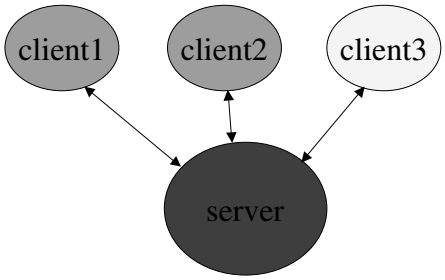
Systems Architecture

Client-Server Systems

Client/Server

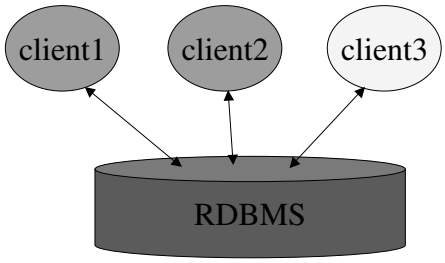
- In general, any application where multiple clients connect to a single server.



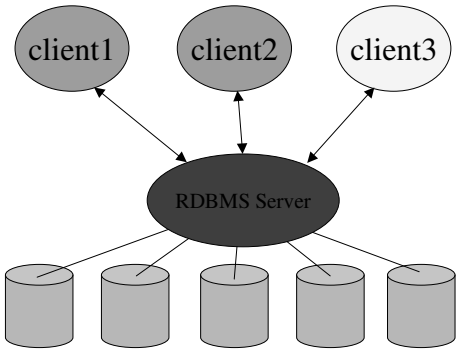
- one client program (most typical)
  or
- multiple client programs

Relational Databases

- Most common client/server program is where the server is a relational database server.
  - warning: some use the term client/server to refer to this usage exclusively (we won't).



Relation Database Implementation



disks

IPC

- "Inter-Process Communications"
  - How processes will communicate and synchronize with one-another.
  - communications mechanisms:
    - shared memory
      - very fast
      - can't use over a network
        - » well, you can
    - message passing
      - can use over a network
      - slower
        - » well, not always
  - will consider only message passing (most important)

IPC Protocols

- Basic message-passing mechanisms provide for a byte-stream only.
- Must implement various protocols on top of this
  - sockets
  - RPC (remote procedure call)
  - DO (distributed objects)

Sockets code example

```
public class Server {
    public static void main(String[] args) throws Exception {
        ServerSocket server = new ServerSocket(1234);
        Socket client = server.accept();
        BufferedReader fromClient = new BufferedReader(
                 new InputStreamReader(client.getInputStream()));
        System.out.println(fromClient.readLine());
    }
}


public class Client {
    public static void main(String[] args) throws Exception {
        Socket server = new Socket("penny", 1234);
        DataOutputStream toServer = new DataOutputStream(
                 server.getOutputStream());
        toServer.writeBytes("hello server");
         server.close();
    }
}
```


Performance

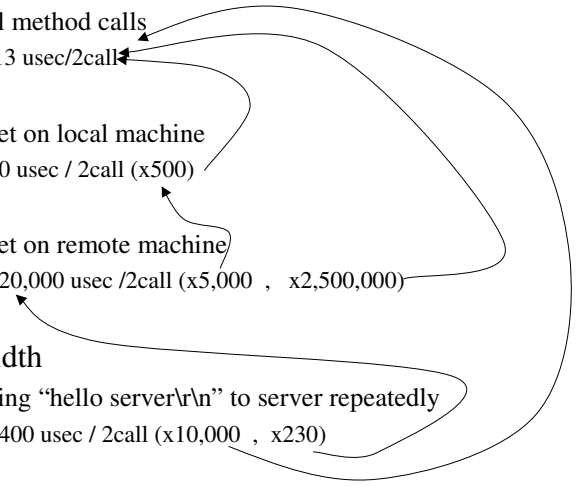
- Latency
  - The time to go back and forth
- Bandwidth
  - The amount of data that can be sent
- Analogy from ocean lines
  - Bandwidth of QE2 is high (can carry a lot)
  - Latency is bad (takes a long time for a round trip).

Test System

- Windows 2000 Java Server
  - Network
    - 100 Mbit/s ethernet
  - CPU
    - dual 1GHz processors
  - Memory
    - 1 GByte
- Windows 98 Java Client
  - Network
    - 100 Mbit/s ethernet
  - CPU
    - 366 MHz
  - Memory
    - 96 MByte

Java/Windows Performance Measures

- Latency: Sending "hello server\r\n" back and forth
  - Local method calls
    - .13 usec/2call
  - Socket on local machine
    - 70 usec / 2call (x500)
  - Socket on remote machine
    - 320,000 usec /2call (x5,000 , x2,500,000)
- Bandwidth
  - Sending "hello server\r\n" to server repeatedly
    - 1400 usec / 2call (x10,000 , x230)



Performance

	In Process	Network
Latency	1	2,500,000
Bandwidth	1	10,000

C/Windows Performance Measures

- Latency: Sending “hello server\r\n” back and forth
  - Local method calls
    - .01 usec/2call (10x Java)
  - Socket on local machine
    - 12 usec / 2call (6x Java)
  - Socket on remote machine
    - 840 usec /2call (380x Java)

