95-702 Distributed Systems

Instructors: Michael McCarthy, Joe Mertz, Marty Barrett

Week 1: Five (optional, dated) videos are also available
Today’s Learning Goals

• Introduce course administration
• Introduce Distributed Systems
Course Web Sites

- [http://www.andrew.cmu.edu/course/95-702/](http://www.andrew.cmu.edu/course/95-702/)
  - read the syllabus
  - read the course description
  - read the weekly schedule
    * project descriptions are posted there
    * lecture slides are posted there
    * project rubric is posted there

- Canvas:
  - grade postings
  - assignment submissions

- Piazza:
  - discussion board
What cool technologies will we use?

- IDE (Netbeans)
- Application Server (Glassfish)
- Web Services (REST, SOAP, Various API’s including Bitcoin’s Blockchain API)
- Message Oriented Middleware (Sun’s JMS Message Queue)
- Distributed Objects (Java RMI, and EJB’s)
- Mobile platform (Android)
- Hadoop and MapReduce (Linux on Amazon or Heinz cluster)
First Lab - This Week

• The first lab will cover instructions on getting started with the course technologies.
• The installation includes Netbeans and Glassfish.
• You earn points for labs.
• This first lab will be for credit.
• Project 1 will be assigned next Friday.
Structure of the Course

- Lectures will often include class time for activities/quizzes
- Labs (with your active hands-on involvement)
- Several in class quizzes
- Projects (programming) The secret is to start early.

- Midterms (2)
- Final examination
Readings

- See the schedule. Readings from the required text are assigned for each lecture -- read them in advance.
- Readings from the web will also be assigned.
- For this week, read Coulouris chapters 1 and 2.
- Read the article on the schedule on Cloudlets.
- Review Secret Lives of Data – Raft Understandable Distributed Consensus
Grading Weights

- Programming Projects (6) 36%
- Midterm 1 10%
- Midterm 2 12%
- Final Exam 25%
- Labs (12) 12%
- In class activities (no make ups allowed) 5%
- Canvas quizzes for practice 0%
- We will be very fussy about deadlines. One second late is late. See late assignment policy on syllabus.
- You have 7 grace days you can use to turn in projects late with no penalty
Review of Syllabus

• In class quizzes (no make ups)
• Late projects, you have seven days to spend. After that -10% per day.
• Projects are not treated the same as labs. Projects must be completed individually.
• Labs allow for team work and help from TA.
• Attendance at your lab is worth .25 points.
• Completion (before your next lecture) of the lab is worth .75 points.
• Closed laptop/device policy
• Do not cheat, R grade is immediate. Don’t share code with each other - we check! Don’t copy code from or post code to external servers (e.g. GitHub) – we check.
• Use the discussion board
• PLEASE: Easy on the email
• If serious problem, contact us via email or phone (we will help)
• TA’s guide you but do not solve problems for you
• Exams take precedence over job interviews and travel
• Complaints about grading, see the rubric & the TA within one week

Master of Information System Management
How does program logic share data or communicate?

- Shared files
  - COBOL 2 COBOL
- Shared database
  - DB2 Mainframe
- Procedure Call or Method Invocation
  - Programming 101
- Messaging through a third party
  - Unix or DOS pipes

Non-distributed

Distributed/Networked

NFS, AFS, HDFS

OData

RPC, Java RMI, Web Apps/Services

Email, WhatsApp, JMS, Enterprise Service Bus
Fundamental characterization of distributed systems

• Components are located on networked computers and execute concurrently.
• Components communicate and coordinate only by passing messages.
• Time differs on each system.
• Typically, we have some goal in mind.
• Many challenges associated with distributed systems are not new...
The Pony Express

Challenges:
- heterogeneity
- geography
- security
- robbers
- reliability
- failures
- failure handling
- replication
- bandwidth
- letters/horse
- latency
- time to arrive

From Wikipedia 12
The Pony Express and The Telegraph

And one system may be replaced by another

Around 1860

Associated Press
Pioneer Plaque early 70’s

An attempt at communicating a universal message.

Challenges:
- reliability
- interoperability
would the arrow even make sense?
In School

Challenges:
- heterogeneity
- security
- teacher is of concern
- reliability
- failure handling
- bandwidth
- latency
At War

Challenges:
- heterogeneity
- security
- reliability
- failure handling
- bandwidth
- latency
- bandwidth

From Wikipedia
Last Example – State of the art

- Raft Consensus
- Goal: Get peers to agree in the presence of failures
- Ongaro, Diego; Ousterhout, John (2013). “In Search of an Understandable Consensus Algorithm”
- See: http://thesecretlivesofdata.com/raft/
What are some challenges in constructing computerized DS?

- All the challenges associated with stand alone systems development plus:
  - **Heterogeneity** of components may hinder interoperability
  - **Security** (Eve and Mallory on the wire)
  - **Scalability** (we may need to ramp up by adding resources)
  - **Failure handling** (networks, processors, remote systems) **Independent Failure** of components
  - **Concurrency** of components adds complexity (e.g. several visits at once)
  - **Openness** (Can we build it so it’s easy to add to or modify the system)
What false assumptions may be made by designers?

• The network is secure.
• The network is synchronous – known bounds exist for message transfer and message processing.
• The network environment is homogeneous.
• Latency is zero.
• Bandwidth is infinite.
• Transport cost is zero.
• There is one administrator.
• The network is reliable.
• Components don’t fail independently.
Why build these things?

