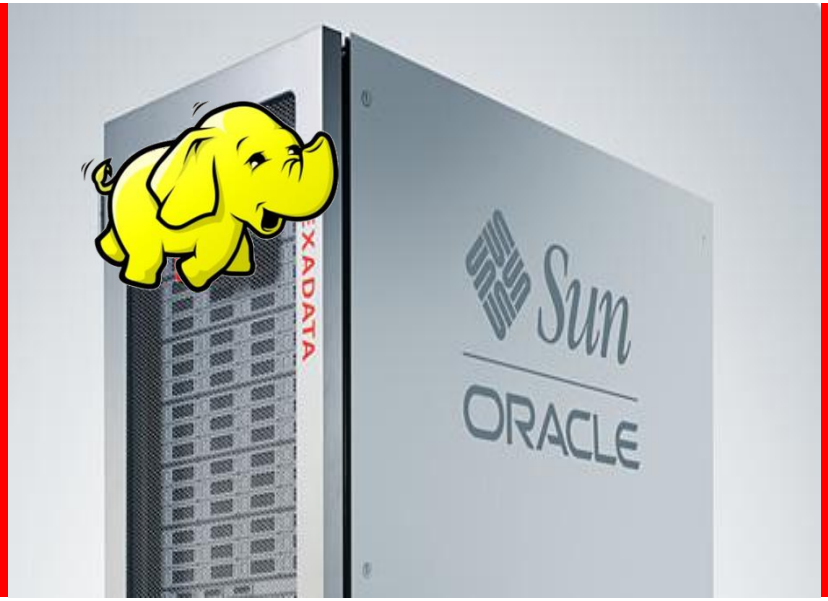

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Oracle In-Database Hadoop: When MapReduce Meets RDBMS

Oracle In-Database Hadoop

When MapReduce Meets RDBMS

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*This work describes a prototype built on top of Oracle DB, which is not a feature of Oracle products.

Oracle In-Database Hadoop
Agenda

- Big Data, Hadoop MapReduce & SQL
- Oracle In-Database Hadoop
  - Architecture & Design
  - Implementation
- Summary

Why Big Data and Hadoop?

Big Data

Big Data Is A Phenomenon

- More commercial and social interactions are mediated by computing technology.
- The cost of storage continues to decrease.
- Cloud computing becomes popular.

- E.g., web logs, business records, social networks, search indexing, photo and video archives, and Internet documents.

Big Data

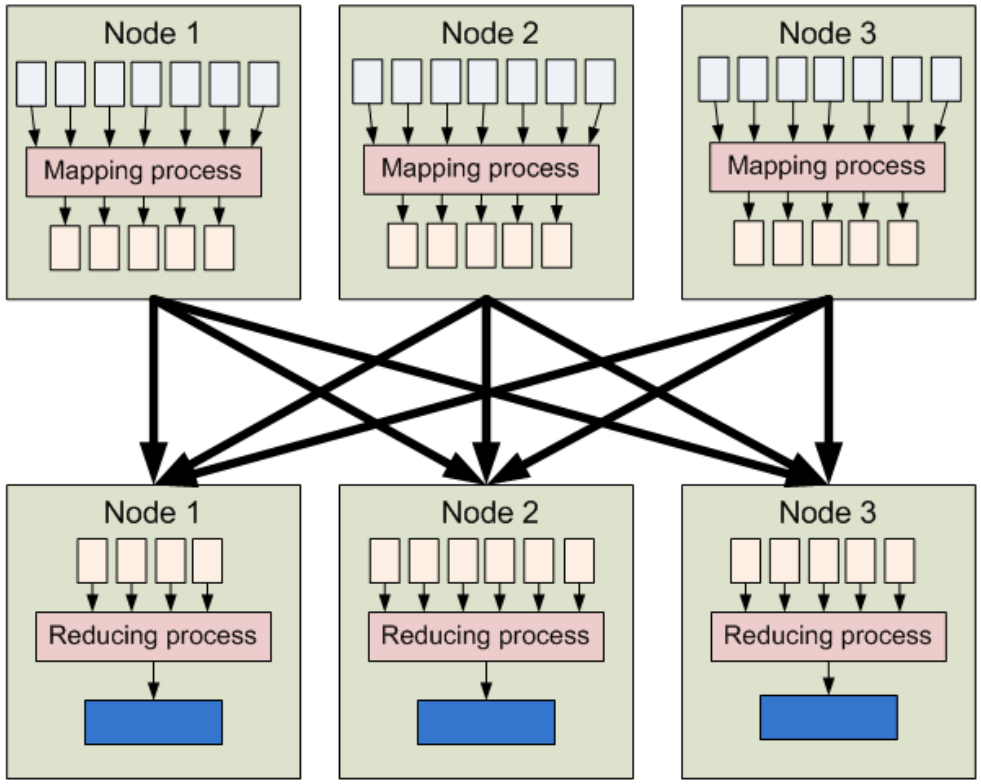
Why Is Processing Big Data Challenging?

