ICS 321 Fall 2011

SQL in a Server Environment

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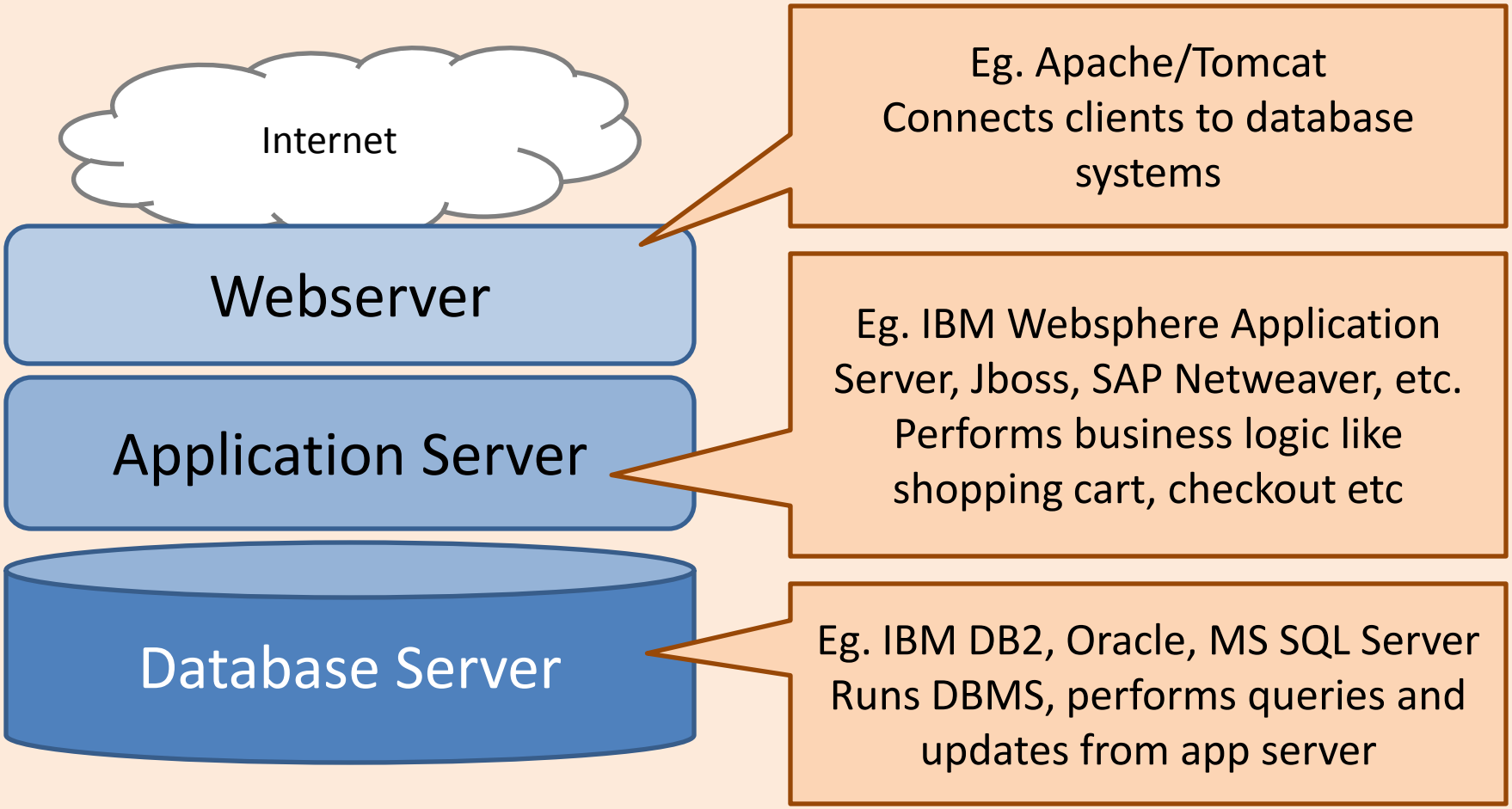
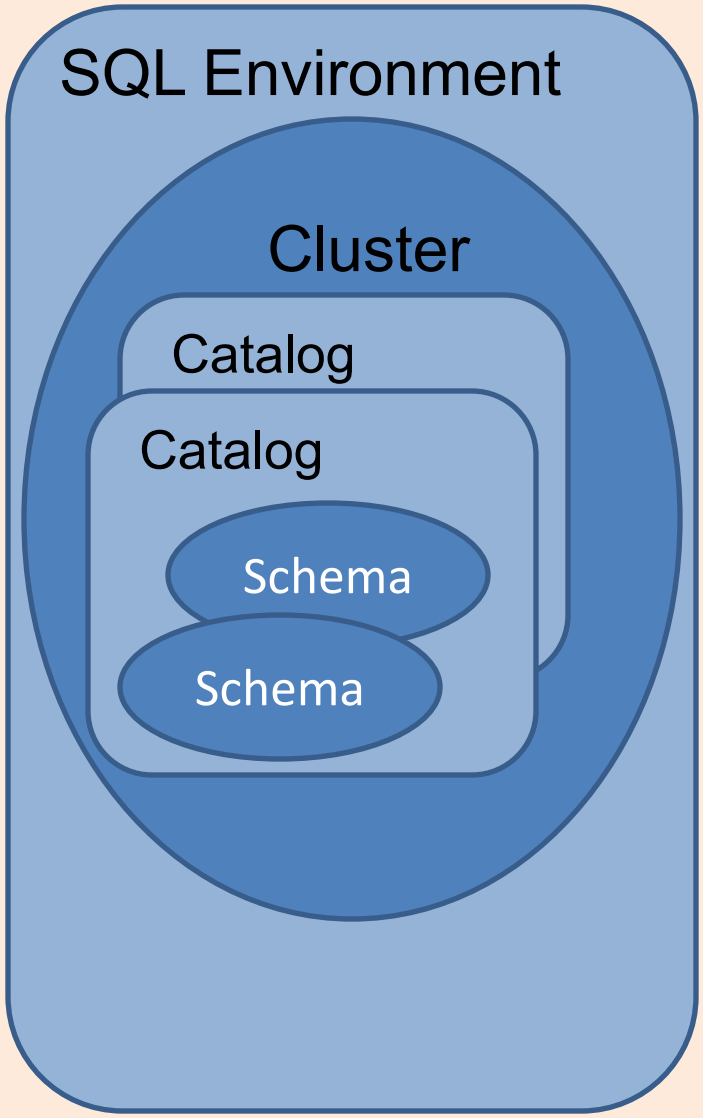
Three Tier Architecture



