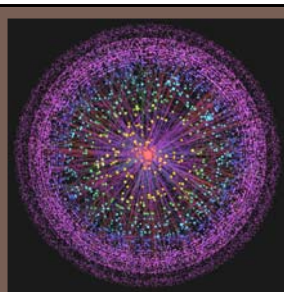

JAVA IN DISTRIBUTED COMPUTING SYSTEMS

Lecture 26 – CS2110 – Fall 2009

Distributed Computing

2

- Up to now we've talked about Java on a single machine
  - Perhaps with threads to exploit multicore parallelism
- But suppose that objects could "live" on other machines?
  - Then if we could just invoke methods on them we would be able to create a distributed program!

Distributed Computing

3

- Java supports this model
  - Called a "Web Services" architecture
  - Your program designates certain interfaces it will make available on the web using *Annotations*

```
package server;
import javax.jws.WebService;

@WebService
public class HelloImpl {
  /**
     * @param name
     * @return Say hello to the person.
     */
    public String sayHello(String name) { return "Hello, " + name + "!"; }
}
```

http://www.artima.com/lejava/articles/threeminutes.html

Talking to the service

4

- Before you can write the client you need to run a program called APT that transforms the server into something that really runs
- APT creates:
  - A so-called "WSDL" file that looks like a web page and describes the new service
  - A"schema" for the messages used to talk to the service
  - Java classes to receive requests and "unpack" them, and to send the response back (which "repacks" them)
  - The client "stub" file

Then…

5

- You start your program on the machine that will be the server
- You also need to wave a magic wand to "register" the service with the "Internet Information Service"
- Then on the client machine you import the service and can then write code to talk to it

Talking to our web service

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- Done using a "client" web-service proxy

```
static void Main(string[] args)
{
   HelloServiceClient proxy = new HelloServiceClient();
   String result = proxy.SayHello("My master");
   Console.WriteLine("Hello Service returned: <" + result + ">");
}
```

- When executed, prints

```
Hello Service returned: <Hello My master!>
```

http://www.artima.com/lejava/articles/threeminutes.html

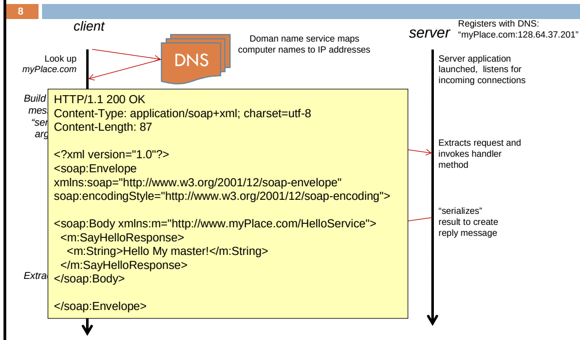
What happened?

7

- A program on one machine invoked an object running on a different machine!
  - You didn't see the code, but the client request was
    - Turned into a message using serialization
    - Sent over HTTP to the service machine
    - Unpacked and then the service method was called
    - Response was serialized back into another message
    - It was sent back to the client machine
- Your client program acted like a web browser!

What happened

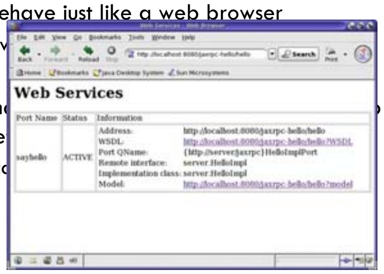
8



Web Browser????

9

- In fact these solutions literally make your client program behave just like a web browser
  - You can ev
- And they m site, comple
  - And you c



How can an object become a web page?

10

- A web page is just an HTML description of how that page should look
  - HTML is the famous markup language invented by Tim Berners-Lee, a researcher at CERN
  - HTML is actually a "dialect" of XML but we don't need to go there
- Web services use special HTML pages to send requests and make sense of replies

Java serialization

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- Java has a built in way of taking data in an object and "writing it down" in text format
  - The result looks like a web page
  - It describes the data including types
- Idea is that we can serialize an object, put it into a message, send it to the web service, and get a result
  - Serialized objects are often rather large but the format is extremely general

Magic distributed computing!

