Class announcements

- **Midterm Thursday!**
  - Study guide posted
Student Presentation

- Robert Gutowsky (news)
A system is decomposed into interacting subsystems.

Each subsystem may have a similar internal decomposition.
Three elements of architecture

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System examples

Let’s quickly look at some system decomposition examples

- Quick tour of information technology systems
Time sharing

ASCII terminal
(no graphics)

Point-to-point wire
(no network)

Mainframe
(database and application server)
Three-tier client/server

Client

Application server

Enterprise data server
System integration

Architecture

-> subsystem implementation

-> system integration

Bring together subsystems and make them cooperate properly to achieve desired system functionality

- Always requires testing
- May require modifications to architecture and/or subsystem implementation
Emergence

Subsystems are more specialized and simpler functionality
Higher-level system functionality arises from the interaction of subsystems

Emergence includes capabilities that arise purely from that interaction (desired or not)

- e.g. airplane flies, but subsystems can’t
Why system decomposition?

- Divide and conquer approach to containing complexity
- Reuse
- Consonant with industry structure (unless system is to be supplied by one company)
- Others?
Networked computing infrastructure

by

David G. Messerschmitt
Layering

Elaboration or specialization

Services

Existing layers
Example of Layering: networking

- Application
  - Messages
  - Transport
    - Packets
    - Network
      - Frames
      - Link
        - Bits
        - Physical
          - Signals
Software Layering

- Application
- Middleware
- Operating System
Operating system functions

- Graphical user interface (client only)
- Hide details of equipment from the application
- Multitasking
- Resource management
  - Processing, memory, storage, etc
- etc
Middleware Functions

- **Capabilities that can be shared by many applications, but that is not part of OS**
  - Example: Database Management System (DBMS)

- **Hide details of OS from application**
  - Java Virtual Machine

- **More purposes we’ll talk about later.**
What's a database?

Database

- File with specified structure
- Example: relational table
## A Database

<table>
<thead>
<tr>
<th>Year</th>
<th>City</th>
<th>Accommodation</th>
<th>Tourists</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>Oakley</td>
<td>Bed&amp;Breakfast</td>
<td>14</td>
</tr>
<tr>
<td>2002</td>
<td>Oakley</td>
<td>Resort</td>
<td>190</td>
</tr>
<tr>
<td>2002</td>
<td>Oakland</td>
<td>Bed&amp;Breakfast</td>
<td>340</td>
</tr>
<tr>
<td>2002</td>
<td>Oakland</td>
<td>Resort</td>
<td>230</td>
</tr>
<tr>
<td>2002</td>
<td>Berkeley</td>
<td>Camping</td>
<td>120000</td>
</tr>
<tr>
<td>2002</td>
<td>Berkeley</td>
<td>Bed&amp;Breakfast</td>
<td>3450</td>
</tr>
<tr>
<td>2002</td>
<td>Berkeley</td>
<td>Resort</td>
<td>390800</td>
</tr>
<tr>
<td>2002</td>
<td>Albany</td>
<td>Camping</td>
<td>8790</td>
</tr>
<tr>
<td>2002</td>
<td>Albany</td>
<td>Bed&amp;Breakfast</td>
<td>3240</td>
</tr>
<tr>
<td>2003</td>
<td>Oakley</td>
<td>Bed&amp;Breakfast</td>
<td>55</td>
</tr>
<tr>
<td>2003</td>
<td>Oakley</td>
<td>Resort</td>
<td>320</td>
</tr>
<tr>
<td>2003</td>
<td>Oakland</td>
<td>Bed&amp;Breakfast</td>
<td>280</td>
</tr>
<tr>
<td>2003</td>
<td>Oakland</td>
<td>Resort</td>
<td>210</td>
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<td>Camping</td>
<td>115800</td>
</tr>
<tr>
<td>2003</td>
<td>Berkeley</td>
<td>Bed&amp;Breakfast</td>
<td>4560</td>
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<tr>
<td>2003</td>
<td>Berkeley</td>
<td>Resort</td>
<td>419000</td>
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<tr>
<td>2003</td>
<td>Albany</td>
<td>Camping</td>
<td>7650</td>
</tr>
<tr>
<td>2003</td>
<td>Albany</td>
<td>Bed&amp;Breakfast</td>
<td>6750</td>
</tr>
</tbody>
</table>
Storage Middleware example: DBMS

- Database Management System (DBMS)
  - Manage Multiple databases
  - Allow multiple applications to access common databases
  - Implement standard data “lookup” (query) functions.
The Internet

by

David G. Messerschmitt
What is the Internet?