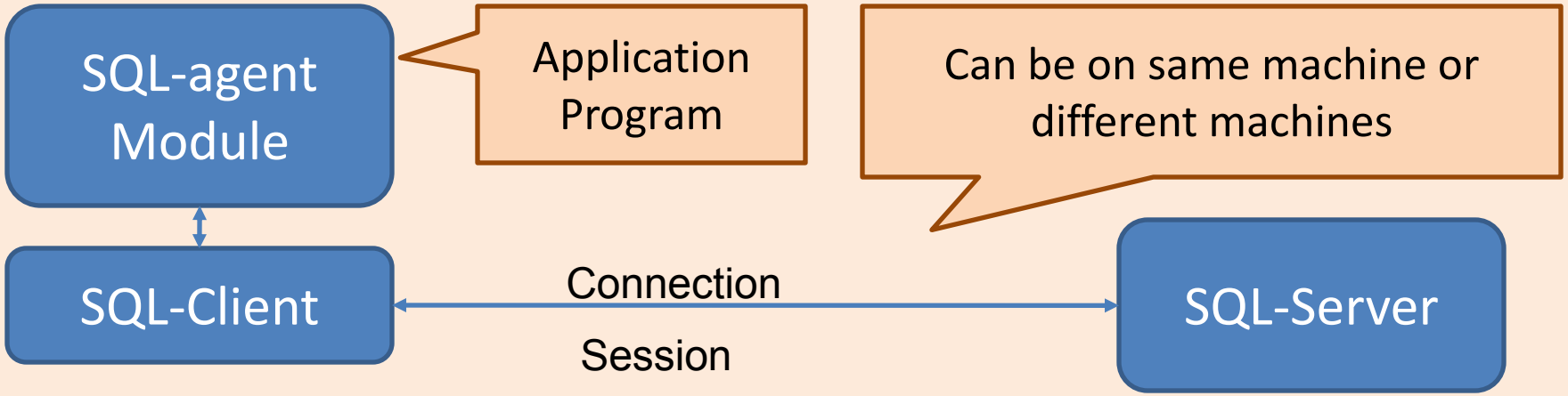
- Commonly used in large internet enterprises

SQL Environment



- Schemas : tables, views, assertions, triggers
  - CREATE SCHEMA <schema name>
  - Your login id is your default schema
  - SET SCHEMA <schema>
  - A fully qualified table name is <schema>.<table>
- Catalogs : collection of schemas
  - Corresponds to “databases” in DB2
- Clusters : collection of catalogs
  - Corresponds to “database instance” in DB2

Client-Server Model



- CONNECT TO <server> AS <connection name> AUTHORIZATION
- DISCONNECT/CONNECT RESET/TERMINATE
- Session – SQL operations performed while a connection is active