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- You can write an object oriented application now but instead of all the objects being on one machine
  - Put them any place you like!
- An object becomes a bit like a web page
- If you know how to find it, you can ask it to do stuff!
  - But must pass arguments by "value", not "reference"

Gotcha's

13

- Reasoning about distributed state is tricky
- Example: the "muddy children" puzzle (Halpern)


"You know the rules! No dessert if you have a muddy face when you come to the dinner table!"

Assumptions

14

- Children don't know if their own faces are muddy… and no child likes to wash his/her face!
- But in fact *every child is muddy*
- Mom repeats herself again and again.
  - Danny reasons: Unless I'm certain my face is muddy, I won't move. But Julia is in BIG trouble! Hee hee hee…
  - Danny (and Julia) don't get dessert

Variation on problem

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- Same setup but Mom says one more thing: "I see some muddy faces here"
- Then reminds the *n* children *n* times.
  - On n'th repetition, all the children jump up and wash their faces!
- How did they deduce that their faces were dirty?
  - …. You guessed it! **Induction!**

Base case?

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- Danny is all alone
- Mom says "I see a muddy face here. Better wash up if that face is yours!"
  - (Danny thinks: *I'm the only kid here)*
  - (gulp). "Yes Mommy. I'll do it right now."

N=2

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- Danny and Julia have muddy faces
- Mom says: "I see a muddy face here. Better wash up if that face is yours!"
  - Danny: *Julia's face is muddy. She's in big trouble!*
  - Julia: *Danny's face is muddy. He won't get dessert!*
    - *… no neither moves*
- *Mom repeats:* "Better wash up if that face is yours!"
  - Danny: *Julia didn't move the first time. If my face had been clean, she would have realized her's was muddy. Ergo my face is muddy!"*
  - Julia reasons identically. Both wash up

N=3

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- Peter (who hopes his face is clean) looks at Danny, and thinks
  - *"Danny, who also hopes his face is clean, will be looking at my clean face… and at Julia's muddy face and thinking…*
    - *"I see that Danny and Peter have clean faces. Sure home mine is clean too!"*
    - But Julia will realize that Mom's comment ("I see muddy faces") proves that this can't be true
    - Ergo Julia's face is muddy
- Each kid figures this out in round 3.

N large

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- Assume that the result holds for N-1 children
  - They would all wash their faces on the N-1'st round
- N'th child joins the group
- Can express the same logic we used to reduce from 2 to 1, but now it gets us from N to N-1
- Children all wash up on the N'th round!

Reasoning about distributed systems

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- Our example reveals that
  - In some ways, these are like other systems. For example, induction is a powerful tool
  - But in other ways they are different
    - Consider Mom. She said "I see some muddy faces" and this somehow made a difference
    - Yet with N>1, children looking around the room could see that *every other child had a muddy face!*
    - So what did Mom tell them that they didn't already know?
- Relates to idea of a "chain of knowledge"
  - She gave them "common knowledge" that someone is muddy

Distributed systems are hard!

21

- Same "problem" posed slightly differently was impossible in one situation, easy in the other
- And issues like this arise all the time
  - In connection to security… privacy… fault-tolerance… consistency

Networking… vs Distributed Computing

22

- A "networked" application is one that talks to some resources on some other machine
  - Like a file or a web page
  - Network applications *make no promises.*
- We're used to this "model" and know about its quirks
  - You often get timeouts
  - Sometimes your order is dropped, or goes in twice

Distributed Computing

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- Some applications (like medical ones) need stronger guarantees:
  - Need to know who the client is
  - And need to "trust" the service
  - May need to protect data against intruders
  - Might want to ensure that the service will be operational even if a crash occurs
- These turn the problem into "distributed computing"

Promises, promises…

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- A distributed system makes promises!
  - …. I promise to behave like a non-distributed service that never fails
  - …. I promise you'll never notice effects of concurrency
  - …. I won't reveal data to the wrong people. Really!
  - …. Even evil-doers won't stop me from doing the right thing, all the time

Example problem

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- A hospital has five servers
  - They hold medical record “objects”
  - And we want fault-tolerance
- You write an application to let a doctor enter a new medication order
  - “Put this patient on 2 units of Caldolor per hour”
  - Need to update the servers
- What if something crashes?

Leads to the idea of a “transaction”

26

- Idea dates to early work on databases
  - Key concept is that either the operation is done to completion, or it fails and does nothing at all
  - A transaction, by definition, must be
    - **atomic**,
    - **consistent**,
    - **isolated**, and
    - **durable**

- How can a client perform an ACID update?