- **An internet** is a “network of networks”
  - Interconnect standard for LAN’s, MAN’s, and WAN’s
- **Internet** = the major global internet
- A private internet is called an **intranet**
- An **extranet** is an interconnection of intranets through the Internet
Intranet

Private internet

Often connected to Internet

- Firewall creates a protected enclave
Extranet

An Extranet is composed of

- Intranets connected through an unprotected domain (typically the Internet)

- Encryption and other security technologies used to
  - protect proprietary information
  - prevent imposters, vandals, etc
Client - Server Computing
Client Server Example

Client

“I want to see www.google.com”

Server

<html><head>
<meta http-equiv="content-type" content="text/html; charset=UTF-8">
<title>Google</title>
<style><!--
body,td,a,p,.h{font-family:arial,sans-serif;}
.h{font-size: 20px;}
.q{color:#0000cc;}
//-->

-->

...
3-Tier Client Server Architecture example

Client

Clicks, keystrokes

Application Server

What is Bob’s balance?

Shared data

Client Balance $0.50

Bank of America | Online Banking | Accounts Overview

$0.50

What is Bob’s balance?
3-Tier Client Server Architecture example

Client

Application Server

Web Server

Common Gateway Interchange

Application Logic

Shared data
3-Tier Client Server Architecture example

Client

Application Server

Web Server

Common Gateway Interchange

Application Logic

What is Bob’s Balance?

Database Management System (DBMS)

What is Bob’s Balance?

Database

Shared data
3-Tier Client Server Architecture example

Client

Application Server

Web Server

Java Servlet

Application Logic

Database Management System (DBMS)

Database

What is Bob’s Balance?

In some implementations Application Logic and Web Server can be put on Different machines.
<table>
<thead>
<tr>
<th>Customer</th>
<th>Balance</th>
<th>Customer Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alice</td>
<td>$527</td>
<td>Silver</td>
</tr>
<tr>
<td>Bob</td>
<td>$0.50</td>
<td>Bronze</td>
</tr>
<tr>
<td>Charles</td>
<td>$1000000</td>
<td>Gold</td>
</tr>
</tbody>
</table>

...
DBMS Responsibilities

- Hide Changes in the Database hardware from the Application

- Standard operations on the data, including searches, such a search is called a query.

- Separate Database Management from Applications, so that many applications can access the same data.

- Security, Integrity, Backup, fault tolerance, etc..
3-Tier Client Server Architecture in General

**Client**
- Accept instructions from user
- Make requests of server
- Display responses of server

**Application Server**
- Takes inputs from client
- Decides what to be done next
- Decides what shared data to access and manipulates it
- Processes shared data
- Support multiple applications with common data
- Protect critical data
- Decouple data administration and application administration

**Shared data**
Clients

Customers

Merchandise

Acquirer bank

Orders

Customer logic

Databases

Fulfillment logic

Book distributors

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Peer to peer

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Peer to Peer

- What is peer to peer good for?
Sun Case
Sun N-tier case

- What does Sun make?
  - Workstations
  - Servers
  - Software
How Successful had Sun been up to 1998?

- Founded in 1982
- Open Standards Workstation
  - Unix Operating System (Solaris)
  - TCP/IP networking
- 1988 - Revenues $1 billion
- 1993 - Market value $3.0 billion
- 1997 - Jumped from 3rd to 1st in Unix Server Market.
How Successful had Sun been up to 1998?

- 1993 - “The network is the computer.”
- 1994 - Internet explodes in popularity
Microsoft mid to late 90s

- Dominated Desktop software
  - Users familiar with Windows, Office, etc.

- NT servers
  - Fine for small intranets, “not industrial strength”
Sun N-Tier Case

What is Java?

- Programming Language
- Portable between computers with different operating systems
- Easy to write programs in
- Easier re-use
- But, programs are slow
What problems did the micro era produce?

- Desktops are expensive to maintain
  - TCO for windows PC $9900!

- Every PC had a lot of software that had to be maintained
  - Office, Windows, etc...

