</td>
<td>1 GB</td>
<td>1 GB</td>
</tr>
<tr>
<td>Bill to 2005</td>
<td>100 MHz WAND link</td>
<td>2 XLA, 2 XDMA, 4 GB DRAM</td>
<td>1 TB disk, 115 MB/s transfer</td>
</tr>
<tr>
<td>Bill to 2005</td>
<td>$5000/mo.</td>
<td>$5/GB</td>
<td>$500</td>
</tr>
<tr>
<td>Bill to 2005</td>
<td>1 GB</td>
<td>1 GB</td>
<td>1 GB</td>
</tr>
</tbody>
</table>

- Ignores operational cost, e.g. tech. support, energy, physical facility management, etc.

So everyone should use the cloud?

- Medium is about 1000 servers. Very large is about 50,000 servers
- Statistical multiplexing allows hardware to be used by more users. Private data center does not have this advantage.
Top 10 challenges (according to Berkeley)
1. Availability of service
   • What happens when the cloud provider is down?

Top 10 challenges (according to Berkeley)
2. Data lock-in
   • What happens when you need to get data out of the cloud? E.g. Cloud provider raise prices, goes bankrupt, etc.
   • Cloud may use own data formats
   • Compare with other types of utilities, e.g. electricity, phone.

Top 10 challenges (according to Berkeley)
3. Data sensitivity and auditability
   • Your data in the cloud is managed by the people hired by the cloud. Why should you trust them?
   • E.g. police database, government database
   • Difficult to run audit on cloud facilities (sometimes needed for compliance)

Top 10 challenges (according to Berkeley)
4. Data transfer bottleneck
   • Want to transfer 10TB of data to cloud
   • 20 Mbit/sec upload link. It would take
     \[10 \times 10^{12} \text{ bytes} / (20 \times 10^6 \text{ bits/second}) = 4,000,000 \text{ seconds},\]
     which is >45 days, and cost about $1000
   • Use Fedex, send 10 1TB disk. About 1 day, cost about $400
   • What if all data is always stored into cloud?

Top 10 challenges (according to Berkeley)
5. Performance unpredictability
   • Users share CPU, memory, IO, with other users
   • Generally have no control over scheduling or hardware choices.

Top 10 challenges (according to Berkeley)
6. Scalable storage
   • Scaling up CPUs is relatively easy compared to scaling up storage.
   • How can users effectively utilize the data they have stored?

Top 10 challenges (according to Berkeley)
7. Bugs in large-scale distributed systems
   • Difficult to catch bugs, sometimes bugs only appear when scaling up

Top 10 challenges (according to Berkeley)
8. Scaling quickly
   • Difficult to scale up or down based on load while maintaining service level agreements (SLA)
Top 10 challenges (according to Berkeley)

9. Reputation fate sharing
   • What happens when one user does something bad, and leads to blacklisting of cloud provider’s IP addresses?

10. Software licensing
   • How will we bill the users?
   • Use open source instead?

Amazon Web Services

• Launched in 2002
• Run by Amazon.com
• Programmed in many languages, including Java, Python, Ruby, and .NET
• Evolved from basic computing to add commerce-based services, such as payment and fulfillment

Google App Engine

• Released in 2008
• Primary languages are Python and Java
• Currently provides basic computing and storage; a few more simple things. Can’t imagine that won’t increase and evolve.
Microsoft Azure

- Launched in 2009
- Program in .NET
- Provides computation and storage services
- Allows access to underlying cloud system ("fabric") for sophisticated tweaking
- I expect to see additional business services as well, perhaps provided by third parties

Why cloud computing now?

- New business models
- Shift from “high-touch, high-margin, high-commitment” service to “low-touch, low-margin, low-commitment” service
- Importance of data analytics
- More companies collect customer data. Need computing power to analyze
- Popularity of mobile interactive applications
- Smartphones use applications that best live on cloud

Déjà vu?

- Before cloud computing, we had grid computing.
- Also provides computing, storage, data, applications, on demand.

Grid computing

- A distributed computing paradigm that spans across multiple virtual organizations (VO)
- A VO can consist of either physically distributed institutions or logically related projects/groups.
- More popular in government research labs and universities
- Target large-scale computation problems using a network of resource-sharing commodity machines
- Because supercomputers and clusters were too expensive

Grid computing

- Generally speaking, a grid computing has 3 characteristics
  1. Coordinates resources without centralized control
  2. Uses standard, open, general-purpose protocols and interfaces
  3. Delivers non-trivial qualities of service.
- Cloud computing usually does not have the first 2 characteristics
Other differences (generally speaking)
• Grid computing uses batch scheduling model.
  – Submit a job with required resources (e.g. so many CPU, etc) to scheduler.
  – When resources available, scheduler will run your job.
• Dedicated resources. Can give better QoS than cloud computing.
  – Good for scientific type applications. Not so good for interactive type applications.

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Introduction to Mobile Computing
• Evolution of cell phones

Introduction to Mobile Computing
• Smartphones (Hardware)
Introduction to Mobile Computing

- Smartphones (Software)
  - iOS
    - 725,000 apps
    - 10 billion downloads in Jan 2011
    - 25 billion downloads in March 2012
  - Android
    - 500,000 apps, 15 billion downloads (May 2012)

Consumer Research

- In 2011, 84% of adults have a cell phone.
- In 2000, 53% of adults owned a cell phone.
- In 2011, ¼ of US households are cell only.