Two-phase commit

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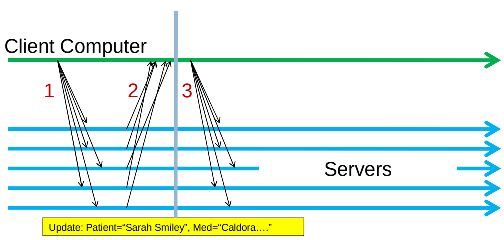
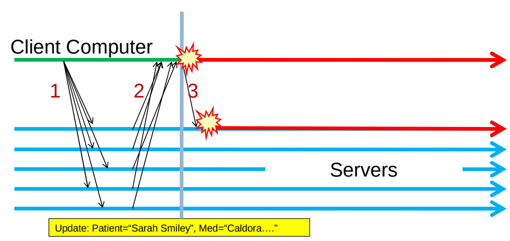


- Idea is to have a “prepare” phase (1, 2) and then a “commit or abort” phase (3)

Problem with two-phase commit

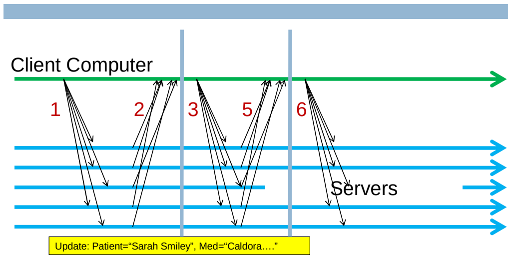
28

- Suppose the client and one machine crash
  - But client had just enough time to send *one* stage-3 msg
- The remainder of the servers might be wedged!



Three-phase commit

29



- With three phase commit can fault-tolerantly do an ACID update… IF failures are detectable

But in general, failures aren’t accurately discoverable

30

- It can be shown that any networked system in which crashes can’t be “accurately” detected can wedge!
  - Network outage can mimic a machine crashing
  - But famous proof (“Fischer, Lynch and Patterson”) shows that in any system where we need to respect what a faulty node thought was true will sometimes hang
- There is a way to evade this “FLP” impossibility result and it relates back to our muddy-kids example
  - Mom needs to tell us which machines failed
  - More generally, we need an “accurate source of knowledge” about crashes

Distributed computing toolkits

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- Because these problems do get complicated, one area of research is concerned with
  - Solving them well, just once
  - Coding solution as a library that others can use
  - Developers trust the library
- Library can offer fancier functionality
  - Like Mom's Magic Failure Detector!

Fancier problems

32

- These are just two examples from a very interesting research area
  - There are other ways to solve these problems
  - Extending notions of correctness to work with fault-tolerance and concurrency can be a challenge
  - Some researchers argue for solutions that can even guarantee correct behavior under attack!
    - For example, if some service is corrupted and "lies"

Distributed Systems Summary

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- Basic idea is to treat computers as "homes" where "objects" live
  - Then can do method invocation on objects just by having a URL for them, like a web page
  - But this only yields "networked" applications
  - Biggest issue is that failures are hard to pin down
- Stronger guarantees require "distributed computing" solutions, and get tricky, but can promise things like security, fault-tolerance, consistency…
  - Learn more in classes like cs5410, cs5310, cs6410

CLOUD COMPUTING

Lecture 26 – CS2110 – Fall 2009

Cloud Computing

35

- Last time we talked about distributed computing
  - Basically, the technology of the Web
  - We use it all the time
- But what happens when these systems get very big?
  - The world has a *lot* of people in it
  - … and plenty use Facebook

Cloud Computing concept

36

- What if we start to offload things from personal computers into the web?
  - Email becomes gmail, hotmail, …
  - Files can be shared: Flickr, Picassa, …
  - Online tools for creating documents: OpenOffice, ….
  - Potentially: put the whole world online

How much data?