- Low information density, often unstructured.
- Overwhelming scale.
- Varied formats and huge computational overhead.

- Tar sands - potentially valuable information resources but requiring huge inputs in energy and technology to exploit.

MapReduce Paradigm

You All Know This Stuff!



Map:
<K1,V1> → {<K2,V2>,…}

Shuffle:
{<K2,V2>, …} → {<K2,{V2,…,V2}>,…}

Reduce:
<K2,{V2,…,V2}> → {<K3,V3>,…}

Hadoop Implementation
API

- Model is similar to "Standard In / Standard Out": Mappers and Reducers rely on the environment to get the input from and to put output in the right place, but do not access File Systems or Data Stores directly.
- Some combination of the Configuration and the Driver program are used to specify the environment.
- This makes Mappers and Reducers more reusable -- a small application surface area that we have to reimplement to allow Mappers and Reducers to run over Tables of SQL types.

Why In-DB Hadoop?

Hadoop & SQL
Why In-DB Hadoop?

For customers who have already invested in a database infrastructure:

- Avoid additional investment into a Hadoop cluster.
- Reduce training and deployment time.
- Mix SQL and MapReduce processing for flexibility and efficiency.

Hadoop & SQL
Previous Efforts

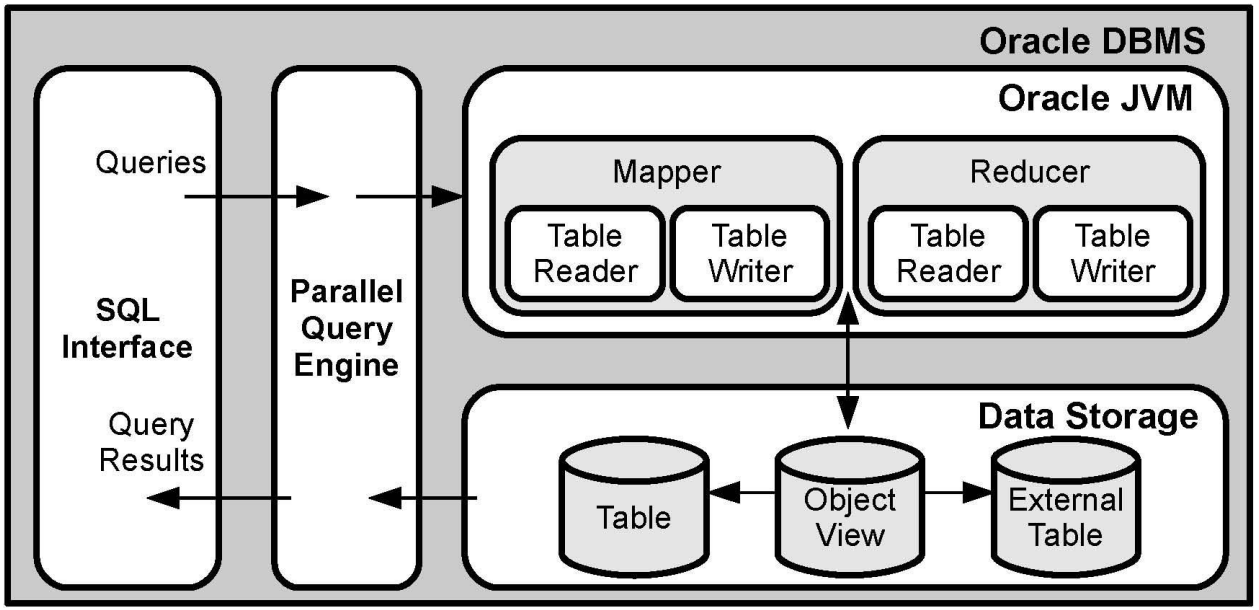
- Oracle user-defined pipelined table functions and aggregation objects, SQL-MapReduce, Pig Latin, Hive, Tenzing, HadoopDB (Hadapt), etc.
- Limitations of previous efforts:
  - Source compatibility: Need to rewrite Hadoop programs in a different language;
  - Dependency on Hadoop infrastructure: Rely on Hadoop clusters for query execution.