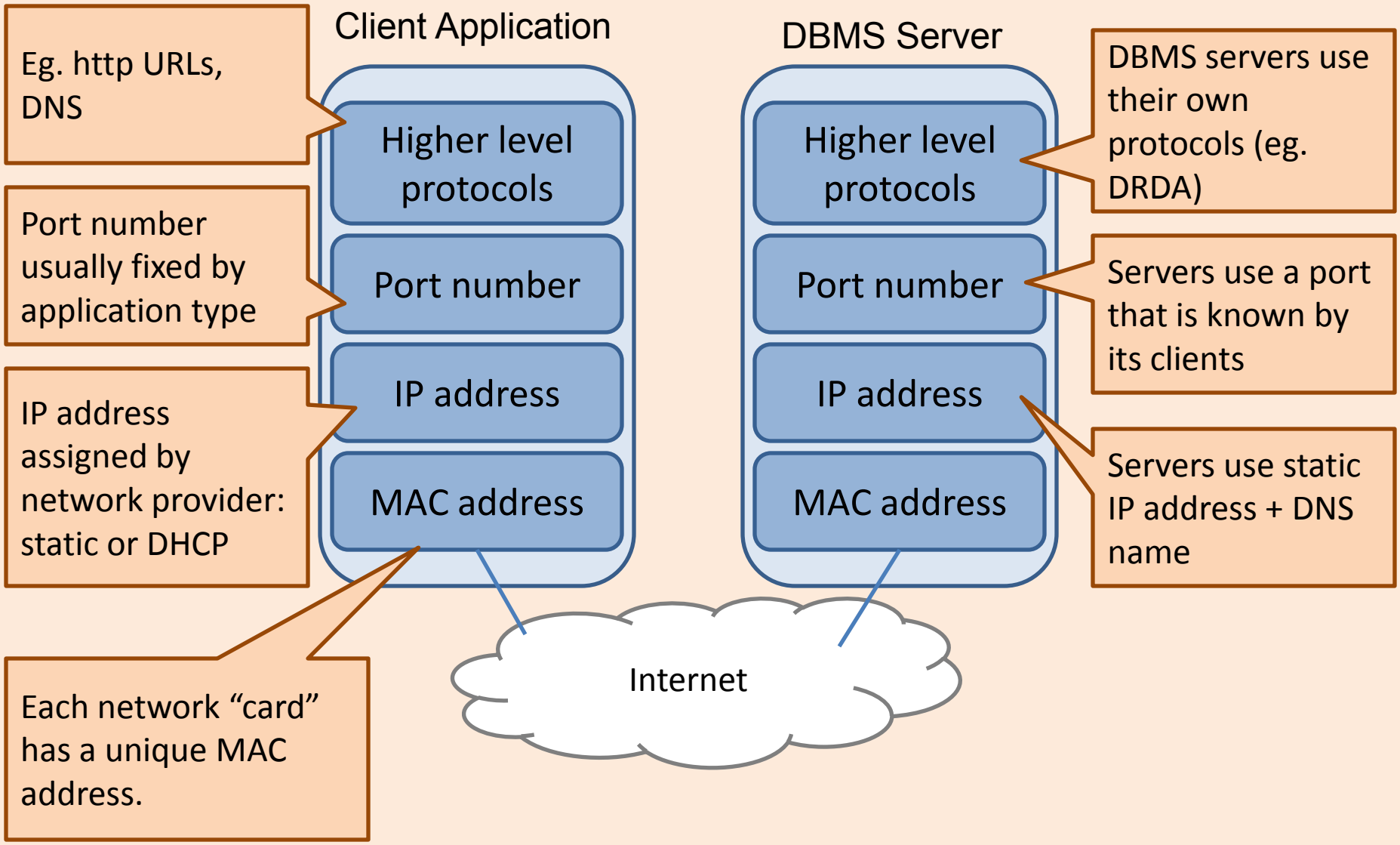
- Programming API
  - Generic SQL Interface
  - Embedded SQL in a host language
  - True Modules. Eg. Stored procedures.

SQL & Other Programming Languages

Two extremes of the integration spectrum:

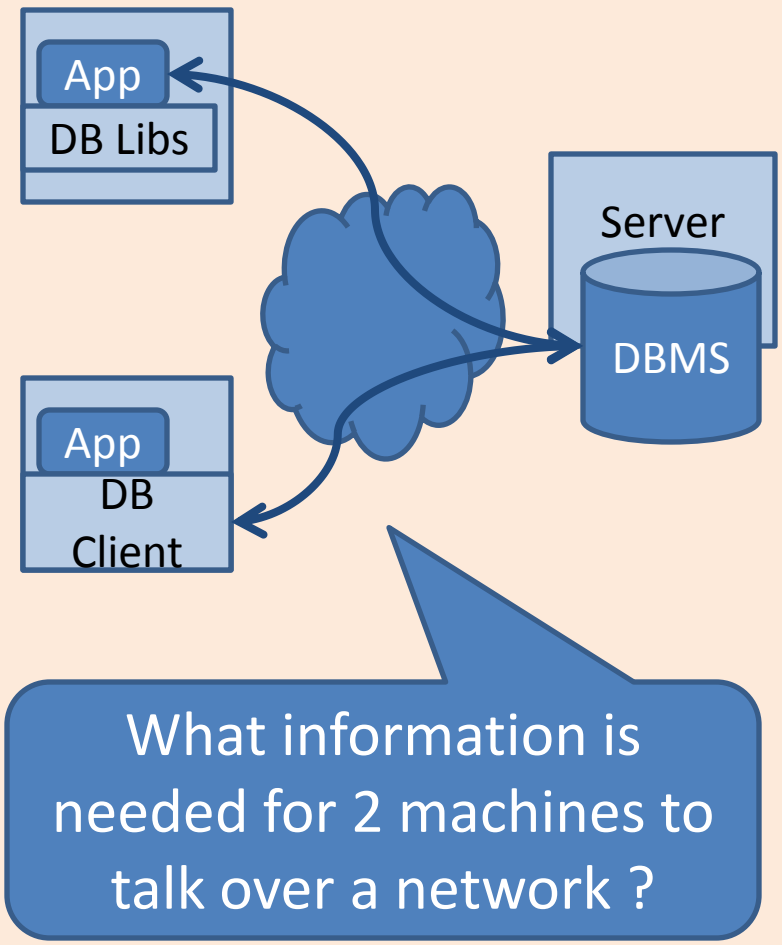
- Highly integrated eg. Microsoft linq
  - Compiler checking of database operations
- Loosely integrated eg. ODBC & JDBC
  - Provides a way to call SQL from host language
  - Host language compiler doesn't understand database operations.
- Requirements:
  - Perform DB operations from host language
  - DB operations need to access variables in host language