37

- Telephone call: 56kbits/second or less
- Photo: 1 few megabytes
- DVD download: 600-700 Mbytes
- 11.5 Billion web pages in 2005, probably 30 Billion today
- Add to this "sensors" such as satellites, surveillance cameras, weather monitors, etc
- Adds up to a whole bunch of data, all of it online

Search

38

- In addition to "hosting" content, cloud systems need to be able to find what you want
  - "That adorable picture of Johnny when he tried to blow out the birthday candles and fell into the cake"
  - "Grateful Dead Live at Fillmore East on 1970-09-19"
  - "Index to coffee shops in Amsterdam"
  - "Best restaurant in Trumansburg New York"

Key elements to the cloud

39

- Huge amounts of data stored
- Indexed "offline" for fast retrieval
  - Basic idea is to associate vector of terms with object
  - For each set of terms, pre-compute the best objects
  - The more pages point to something, the more likely that something is to be what you want
  - But many, many refinements on this
- Many saw this opportunity but Google was first to do a really good job of answering queries

Cloud computing is big business

40

- Fastest sector for growth in the industry right now
  - Cloud computing systems are BIG
    - **One** Microsoft data center is 12x the size of a football field
    - Entirely packed with "containers" full of computers
    - Built near a dam: Power from next door
    - In a cool place: Not air conditioned; just uses outside air
  - A single system like this may have more horsepower than all the worlds supercomputers combined!

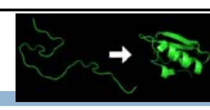
Clouds in Science

41

- Cloud computing is revolutionizing scientific research in many fields
  - Collect vast amounts of data
  - Pose questions about "reality" rather than needing to develop abstract models…

…. a new paradigm!

Examples: Folding



42

- Protein folding problem is computationally very hard and probably not really solvable
- But the physical world knows how to fold a protein and does it all the time.
- Could we somehow create software that uses a database of protein folding examples?
  - Software would take a protein as input
  - Then look for "familiar patterns" within it and see how those folded in the database

Examples: Smart drugs

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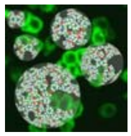
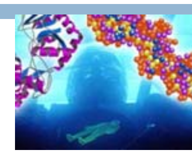
- Smart drug design
  - Given a target, like a virus, design a drug that can attack that target
  - Do it by looking for “matching shapes” in a massive collection of real-world data



Examples: Digital Human

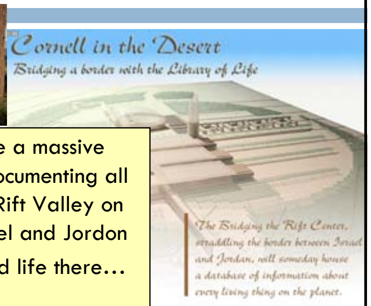
44



- This project is at the Univ. of Michigan
  - Goal: create a digital simulator for a human being
  - Use it for virtual medical experiments, practicing surgery, understanding the human body

Examples: Bridging the Rift

45



- A project to create a massive “library of life” documenting all the species in the Rift Valley on the border of Israel and Jordon
- Seek to understand life there… and relationships

Examples: Search for Asteroids

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- Cornell is using Arecibo radio telescope to capture massive numbers of sky images
- Then writing software to search those images for asteroids (they occlude background stars)
  - Goal is to learn about our solar system
  - And maybe also learn about threats to the planet so that Bruce can save us…

Examples: Global Warming

47

- Researchers agree that something is definitely happening (this is *not* disputed at all)
- Less clear precisely why. Or what it implies
- Goal: Capture huge amount of data about climate that can be studied directly

Challenges of “big data”

48

- It has become much easier to collect data than to make sense of it
  - We’re drowning in the stuff!
  - So the huge challenge is now to build tools that let us understand what we’re seeing
- Much of Cloud Computing seems to focus on “silly” social applications like Twitter… but the bigger issues are universal and fascinating

Where's Waldo?

49

- When you access a file, like
  - http://en.wikipedia.org/wiki/World_Wide_Web
- … how does your request get to a server?
- A cloud system has lots of computers sitting at the internet address "http://en.wikipedia.org"
  - In fact it may even have more than one data center!
- Requests are "load balanced" over the machines

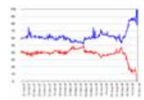
Social Network Research

Corporate Email

50

- The cloud captures evidence of the way society is organized
- We can study this to learn things
  - Like how the flu spreads ("Google Flu")
  - Or how your circle of friends impacts your likelihood of quitting smoking
  - Or who to treat if you want to eliminate TB but don't have infinite resources
  - How new products are adopted
- Spring Course (fantastic!): CS 2850 - Networks