- Small differences, like the order in which software is installed, could make different PCs behave differently!
In the Networking Era

- These “bloated” PCs are networked and termed *fat clients*.
- But networking of PCs offered the possibility of
  - putting most of the functionality into servers
  - *Getting rid of much of the software on the client*
  - These clients would be called *thin clients*.
- Sun, Oracle, and others saw it as the future.
Hardware for thin clients

- A **Network Computer** (NC) - a computer with minimal hardware that depends on a network connection to a server to function
  - Be careful not to confuse it with the phrase “networked computer!”
  - Example: Sun’s JavaStation (1996-2000)
  - It is the hardware one would use to implement a *thin-client* computing model.
Another term from that era..

- A **NetPC** was a PC introduced by Microsoft and Intel in 1996
  - Same software as a normal PC
  - Did not allow users to install their own software
  - NetPC died out
  - Features of it, and Microsoft’s Zero Administration Kit, live on in today’s version of windows.
Microsoft Vision

- Keep “fat-client” model
- Add some features to Windows to reduce administration costs
Sun’s Vision

- Thin Client model.
- Application Servers with Applications written in Java.
- NCs could retrieve applications from application server as needed.
- Applications compatible with any NC hardware and OS.
- Applications could be fixed, added, updated at the server level, rather than maintaining each PC.
SUN 3 - Tier

Exhibit 1 Three-tier Architecture

Tier Three

Tier Two

Tier One

Asia

United States

Europe

Applets
App Server

Database

Applets
App Server

Client Applets
Client Hardware

HTTP

RMI

JDBC: Stands for Java Database Connectivity. It is a programming interface that lets Java applications access a database via the SQL language. RMI: Stands for Remote Method Invocation. It is the method by which a remote Java object from one location can be invoked from other Java virtual machines. HTTP: Stands for HyperText Transport Protocol. It is the communications protocol used to connect to servers on the World Wide Web.
Sun N-tier

Tier Four

Tier Three

Tier Two

Tier One

Asia

United States

Europe

client

Client

Webtop Server

Webtop Server

App Server

database

app server talks to central database

1st time applet sent

1st time, applet sent

High latency servlet talks back & forth

applet cached

If bug found, change code here. Next time, corrected applet is sent down

1st time Servlet sent
Sun N-Tier

Step 1: The user logs into his client and calls down an application. This message is sent to the Application Server.

Step 2: An initial applet is sent to the client. At the same time a servlet is sent to the Webtop Server.

Step 3: The applet talks back and forth with the Webtop Server via the LAN.

Step 4: As new data is received (i.e., a new customer's name) the App Server communicates with the database to update that information.

Local: The Webtop Server and client communicate via a LAN.

Remote: The database and App Server communicate with the Webtop Server via a WAN.

Exhibit 3 How the N-tier Architecture Works
### Sun's Performance

<table>
<thead>
<tr>
<th>Year</th>
<th>Net Income</th>
</tr>
</thead>
<tbody>
<tr>
<td>1994</td>
<td>355.8</td>
</tr>
<tr>
<td>1995</td>
<td>476.4</td>
</tr>
<tr>
<td>1996</td>
<td>762.4</td>
</tr>
<tr>
<td>1997</td>
<td>762.9</td>
</tr>
<tr>
<td>1998</td>
<td>1,031.3</td>
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<tr>
<td>1999</td>
<td>1,854.0</td>
</tr>
<tr>
<td>2000</td>
<td>927.0</td>
</tr>
<tr>
<td>2001</td>
<td>(587.0)</td>
</tr>
<tr>
<td>2002</td>
<td>(3,429.0)</td>
</tr>
<tr>
<td>2003</td>
<td>(388.0)</td>
</tr>
<tr>
<td>2004</td>
<td>(106.0)</td>
</tr>
</tbody>
</table>
Today

- 3-tier model common.
- Sun’s version of 4-tier model not-common.
- N-tier model where Webserver and Application Server on separate equipment also common.
- Sun’s hardware business not strong.
  - Linux on cheap PCs most common servers
  - Microsoft desktops replacing Sun workstations
Today

- **Java**
  - Common in Server implementations
    - Example: Java Servlet implementing application logic in a banking application.
  - Often used to push simple applets onto client
  - Not common
    - For “big” desktop applications
    - Office Suite in Java not popular
  - **Microsoft is still in business...**