Can We Do Better?

Oracle In-Database Hadoop
Design Goals

- Source-compatibility: Accept Hadoop programs written in Java.
- Direct data access: No need to move Oracle RDBMS resident data to a separate infrastructure.
- Minimal dependency: No Hadoop clusters.
- Seamless integration: MapReduce functionality embedded in Oracle SQL.
- Java interface: Allow Hadoop users to execute their applications in the traditional Java way.

Oracle In-Database Hadoop
Architecture



- Data storage: Table, external table, object view.
- PQ engine: Data partitioning & task scheduling.
- Oracle JVM: Task execution.
- TableReader, TableWriter: Data type mapping.

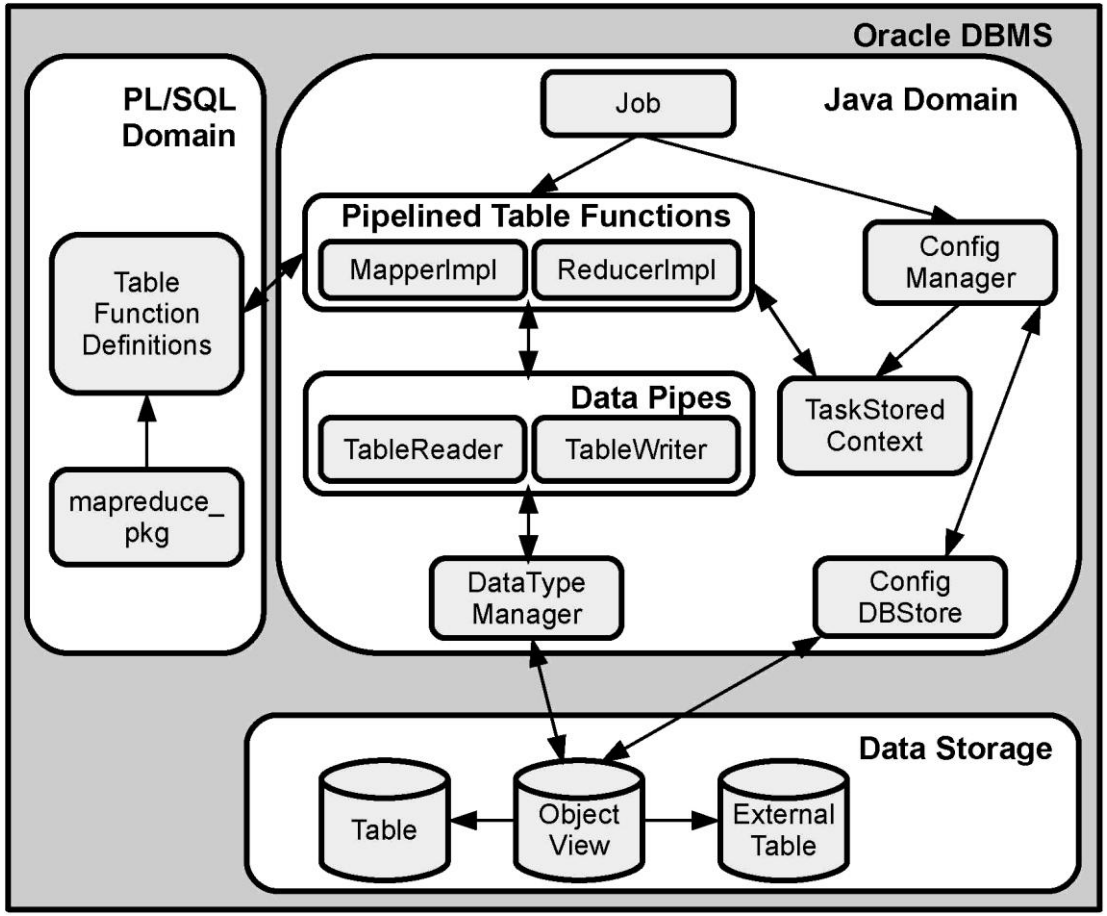
Hadoop SQL Queries
One Example

- Mix Hadoop with SQL.
- MapReduce steps as pipelined table functions.
- A link to retrieve configuration parameters.

```
INSERT INTO OutTable
SELECT * FROM TABLE
  (Word_Count_Reduce(:ConfKey,
    CURSOR(SELECT * FROM TABLE
  (Word_Count_Map(:ConfKey,
    CURSOR(SELECT * FROM InTable))))))
```

What's Under the Hood?