Networking Basics



Remote Client Access

- Applications run on a machine that is separate from the DB server
- DBMS "thin" client
  - Libraries to link your app to
  - App needs to know how to talk to DBMS server via network
- DBMS "full" client layer
  - Need to pre-configure the thick client layer to talk to DBMS server
  - Your app talks to a DBMS client layer as if it is talking to the server



Configuring DBMS Client Layer

- Tell the client where to find the server

db2 CATALOG TCPIP NODE mydbsrv
REMOTE 123.3.4.12 SERVER 50001

- Tell the client where to find the server

db2 CATALOG DATABASE bookdb AS
mybookdb AT NODE mydbsrv

Give a name for this node

Specify the IP address/hostname and the port number of the DB server machine

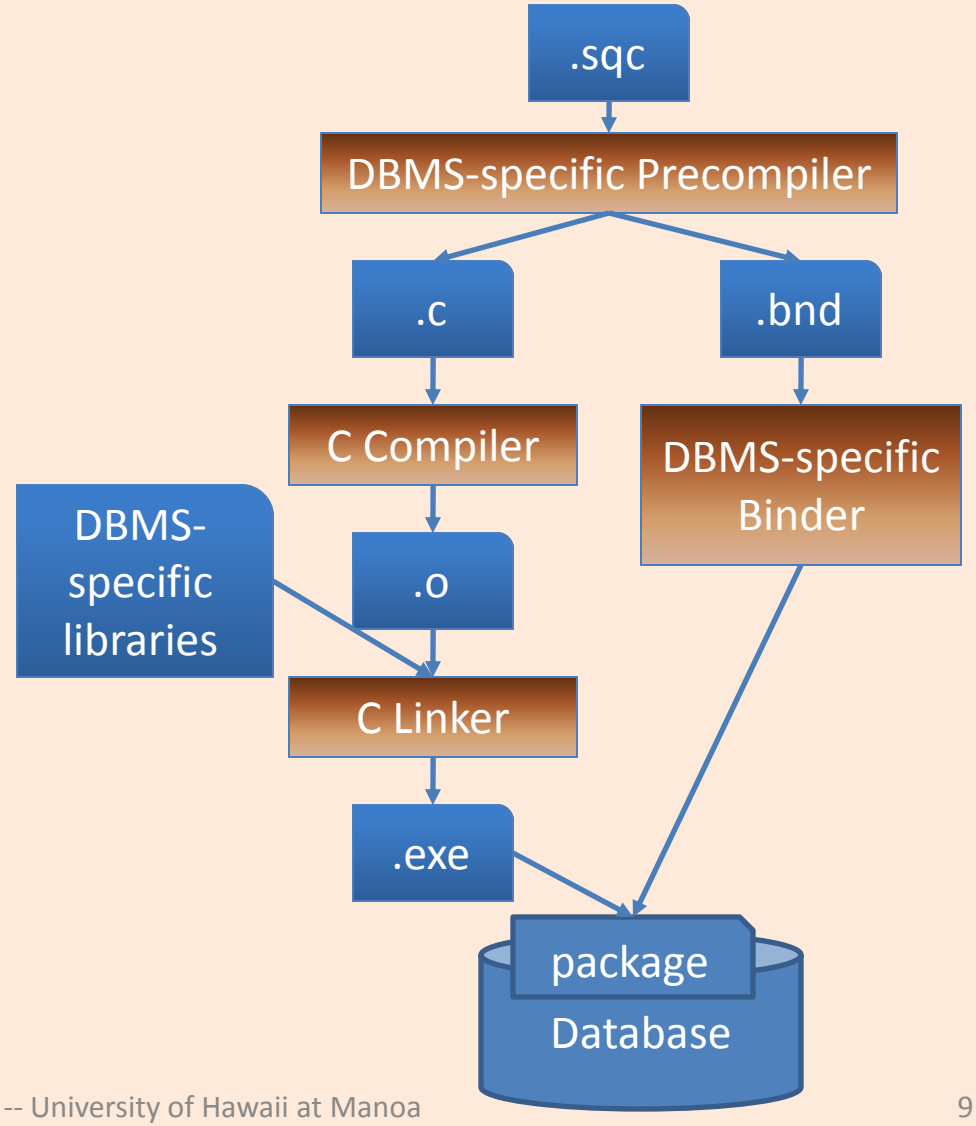
Specify the name of the database on the server