- To communicate and share resources.
- We want to share:
  Executable code – Javascript, MapReduce
  Data (Odata)
  CPU cycles (SETI search for aliens)
  Documents (The original WWW)
  Printers, Files (NFS, AFS)
  Objects (Java RMI, EJB’s, Enterprise Objects)
  Services in a Service Oriented Architecture
Key Issues - Chapter Two

Architecture
Architectural Elements of a Distributed System
   Communicating entities
   Communication Paradigms
   Roles played by communicating entities
   Placement of communicating entities
Architectural Patterns
Transparency
System Architecture

**Definition:** The architecture of a system is its structure in terms of separately specified components and their interrelationships.

**Goal:** The structure will meet present and future demands.

**Concerns:** reliability, manageability, adaptability, cost-effectiveness, security
Architectural Elements of a Distributed System

• Communicating entities
• Communication paradigms
• Roles played by communicating entities
• Placement of communication entities
Communicating Entities

• From a system level: Processes, threads or simply nodes are communicating.
• From a problem level: Objects, Components, Web Services are communicating.
• In asynchronous systems, the client makes a call and continues with other business. Perhaps it provides a means for a response.
• In synchronous systems, the client calls, blocks and waits for the response.
Architectural Elements of a Distributed System

• Communicating entities
• Communication paradigms
• Roles played by communicating entities
• Placement of communication entities
DS Communication Paradigms

**Coupling** is the degree to which some communicating entity makes assumptions about its partner. For example, the web is loosely coupled.

**Interprocess communication** (TCP Sockets, UDP Sockets, Multicast Sockets)
Low level. Often use to build higher level abstractions. Coupled in time.

**Remote invocation** (Two way exchange with a remote operation, procedure or method) RPC, RMI, HTTP, DCOM, CORBA. Higher level abstractions.

  - Coupled in time (both parties exist during interaction)
  - Coupled in space (parties likely know who they are interacting with)

**Indirect communication** (less tightly coupled and involving a third party)
Communicating to a group be sending a message to a group identifier
**Publish-subscribe** (AKA distributed event based systems) routes messages to interested parties. One-to-many style of communication.
**Message queues** (AKA channels) for point-to-point messaging.
**Tuple spaces** allows for the placement and withdrawal of structured sequences of data.
Architectural Elements of a Distributed System

• Communicating entities
• Communication paradigms
• Roles played by communicating entities
• Placement of communication entities
Roles and Responsibilities

• Entities interact to perform a useful activity.
• One entity may act as a client and another as a server.
  - Request/Response
  - Request/Acknowledge
  - Request/Acknowledge/Poll
  - Request/Acknowledge/Callback
• Each entity may act as a peer.
Architectural Elements of a Distributed System

- Communicating entities
- Communication paradigms
- Roles played by communicating entities
- Placement of communication entities
Placement of Communicating Entities

- Entities may be placed on a single or multiple machines.
- Data may be cached and services replicated. Why replicate?
- Mobile code (e.g. applets, Java Script).
- Mobile agents or worms.
Architectural Patterns (1)

A **Layered architecture** is the vertical organization of services into layers of abstraction:

* applications and services layered on the top.
* middleware appears between the application and the operating system.
* The operating system sits on top of the computer and network hardware.
Architectural Patterns (2)

A Tiered architecture:

- is complimentary to layering.
- is usually applied to the applications and services layer.
- is a technique to organize the functionality of a given layer and place this functionality into appropriate servers and onto physical devices.
- An application may be described in terms of presentation logic, business logic, and data logic.
- May partition an application into two tiers or three.
- Main driver: To promote separation of concerns.

Why is separation of concerns so important?

Note: presentation logic may present data to a non-human.
Architectural Patterns (3)

In a two-tier solution, the business logic and user interface may reside on the client and the data logic layer may be placed on the server. This is the classic client server architecture.

Other organizations are possible:

In a three-tier solution, the logical description may correspond directly to the physical machines and processes.

An AJAX application such as Google Maps is an example of a responsive multi-tiered application. New map tiles (256X256 pixel images) are fetched as needed.

The thin client approach is a trend in distributed computing. Move complexity into internet based services. Cloud computing and Virtual Network Computing (remote desktop) are examples.
Two commonly occurring architectural patterns in distributed systems

• The **proxy pattern**: the client makes calls on a local object (the proxy) that has the same interface as a remote object. The proxy hides the communication details.

• The **brokerage pattern** consists of a trio of service provider, service requestor and service broker (typically with lookup and bind operations). **In economics, how is a broker different from a dealer?**
Transparency

• Goal: To raise the level of abstraction by separation of concerns.
Transparency raises the level of abstraction

• Types of Transparency (think concealment)

*Access transparency*: enables local and remote resources to be accessed using identical operations.

*Location transparency*: enables resources to be accessed without knowledge of their location.

*Concurrency transparency*: enables several processes to operate concurrently using shared resources without interference between them.

*Replication transparency*: enables multiple instances of resources to be used to increase reliability and performance without knowledge of the replicas by users or application programmers.
Transparency to raises the level of abstraction

*Failure transparency:* enables the concealment of faults, allowing users and application programs to complete their tasks despite the failure of hardware or software components.

*Mobility transparency:* allows the movement of resources and clients within a system without affecting the operation of users or programs.

*Performance transparency:* allows the system to be reconfigured to improve performance as loads vary.

*Scaling transparency:* allows the system and applications to expand in scale without change to the system structure or the application algorithms.