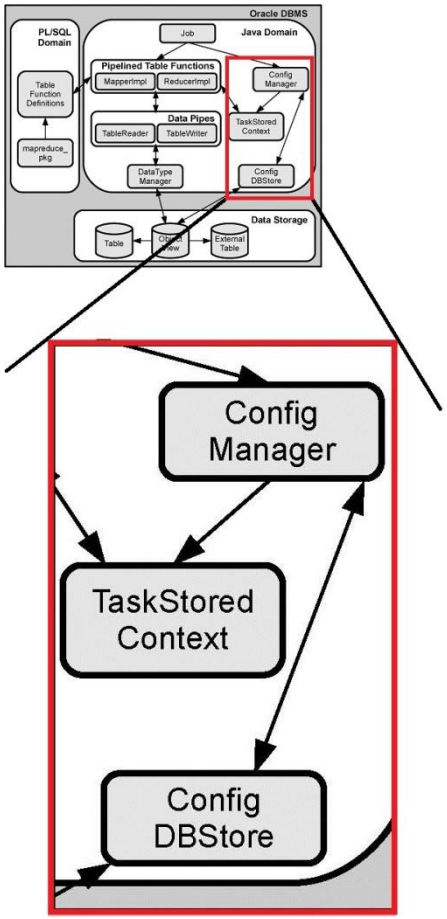
Implementation
Software Components



- Oracle 11.2.
- Oracle JVM compatible with JDK 1.5.
- Documented public APIs.
- Hadoop 0.20.2.

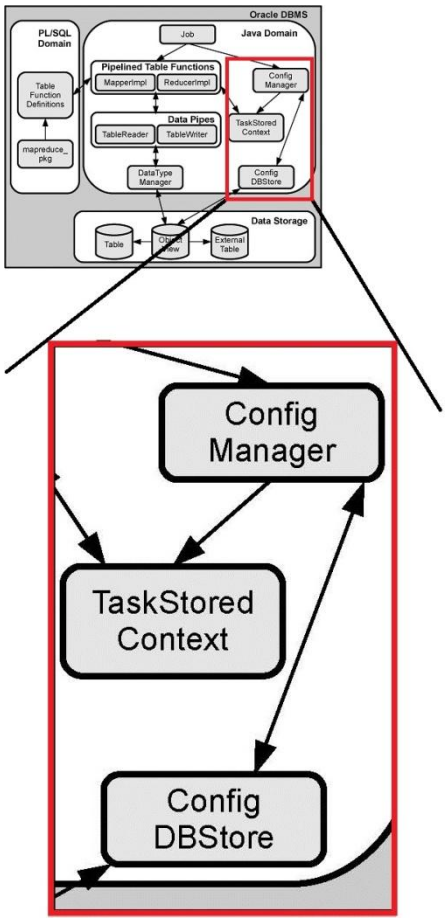
Hadoop Job Configuration

Setup, Storage and Retrieval



- Context-switching between Java and SQL environments -- need a way to pass Hadoop configurations.
- Users setup configuration parameters in job drivers as in Hadoop.
- The framework stores and retrieves Hadoop configuration objects from a row in the database using our own specialization of the Hadoop ConfigManager.