Give a local alias for the database

Specify the name of the node that is associated with this database

Embedded SQL in C Programs

- DBMS-specific Preprocessor translates special macros to DB-specific function calls
- Pre-processor needs access to DBMS instance for validation.
- Executable needs to be bound to a specific database in a DBMS in order to execute



Connecting SQL & Host Language

- Need a way for host language to get data from SQL environment
- Need a way to pass values from host language to SQL environment
- Shared variables
  - DECLARE SECTION
  - In SQL, refer using

  :Salary, :EmployeeNo

```
EXEC SQL BEGIN DECLARE SECTION;
char EmployeeNo[7];
char LastName[16];
double Salary;
short SalaryNI;
EXEC SQL END DECLARE SECTION;
```

An Example of Embedded SQL C Program

```
#include <stdio.h>
#include <string.h>
#include <sql.h>
int main()
{
// Include The SQLCA Data Structure Variable
EXEC SQL INCLUDE SQLCA;

// Define The SQL Host Variables Needed
EXEC SQL BEGIN DECLARE SECTION;
char EmployeeNo[7];
char LastName[16];
double Salary;
short SalaryNI;
EXEC SQL END DECLARE SECTION;

// Connect To The Appropriate Database
EXEC SQL CONNECT TO SAMPLE USER
     db2admin USING ibmdb2;

// Declare A Static Cursor
EXEC SQL DECLARE C1 CURSOR FOR
SELECT EMPNO, LASTNAME, DOUBLE(SALARY)
FROM EMPLOYEE
WHERE JOB = 'DESIGNER';

// Open The Cursor
EXEC SQL OPEN C1;
```

An Example of Embedded SQL C Program

```
// If The Cursor Was Opened Successfully,
while (sqlca.sqlcode == SQL_RC_OK)
{
    EXEC SQL FETCH C1 INTO :EmployeeNo,
            :LastName, :Salary, :SalaryNI;

    // Display The Record Retrieved
    if (sqlca.sqlcode == SQL_RC_OK)
    {
            printf("%-8s %-16s ", EmployeeNo,
                    LastName);
            if (SalaryNI >= 0)
                    printf("%lf\n", Salary);
            else
                    printf("Unknown\n");
    }
}
```

```
// Close The Open Cursor
EXEC SQL CLOSE C1;
// Commit The Transaction
EXEC SQL COMMIT;
// Terminate The Database Connection
EXEC SQL DISCONNECT CURRENT;
// Return Control To The Operating System
return(0);

}
```

- A cursor is an iterator for looping through a relation instance.
- Why is a cursor construct necessary ?

Updates

- SQL syntax except where clause require current of <cursor>

```
EXEC SQL BEGIN DECLARE
     SECTION;
  int certNo , worth ;
  char execName[31],
     execName[31],
     execAddr [256],
     SQLSTATE [6];
EXEC SQL END DECLARE
     SECTION;
```

```
EXEC SQL DECLARE execCursor CURSOR FOR
     MovieExec;
EXEC SQL OPEN execCursor
while (1) {
  EXEC SQL FETCH FROM execCursor INTO
     :execName, :execAddr, :certNo, :worth;
  if (NO_MORE_ TUPLES) break;
  if ( worth < 1000)
    EXEC SQL DELETE FROM MovieExec
                WHERE CURRENT OF execCursor;
  else
    EXEC SQL UPDATE MovieExec
                SET netWorth=2*netWorth
                WHERE CURRENT OF execCursor;
}
EXEC SQL CLOSE execCursor
```

Static vs Dynamic SQL

- Static SQL refers to SQL queries that are completely specified at compile time. Eg.

