Class announcements

- Midterm Tuesday!
  - Study guide to be posted soon.
Student Presentation
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>
</tr>
<tr>
<td>2003</td>
<td>Berkeley</td>
<td>Camping</td>
<td>115800</td>
</tr>
<tr>
<td>2003</td>
<td>Berkeley</td>
<td>Bed&amp;Breakfast</td>
<td>4560</td>
</tr>
<tr>
<td>2003</td>
<td>Berkeley</td>
<td>Resort</td>
<td>419000</td>
</tr>
<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
Intranet

**Private** internet

Often connected to Internet

- **Firewall** creates a protected enclave

Global Internet

Router

Firewall
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
Communication between intranets encrypted.
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
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>
</head>
<body>
<!--
body,td,a,p,.h{font-family:arial,sans-serif;}
.h{font-size: 20px;}
.q{color:#0000cc;}
//--> ...
```
Client Server Example - Layers Revealed

Client

Application:

Server

Application

Internet

Infrastructure

Packet

Packet

Packet

Packet
3-Tier Client Server Architecture example

Client

Application Server

Clicks, keystrokes

What is Bob’s balance?

$0.50

Shared data

$0.50

Balances Overview

Bank of America | Online Banking | Accounts Overview

<meta name="Description" content="Bank of America Online Banking - Accounts Overview">

<link rel="stylesheet" type="text/css" href="/eas-docs/images/win_ie.css"/>

<script language="JavaScript" type="text/javascript" src="/eas-docs/ias_js/scripts.js"></script>

function hover(ref, classRef) { eval(ref.className = classRef); }//-->

<script language="JavaScript" type="text/javascript">

"I want to..."

View my account details
Pay a bill from Bank of America or transfer funds between accounts
Pay an automatic bill using Bill Pay'

Customer

Announcements

Account Settings

Bank Account

Checking

Stop m

Open an A

The Balance

Savings Account

Regular Savings Account

Transfer funds between accounts

Pay an automatic bill using Bill Pay"
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
  - Database Management System (DBMS)
  - Database

**Shared data**

**Questions:**
- What is Bob’s Balance?
3-Tier Client Server Architecture example

In some implementations, Application Logic and Web Server can be put on different machines.
### Relational Database

<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
- Takes inputs from client
- Decides what to be done next
- Decides what shared data to access and manipulates it
- Processes shared data
- Accept instructions from user
- Make requests of server
- Display responses of server

Application Server
- Support multiple applications with common data
- Protect critical data
- Decouple data administration and application administration

Shared data
Financial institution

Book distribution centers

Customers

books4u.com

Consumer

Enterprise

Inter-enterprise

Slide adapted from slides for *Understanding Networked Applications*
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Peer to peer

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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”
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.
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 One
- Client

Tier Two
- Webtop Server
  - 1st time, applet sent
    - App Server
      - database
        - app server talks to central database

Tier Three
- High latency
  - servlet talks back & forth
    - App Server
      - if bug found, change code here. Next time, corrected applet is sent down

Tier Four
- Client
- Client

Asia

United States

Europe
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.

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

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

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>
</tr>
<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...