Hadoop Job Configuration
Additional DB Parameters



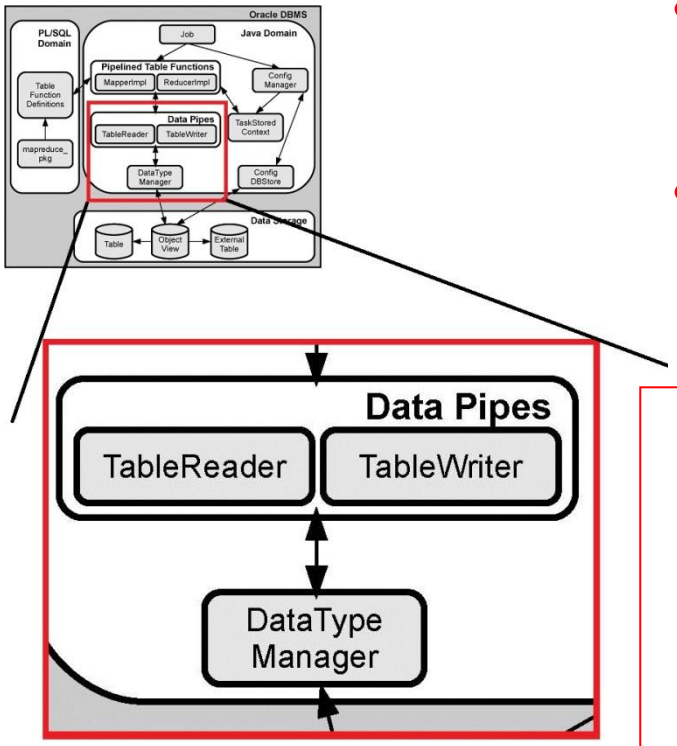

```
Configuration conf = new Configuration();
Job job = new Job(conf, "word count");

/* Set mapper and reducer classes. */
job.setMapperClass(TokenizerMapper.class);
job.setReducerClass(IntSumReducer.class);

/* Set input and output Hadoop types. */
job.setInputKeyClass(Object.class);
job.setInputValueClass(Text.class);
job.setOutputKeyClass(Text.class);
job.setOutputValueClass(IntWritable.class);

/* Set the output SQL types. */
job.setOutputKeyDBType("VARCHAR2(100)");
job.setOutputValueDBType("NUMBER");
```

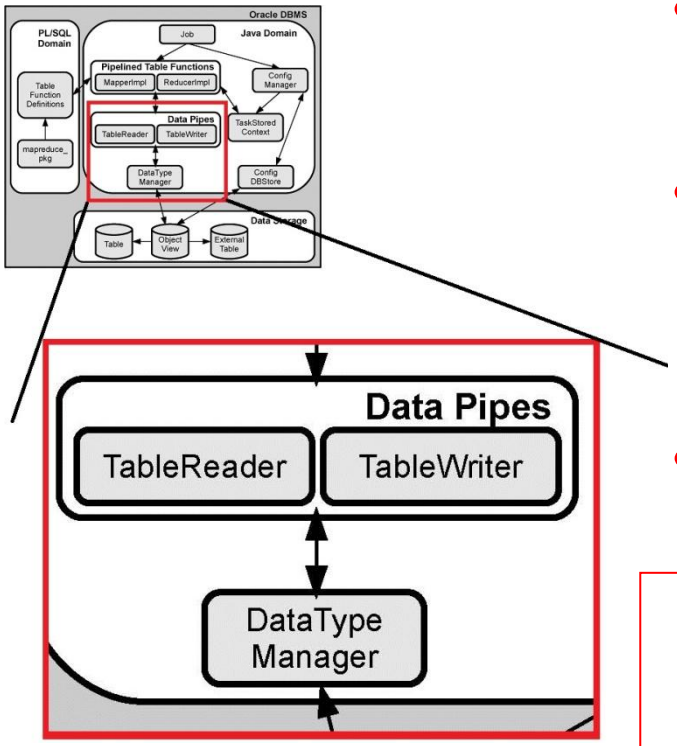
SQL Data Types
Input Generics



- Make use of the ANYDATA type defined in PL/SQL.
- Users can store data in any supported formats.

```
TYPE MapReduceInputType IS RECORD (
  KEYIN SYS.ANYDATA,
  VALUEIN SYS.ANYDATA
);
TYPE inputcur IS REF CURSOR
  RETURN MapReduceInputType;
```