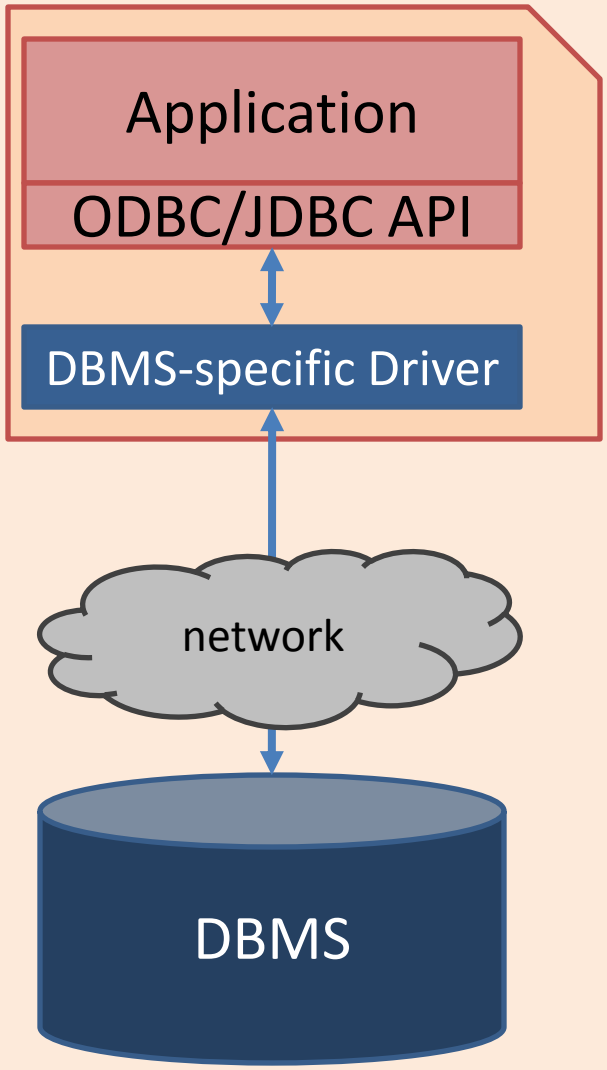
```
// Declare A Static Cursor
EXEC SQL DECLARE C1 CURSOR FOR
SELECT EMPNO, LASTNAME,
    DOUBLE(SALARY)
FROM EMPLOYEE
WHERE JOB = 'DESIGNER';
```

- Dynamic SQL refers to SQL queries that are note completely specified at compile time. Eg.

```
strcpy(SQLStmt, “SELECT * FROM
    EMPLOYEE WHERE JOB=");
strcat(SQLStmt,  argv[1]);
EXEC SQL PREPARE SQL_STMT FROM
    :SQLStmt;
EXEC SQL EXECUTE SQL_STMT;
```

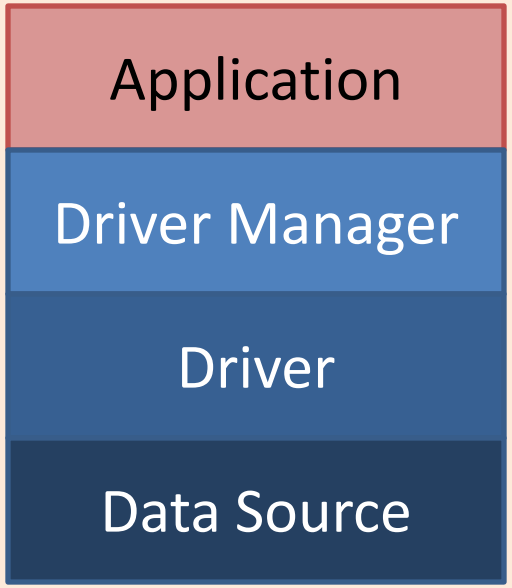
Alternative to Embedded SQL

- What if we want to compile an application without the need for a DBMS-specific pre-compiler ?
- Use a library of database calls
  - Standardized (non-DBMS-specific) API
  - Pass SQL-strings from host language and presents result sets in a language friendly way
  - Eg. ODBC for C/C++ and JDBC for Java
  - DBMS-neutral
    - A driver traps the calls and translates them into DBMS-specific code



ODBC/JDBC Architecture

- Application
  - Initiates connections
  - Submits SQL statements
  - Terminates connections
- Driver Manager
  - Loads the right JDBC driver
- Driver
  - Connects to the data source,
  - Transmit requests,
  - Returns results and error codes
- Data Source
  - DBMS



4 Types of Drivers

- Type I: Bridge
  - Translate SQL commands to non-native API
  - eg. JDBC-ODBC bridge. JDBC is translated to ODBC to access an ODBC compliant data source.
- Type II: Direct Translation to native API via non-Java driver
  - Translates SQL to native API of data source.
  - Needs DBMS-specific library on each client.
- Type III: Network bridge
  - SQL stmts sent to a middleware server that talks to the data source. Hence small JDBC driver at each client
- Type IV: Direct Translation to native API via Java driver
  - Converts JDBC calls to network protocol used by DBMS.
  - Needs DBMS-specific Java driver at each client.

High Level Steps

1. Load the ODBC/JDBC driver
2. Connect to the data source
3. [optional] Prepare the SQL statements
4. Execute the SQL statements
5. Iterate over the resultset
6. Close the connection

Getting Data to/fro Host Language

- No declaration of shared variables
- Variables in host language is bound to columns of a SQL cursor
- ODBC
  - SQLBindCol – gets data from SQL environment to host variables.
  - SQLBindParameter – gets data from host variables to SQL environment
- JDBC
  - ResultSet class
  - PreparedStatement class

Prepare Statement or Not ?

```
String sql="SELECT * FROM books WHERE price < ?";
PreparedStatement pstmt = conn.prepareStatement(sql);
Pstmt.setFloat(1, usermaxprice);
Pstmt.executeUpdate();
```