Major Platforms

- 35% of smartphone owners / 15% of cell owners
  - Young adults (especially 18-24)
- 24% of smartphone owners / 10% of cell owners
  - College grads
  - HH income $75k or more
  - Employed full-time

Tablet and E-Reader Use is Growing

- Tablet ownership rose from 4% to 10% between September 2010 and August 2011

2/3 Adults are Wireless Internet Users (2011)
How People Use Their Phones

<table>
<thead>
<tr>
<th>Activity</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Send/receive text messages</td>
<td>73%</td>
</tr>
<tr>
<td>Take a picture</td>
<td>73%</td>
</tr>
<tr>
<td>Access the internet</td>
<td>44%</td>
</tr>
<tr>
<td>Send a photo or video to someone</td>
<td>54%</td>
</tr>
<tr>
<td>Send or receive email</td>
<td>76%</td>
</tr>
<tr>
<td>Record a video</td>
<td>59%</td>
</tr>
<tr>
<td>Access a social networking site</td>
<td>59%</td>
</tr>
<tr>
<td>Watch a video</td>
<td>54%</td>
</tr>
<tr>
<td>Post a photo or video online</td>
<td>45%</td>
</tr>
<tr>
<td>Access Twitter</td>
<td>15%</td>
</tr>
</tbody>
</table>

Apps

- Top 4 popular categories of apps (Nielsen data, June 2010)
  - Games (65%)
  - News/Weather (56%)
  - Maps/Navigation/Search (55%)
  - Social Networks (54%)

Apps Provide Connections to Information

<table>
<thead>
<tr>
<th>Activity</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>News, weather, sports or stocks updates</td>
<td>34%</td>
</tr>
<tr>
<td>Learn about something you’re interested in</td>
<td>35%</td>
</tr>
<tr>
<td>Get info about a destination you’re visiting</td>
<td>54%</td>
</tr>
<tr>
<td>Help shop or make purchases</td>
<td>34%</td>
</tr>
<tr>
<td>Get more info about an event you’re attending</td>
<td>35%</td>
</tr>
</tbody>
</table>

Information is Location-Based

- 28% of cell owners use their phones to get directions or recommendations based on their current location, but only 5% use check-in services on their phone
- 1/3 of adults use mobile devices to check weather or to find local restaurants or businesses
- 1/5 use mobile devices to get information about local traffic or transportation
- 1/6 use mobile devices to get discounts/use coupons at local stores

One word best describes your cell phone

- 72% of responses positive, 16% negative

Impact on People’s Life

- Mobile (and smartphones especially) changes the relationship between information, time and space...
- 51% of cell owners use phone to get information they need right away (smartphone owners: 79%)
- 42% use phone to entertain themselves when bored (smartphone owners: 72%) and 40% have been helped by phone in an emergency situation
- 29% turn phone off occasionally just to get a break
- 13% have pretended to be using their phone to avoid interacting with people around them
- 36% of smartphone owners have been frustrated by slow download times, and 34% have had trouble doing something recently because they didn’t have their phone
Tablet Users

- 77% use their tablet every day
- Users spend an average of 1 hour, 35 minutes on their device daily
- 53% get news on their tablet daily

Other common daily activities:
- Email (54%)
- Social Networks (39%)
- Games (30%)
- Read Books (17%)
- Watch Videos (13%)

History of Smartphone

- Jan. 2007, Steve Jobs unveils the iPhone, which he says is "a revolutionary and magical product that is literally five years ahead of any other mobile phone". Microsoft chief executive Steve Ballmer calls it "the most expensive phone in the world".

- Apr. 2007, Gartner says that in the first three months of 2007 Microsoft's Windows Mobile had an 18% share of the smartphone market (then totaling 17m handsets).

- Nov. 2007, Google announces it will offer the Android mobile operating system for free. Anyone can use it and change it. Asked if there will be a Google phone, head of Android, Andy Rubin, replies: "There will be thousands of Google phones – some you like, some you don't." Microsoft's Ballmer says "Well have to see what Google does. Right now they have a press release, we have many, many millions of customers, great software, many hardware devices, and they're welcome in our world!"

- Oct. 2008, Apple announces it sold 4.7m iPhones in the summer quarter, giving it nearly 13% of the smartphone market. Research in Motion had 15%.

- Nov. 2008, First Android phone, the G1, launches. It has a slide-out keyboard and limited touchscreen capability.

- Dec. 2008, Microsoft decides to kill off Windows Mobile because it can't compete with the iPhone and Android, and develop Windows Phone – a completely new mobile operating system.

- Jan. 2010, Apple launches the iPad, a 10in tablet.

- Feb. 2010, Android phones with full touchscreen interaction like the iPhone's appear.

- Apr. 2010, Google's Android gained just under 10% of the market in the first three months of 2010, says Gartner.

- Oct. 2010, Microsoft's first phones running Windows Phone. Sales are low. Mike Lazaridis, RIM's co-chief executive, shows off the Playbook, a 7in tablet.

- Jan. 2011, Researchers Gartner and IDC announce that smartphones outsold PCs worldwide in the last three months of 2010 – 100m as against 93m.

- Apr. 2011, Apple becomes the largest smartphone vendor by numbers and revenue, selling 18.6m iPhones in the year's first quarter. Android becomes the best-selling smartphone platform, with a 36.6% share, ahead of Symbian's 27%. Apple sues Samsung in the US over the appearance of the Galaxy Tab tablet, and follows it up with a string of legal cases around the world claiming infringement of patents and "trade dress".

- Nov. 2011, Android had more than 50% of the smartphone market in the third quarter of 2011, says Gartner.

- Dec. 2011, RIM takes a $485m charge against an estimated 1.2m unsold Playbooks sitting in its warehouses.

- Jan. 2012, Microsoft gets LG to pay undisclosed per-handset royalties. Microsoft says it now has such agreements for 70% of Android handsets sold in the US. Jim Balsillie and Mike Lazaridis resign as co-CEOs and co-chairmen of RIM. Replaced by Thorsten Heins and Barbara Stymiest, who have been with the company for some years.