SQL Data Types
Type-Specific Output

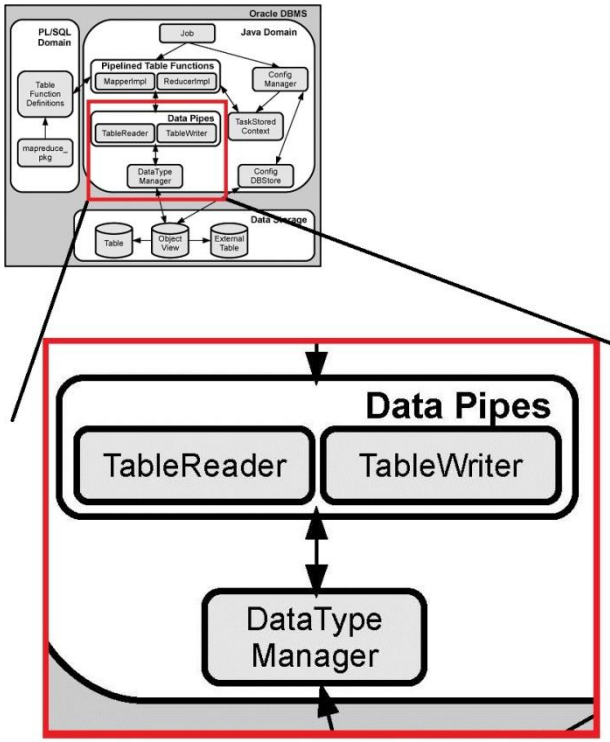


- Users configure output key/value types as in Hadoop.
- The framework automatically generates corresponding object and table types for SQL.
- Name convention:

```
MAPOUT_<MAPOUTKEYTYPE>_<MAPOUTVALUETYPE>
OUT_<REDOUTKEYTYPE>_<REDOUTVALUETYPE>
```

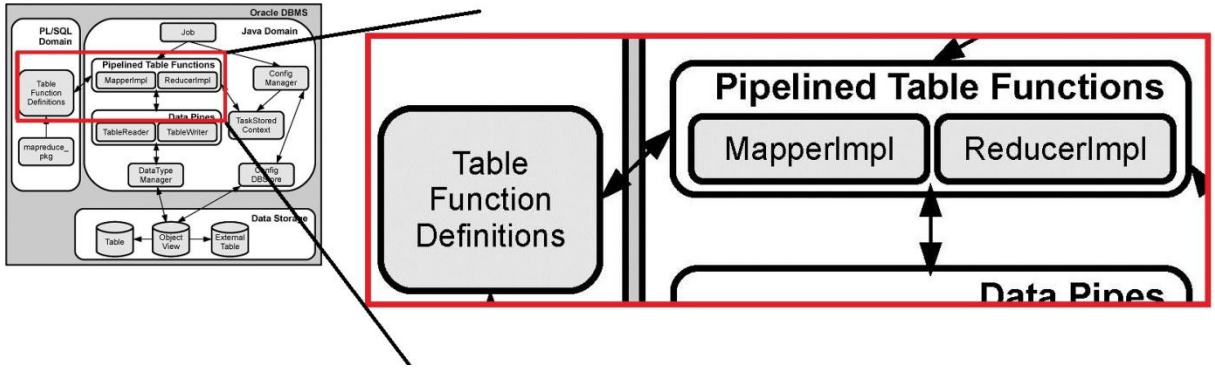
SQL Data Types

Mapping Between SQL and Hadoop Types



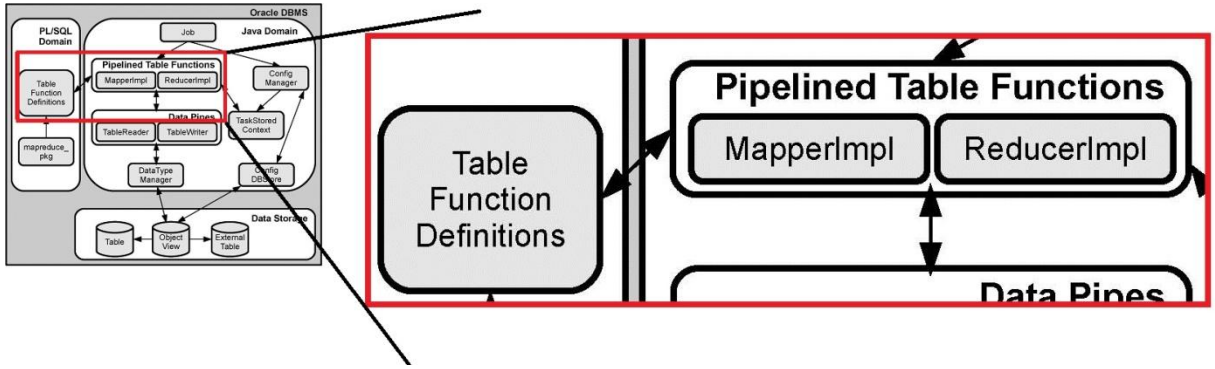
- Convert data between Hadoop Writables and SQL types.
- Automatically invoked in TableReader & TableWriter.
- Implicit mappings between SQL scalar types, VARRAY and corresponding Hadoop types.
- Composite types are handled by DBA creating SQL Object views that match the structure of the Hadoop classes.