- Executing without preparing statement
  - After DBMS receives SQL statement,
    - The SQL is compiled,
    - An execution plan is chosen by the optimizer,
    - The execution plan is evaluated by the DBMS engine
    - The results are returned
- conn.prepareStatement
  - Compiles and picks an execution plan
- pstmt.executeUpdate
  - Evaluates the execution plan with the parameters and gets the results

cf. Static vs Dynamic SQL

ResultSet

```
ResultSet rs = stmt.executeQuery(sqlstr);
while( rs.next() ){
        col1val = rs.getString(1); …
}
```

- Iterate over the results of a SQL statement -- cf. cursor
- Note that types of column values do not need to be known at compile time

SQL Type	Java Class	accessor
BIT	Boolean	getBoolean
CHAR, VARCHAR	String	getString
DOUBLE, FLOAT	Double	getDouble
INTEGER	Integer	getInt
REAL	Double	getFloat
DATE	Java.sql.Date	getDate
TIME	Java.sql.Time	getTime
TIMESTAMP	Java.sql.TimeStamp	getTimestamp

RowSet

- When inserting lots of data, calling an execute statement for each row can be inefficient
  - A message is sent for each execute
- Many APIs provide a rowset implementation
  - A set of rows is maintained in-memory on the client
  - A single execute will then insert the set of rows in a single message
- Pros: high performance
- Cons: data can be lost if client crashes.
- Analogous rowset for reads (ie. ResultSet) also available

Stored Procedures

- What ?
  - A procedure that is called and executed via a single SQL statement
  - Executed in the same process space of the DBMS server
  - Can be programmed in SQL, C, java etc
  - The procedure is stored within the DBMS
- Advantages:
  - Encapsulate application logic while staying close to the data
  - Re-use of application logic by different users
  - Avoid tuple-at-a-time return of records through cursors

SQL Stored Procedures

CREATE PROCEDURE ShowNumReservations

SELECT S.sid, S.sname, COUNT(*)

FROM Sailors S, Reserves R

WHERE S.sid = R.sid

GROUP BY S.sid, S.sname

- Parameters modes: IN, OUT, INOUT

CREATE PROCEDURE IncreaseRating (IN sailor_sid INTEGER, IN increase INTEGER)

UPDATE Sailors

SET rating = rating + increase

WHERE sid = sailor_sid

Java Stored Procedures

```
CREATE PROCEDURE TopSailors (
        IN num INTEGER)
    LANGUAGE JAVA
    EXTERNAL NAME
        "file:///c:/storedProcs/rank.jar"
```

Calling Stored Procedures

- SQL: **CALL** IncreaseRating(101, 2);

- Embedded SQL in C:

```
EXEC SQL BEGIN DECLARE SECTION
int sid; int rating;
EXEC SQL END DECLARE SECTION
EXEC SQL CALL IncreaseRating(:sid, :rating);
```

- JDBC

```
CallableStatement cstmt =  conn.prepareCall("{call Show Sailors});
ResultSet rs=cstmt.executeQuery();
```

- ODBC

```
SQLCHAR *stmt = (SQLCHAR *)"CALL ShowSailors";
cliRC = SQLPrepare(hstmt, stmt, SQL_NTS);
cliRC = SQLExecute(hstmt);
```

User Defined Functions (UDFs)

- Extend and add to the support provided by SQL built-in functions
- Three types of UDFs
  - **Scalar**: returns a single-valued answer. Eg. Built-ing SUBSTR()
  - **Column**: returns a single-valued answer from a column of values. Eg. AVG()
  - **Table**: returns a table. Invoked in the FROM clause.
- Programable in SQL, C, JAVA.

Scalar UDFs

- Returns the tangent of a value

```
CREATE FUNCTION TAN (X DOUBLE)
    RETURNS DOUBLE
    LANGUAGE SQL
    CONTAINS SQL
    RETURN SIN(X)/COS(X)
```