Performance

	In Process	Network
Latency	1	84,000

Performance Implications

- Do as few calls as possible over the net
- Prefer asynchronous approaches
  - problem: success/failure indications
  - send lots of stuff, then synchronize
- Use bigger transactions
- Prefer one call with lots of data to many calls with the same amount of data
  - but not by much
- Send as little data as possible

Relational Databases

- Most common type of client/server software is where the server is an RDBMS server:
  - Oracle
  - SQLserver
  - Sybase
  - Informix

Database Access

- Access using SQL (Standard Query Language)
  - select itemname,quantity
    - from
      - orderitems,items
    - where
      - orderid = 239
        - » and
      - orderitems.itemid = items.itemid

"stored procedure" if this is parameterized and the whole thing is named

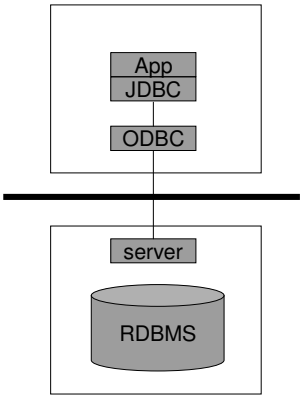
query result	
itemname	quantity
bread	2142
sugar	345

Programmatic Database Access

- Can access database by
  - typing commands at an sql command prompt
  - by running a GUI tool
  - programmatically
    - ODBC
      - Open Database Connectivity – Microsoft standard API
      - ANSI/ISO CLI is ODBC level1 compliant (Call Level Interface)
        - » (see also DAO, OLE DB and ADO)
    - JDBC
      - very similar to ODBC
    - Various embedded SQL hacks

JDBC

- All sorts of possible configurations of client-side & server-side drivers



Database Access from Java

```
import java.sql.*;
public class Main {
   private static final query =
       "select itemname,quantity " +
       "from orderitems,items " +
       "where orderid=1 and orderitems.itemid=items.itemid";

    public static void main(String[] args) throws Exception {
         Class.forName("sun.jdbc.odbc.JdbcOdbcDriver");
         Connection c = DriverManager.getConnection("jdbc:odbc:grocery");
         Statement s = c.createStatement();
         if( s.execute(query) ) {
             ResultSet r = s.getResultSet();
             printResults(r);
         }
    }

     private static void printResults(ResultSet r) throws Exception {
        final int nC = printHeadings(r);
        printRows(nC, r);
    }
    …
}
```


Database Access from Java

```
private static int printHeadings(ResultSet r)
        throws Exception {

    ResultSetMetaData m = r.getMetaData();
    final int nC = m.getColumnCount();
    for(int c = 1; c <= nC; c++) {
        System.out.print(m.getColumnName(c));
        System.out.print("\t");
    }
    System.out.println();
    return nC;
}
```

Database Access from Java

```
private static void printRows(int nC, ResultSet r)
        throws Exception {
    while( r.next() ) {
        for(int c = 1; c <= nC; c++) {
            System.out.print(r.getString(c));
            System.out.print("\t");
        }
        System.out.println();
    }
}
```


Without ODBC

```
Class.forName(
    "org.gjt.mm.mysql.Driver"
    );
```

```
Connection c = DriverManager.getConnection(
    "jdbc:mysql://penny.dhcp.cs.toronto.edu/grocery"
    );
```

Performance

- localhost
  - JDBC:ODBC
    - 850 us/query
  - JDBC:MYSQL
    - 500 us/query
- over network
  - JDBC:ODBC
    - 3,800 us/query
  - JDBC:MYSQL
    - 1,600 us/query
- local Java method call
  - 0.13 us/query
- C socket over network
  - 840 us/query

Data Compatibility

- Issue with any sort of system is how to support changes in data format from release to release of the software:
  - backwards compatible
    - newer releases of the software can open older datasets
  - forwards compatible
    - older releases of the software can open newer datasets
- General approach
  - have some sort of flexible header format
  - for backwards compatibility:
    - encode a current data version number
  - for forwards compatibility
    - store the oldest data version number such that
      - older software that uses that data version can still use this data

RDBMS Compatibility Advantages

- RDBMS's have 2 advantages w.r.t compatibility:
  - The data is not highly fragile.
    - e.g., in a binary file format, one small change somewhere can screw up the whole file
    - in SQL the schema can change considerable yet the data can still be accessed
  - RDBMSs support schema evolution
    - SQL
      - CREATE TABLE
      - MODIFY TABLE

      Can work on in-place databases

UpdateDatabase Code Example

```
private void updateDatabase() {
    int version = getDataVersion();
    if( version < 1 )
        die("DB consistency error: Version number must be 1 or greater");
    switch(version) {
        case 1:
            updateDatabaseToVersion2();
            // fall-through
        case 2:
            updateDatabaseToVersion3();
            // fall-through
        case 3:
            o.println("<Database is up-to-date>");
            break;
        default:
            die("Database was created with newer version of software");
            break;
    }
}
```

Update Database Code

```
private void updateDatabaseToVersion2() {
    o.println("<Converting database from version 1 to version 2>");
    try {
       sqlup("ALTER TABLE Coders ADD COLUMN w REAL");
       sqlup("UPDATE Coders SET w = 0.6");
       sqlup("UPDATE Version SET version = 2");
       sqlcommit();
    } catch(Exception e) {
       try {
         sqlrollback();
       } catch(Exception e2) { }
         die("Error converting database to version 2: " + e.getMessage());
    }
   }
```