Pipelined Table Functions
General Design



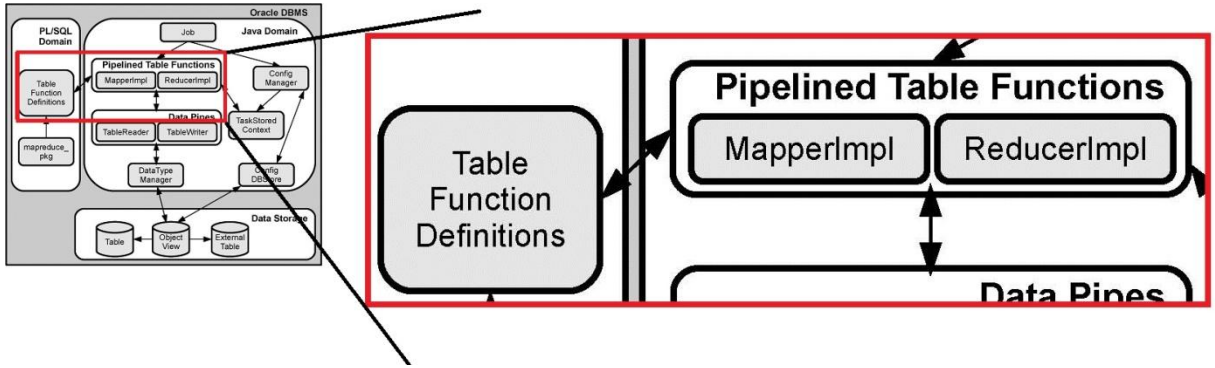
- Take a stream of rows as input and return a stream of rows as output.
- Implemented in Java. Invoked from the SQL domain and executed in the Java domain.
- Data pipelining, the avoidance of barriers and intermediate data materialization.

Pipelined Table Functions
Declaration




```
CREATE OR REPLACE FUNCTION
  Reduce_<REDOUTKEYTYPE>_<REDOUTVALUETYPE>
  (jobKey NUMBER, p mapreduce_pkg.inputcur)
RETURN (OUTSET_<REDOUTKEYTYPE>_<REDOUTVALUETYPE>)
PIPELINED PARALLEL_ENABLE
  (PARTITION p BY hash(KEYIN)) CLUSTER p BY (KEYIN)
USING ReducerImpl;
```