- Reverses a string

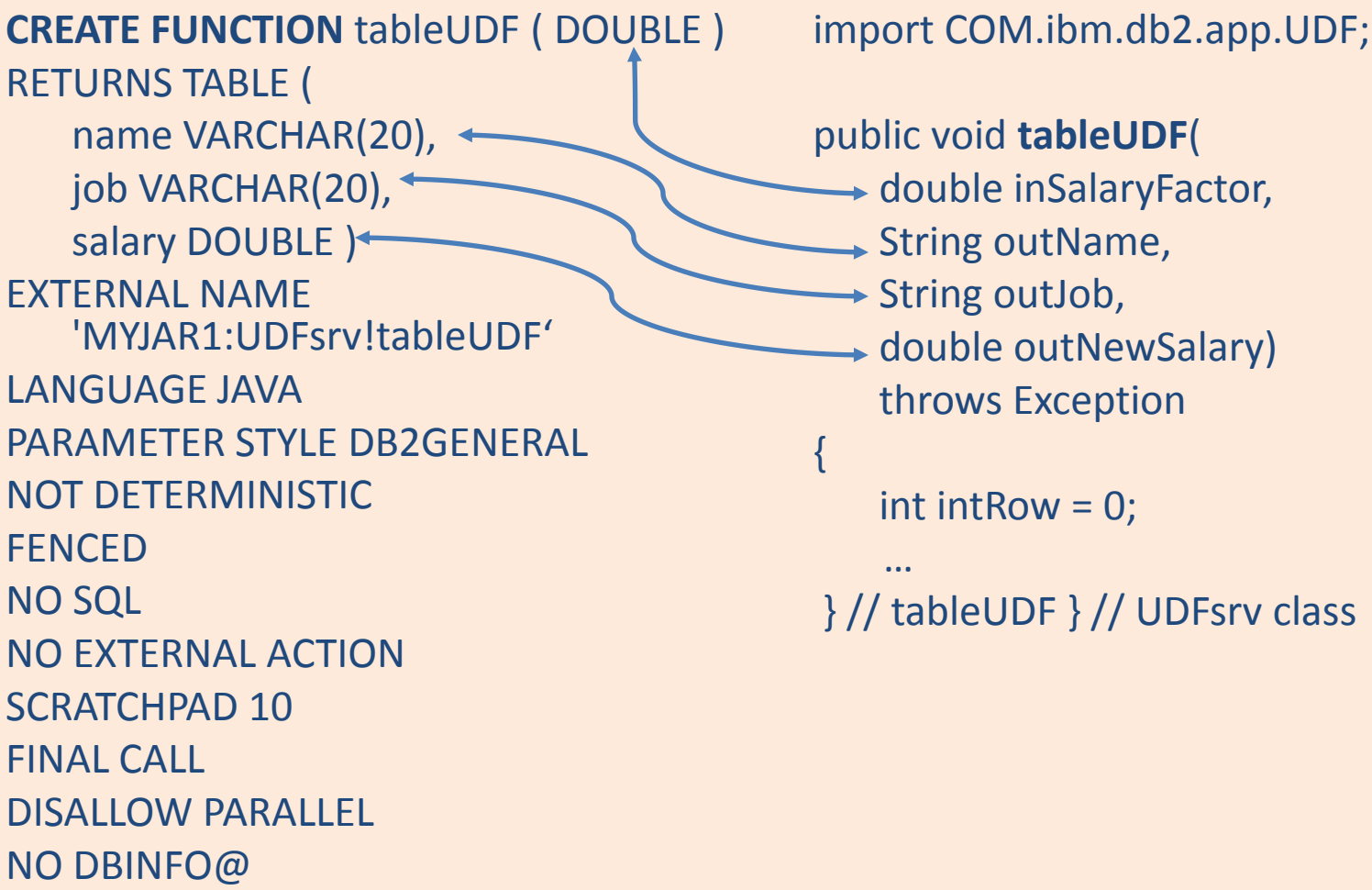
```
CREATE FUNCTION REVERSE(INSTR
    VARCHAR(4000))
    RETURNS VARCHAR(4000)
    CONTAINS SQL
BEGIN ATOMIC
    DECLARE REVSTR, RESTSTR
        VARCHAR(4000) DEFAULT '';
    DECLARE LEN INT;
    IF INSTR IS NULL THEN
        RETURN NULL;
    END IF;
    SET (RESTSTR, LEN) = (INSTR,
        LENGTH(INSTR));
    WHILE LEN > 0 DO
        SET (REVSTR, RESTSTR, LEN)
    = (SUBSTR(RESTSTR, 1, 1) CONCAT
    REVSTR, SUBSTR(RESTSTR, 2, LEN
    - 1), LEN - 1);
    END WHILE;
    RETURN REVSTR;
END
```

Table UDFs

- returns the employees in a specified department number.

```
CREATE FUNCTION DEPTEMPLOYEES (DEPTNO CHAR(3))
    RETURNS TABLE (
                    EMPNO CHAR(6),
                    LASTNAME VARCHAR(15),
                    FIRSTNAME VARCHAR(12))
    LANGUAGE SQL
    READS SQL DATA
    RETURN
        SELECT EMPNO, LASTNAME, FIRSTNME
        FROM EMPLOYEE
        WHERE EMPLOYEE.WORKDEPT
                        = DEPTEMPLOYEES.DEPTNO
```

Java UDFs



```
CREATE FUNCTION tableUDF ( DOUBLE )
RETURNS TABLE (
    name VARCHAR(20),
    job VARCHAR(20),
    salary DOUBLE )
EXTERNAL NAME
    'MYJAR1:UDFsrv!tableUDF‘
LANGUAGE JAVA
PARAMETER STYLE DB2GENERAL
NOT DETERMINISTIC
FENCED
NO SQL
NO EXTERNAL ACTION
SCRATCHPAD 10
FINAL CALL
DISALLOW PARALLEL
NO DBINFO@
```

```
import COM.ibm.db2.app.UDF;

public void tableUDF(
    double inSalaryFactor,
    String outName,
    String outJob,
    double outNewSalary)
    throws Exception
{
    int intRow = 0;
    …
 } // tableUDF } // UDFsrv class
```