High-School Dating



Using markets to predict the winners of elections

Trails of Flikr Users in Manhattan

Clouds: Pro and Con

51

- Cloud computing could give us anytime, anywhere access to all our stuff
  - No need to carry a heavy PC
  - Just take your phone and talk to it… they can convert voice to a query and fetch what you need!
- A personal butler with perfect memory

- But search engines can't fetch what they haven't seen

Clouds: Pro and Con

52

- A personal butler with perfect memory…
  - Including stuff you might wish to forget
  - And stuff you didn't think it knew, like that your aunt Hilda died of a heart attack, and uncle Fred went insane
  - Employers and insurance companies are using this kind of data already and may do it more in the future!
  - Some employers don't like gay employees, or people who have had abortions, or who donate to PETA
- On the web, *everything* is public and permanent

Hey, I have a right to privacy!

53

- Really?
  - You do have a right to freedom from "search and seizure" and also to not "incriminate yourself"
  - But where does it say that you have a right to take down the Facebook pictures from Spring Break?
    - And even if you take them down… did Facebook keep copies?
- This is the core issue!
  - Technology is moving way faster than the law
  - Lessig: "East Code versus West Code"

Right now: A mess

54

- I don't have a right to spy on you with a parabolic microphone, but I do have a right to take pictures with a telephoto lens
- It isn't legal to tape a telephone conversation, but if I leave a message on your Android phone, it IS legal for Google to create a transcript. And index it.
- It isn't legal to download music from free services but people do it a lot

Googled

55

- One real worry is that free search could wipe out entire industries
  - Right now this seems farfetched, like believing that global warming could melt the ice at the poles
  - Yet newspapers are failing left and right, the music and film industries are making fewer films, small bookstores are going under
- The world changes. But does it necessarily get better?

Googled

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- What about bad data?
  - E.g., if someone lies about you on the web
- And who's responsible?
  - For much of a week, Google images pulled up a racist image of Michelle Obama
    - They wouldn't take it down, pointing out that it wasn't on their web site… yet their web "images" search would find it and display it in thumbnail
    - Also asserted right of "Hot Girls.com" to free speech
  - Who was insulting the First Lady? Google? "Hot Girls.com"?
- What if an image search runs into child pornography:
  - Does this make you "guilty" of downloading child porno images?

Googled

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- Google tools are free, right?
  - Actually, you are "selling them your data"
  - And they provide services in exchange
- They also place advertising, very selectively





Building a "mission critical cloud"

58

- The cloud works well for search, and saves money
  - By some metrics, cloud computing is 10x cheaper than computing with private computers in your office
  - So naturally there is a trend to shift medical records, banking, other "critical" things to the cloud
- Can we make the cloud secure and reliable enough?
  - A challenge that may require a mixture of laws and technology…

Building a "mission critical cloud"

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- Examples of research issues:
  - Once data is in the cloud, how confident can we be that it won't "rot"?
  - Are cloud platforms at risk of viruses?
  - What if a big cloud company goes bankrupt?
  - If we "depend" on cloud systems, who is at fault if one of them has a bug
    - E.g. if a doctor makes a mistake because she saw erroneous data
    - Or if Wall Street stampedes and wipes out a company because its financial state was inaccurately reported?
- The list really goes on and on!

The Future is Coming…

60

- A future without secrets…. And someday, other people will be in charge at Google, Microsoft, Yahoo
- What if we have a new McCarthy era?
- Could Google figure out your deepest thoughts?
- Could organized criminals "data mine" Google?
- What about insider trading based on "snooping" digital data from people who are naïve?

So what can I do?

- Don't "opt out"… opt in but be an activist
  - Impossible to just walk away from a societal trend
- We need to find ways to push back
  - Change the laws. Cloud computing is bound by law.
  - Help others understand the issues
  - And build better computing systems!
    - CS and IS courses can help you learn how…

CS courses to consider

- CS 2850 - Networks
- CS 3110 – Functional Programming
- CS 3410 – Computer Architecture
- CS 4700 – Artificial Intelligence
- Helps to think in terms of "areas"
  - Systems (databases, operating systems, cloud)
  - Programming Languages
  - Machine learning, NLP, AI
  - Scientific computing
  - Graphics, computer vision

Computer Science "tree"