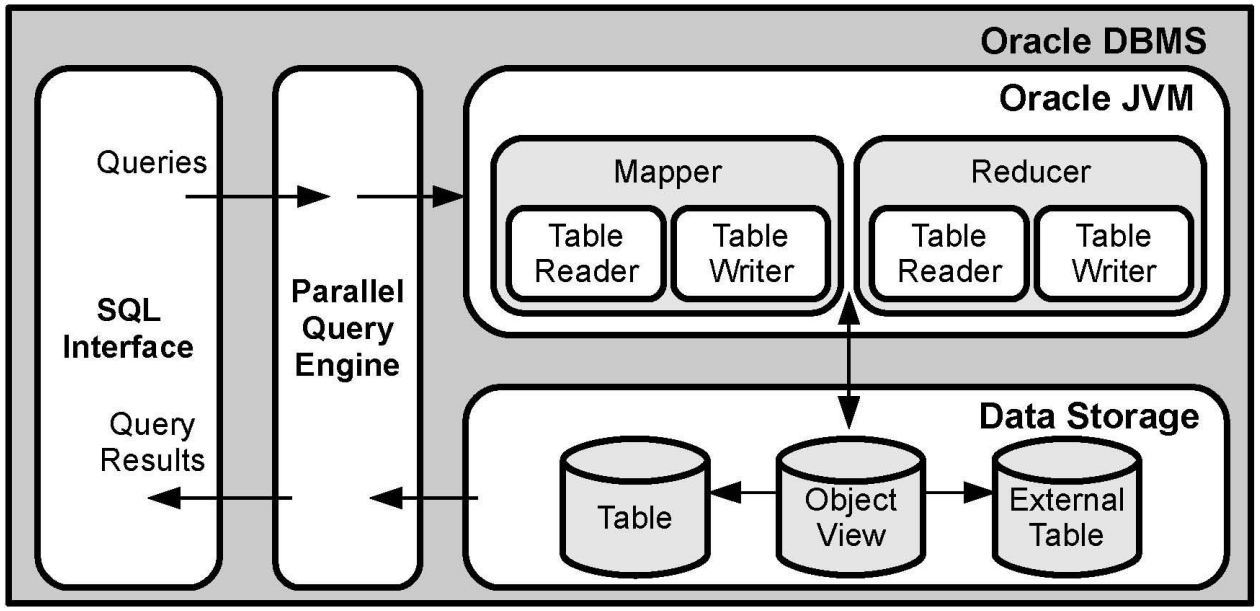
Pipelined Table Functions
Interface



- ODCITableStart:
  - Instantiate user provided Hadoop Mapper/Reducer classes.
  - Gain access rights via Java reflection.
  - Accept configuration parameters and set up environment.
- ODCITableFetch:
  - Execute Mapper/Reducer program on input data.
- ODCITableClose:
  - Clean up and return.

Hadoop SQL Queries Revisited

Two Interfaces: SQL & Java



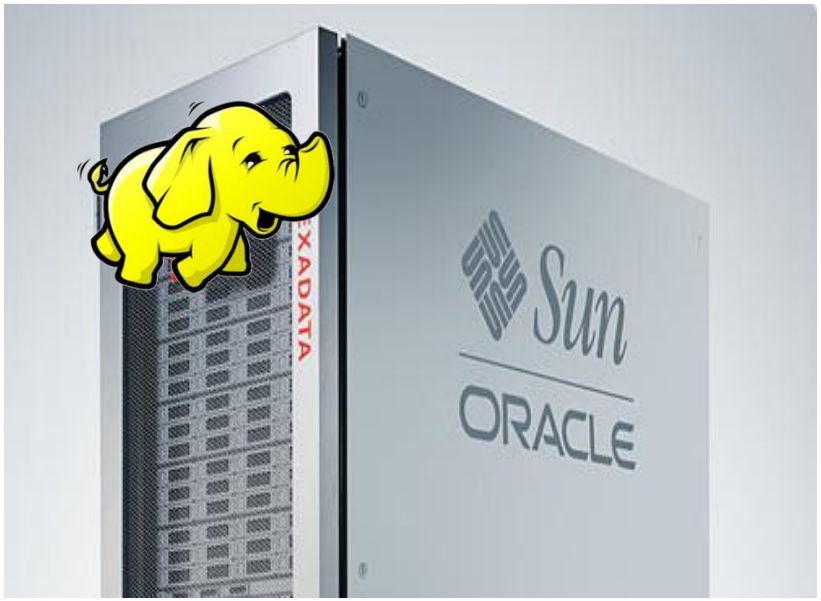

```
SELECT * FROM TABLE
  (Reduce_VARCHAR2_NUMBER(:ConfKey,
    CURSOR(SELECT * FROM TABLE
  (Map_VARCHAR2_NUMBER(:ConfKey,
    CURSOR(SELECT * from InTable))))))
```

```
public class WordCount {
public static void main() throws Exception {
  /* Setup the parameters and run the job */
  ……
  job.init();
  job.run();
}
```

What Have We Done?

Oracle In-Database Hadoop

Summary



A prototype of Oracle In-DB Hadoop:

- Source compatibility with Hadoop.
- Access to Oracle RDBMS resident data without the need to move the data to a separate infrastructure.
- Minimal dependency on the Apache Hadoop infrastructure.
- Greater efficiency in execution due to data pipelining, the avoidance of barriers and intermediate data materialization in the Oracle implementation.
- Seamless integration of MapReduce functionality with Oracle SQL, allowing mixing MapReduce steps with sophisticated SQL queries.

Where Can We Go From Here?

Potential Extensions

- SQL extensions: Allow table functions to compute their output type based on configuration parameters and the types of the input parameters.
- JDBC extensions: Map between Hadoop Writable types and SQL types, not PL/SQL types. PL/SQL is the Oracle specific stored procedure language.
- Support more Hadoop classes running inside the DB: InputFormat and OutputFormat classes would allow SQL to access any Hadoop data source or sink.