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Stratosphere for Hadoop Users

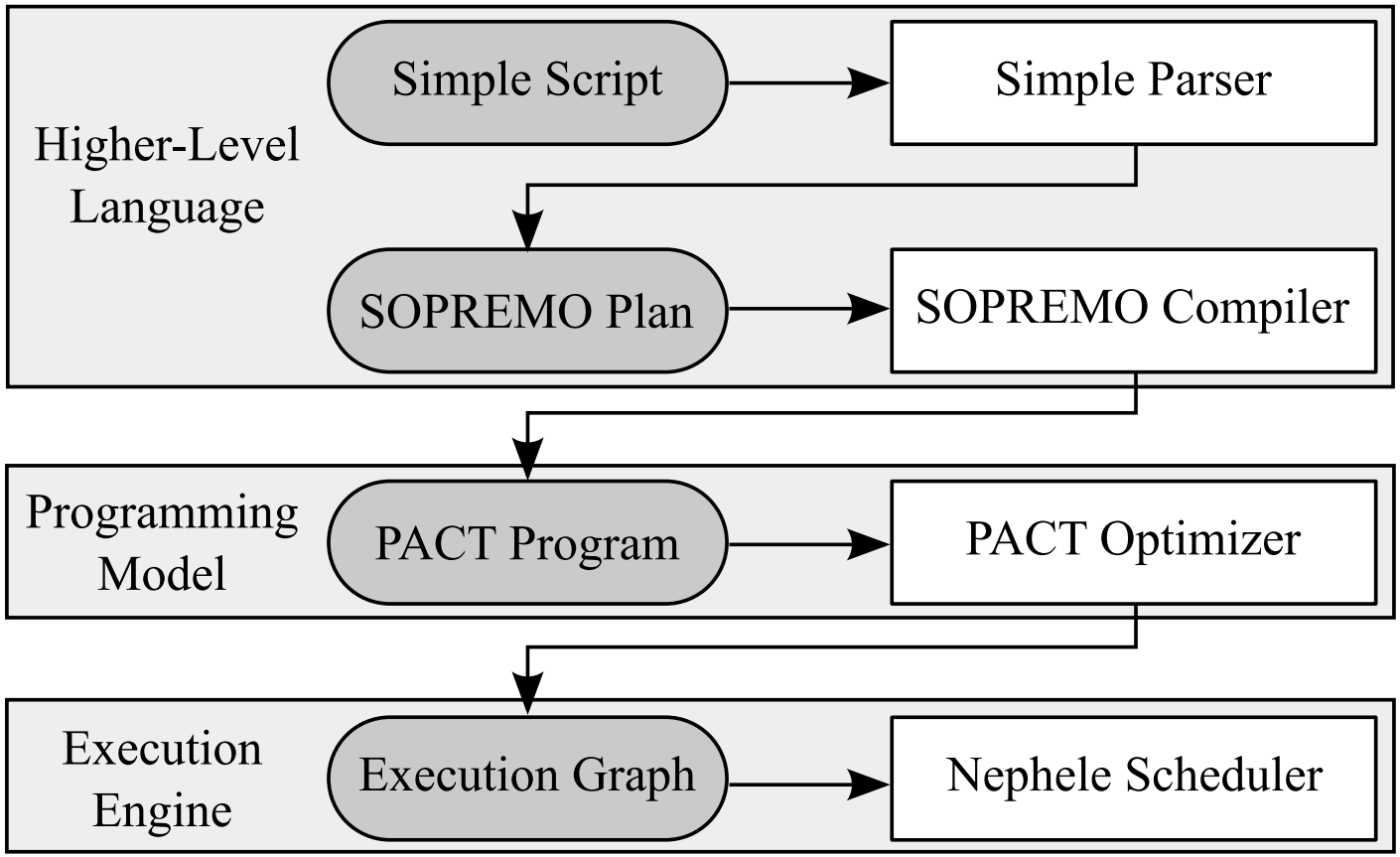
Potsdam, January 03, 2012

Arvid Heise

Outline

1. Overview over Stratosphere
2. Dataflow Orientation
3. Tuple-based Data Model
4. Other Differences
5. Seminar Organization

Stratosphere Stack



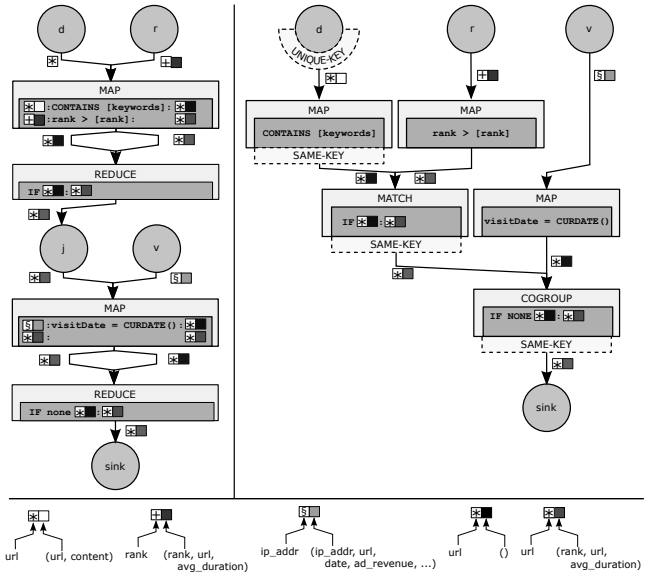
Pact (PArallelization ConTracts)

- Parallel programming model
- Implementation and generalization of Map/Reduce
- Similar interface as Hadoop
- Defines the parallelization semantics of tasks
- Pact plan is dataflow-oriented
- Pact optimizes plans and compiles them to execution graphs for Nephele

- Alexandrov et al. 2010. MapReduce and Pact - Comparing Data Parallel Programming Models.

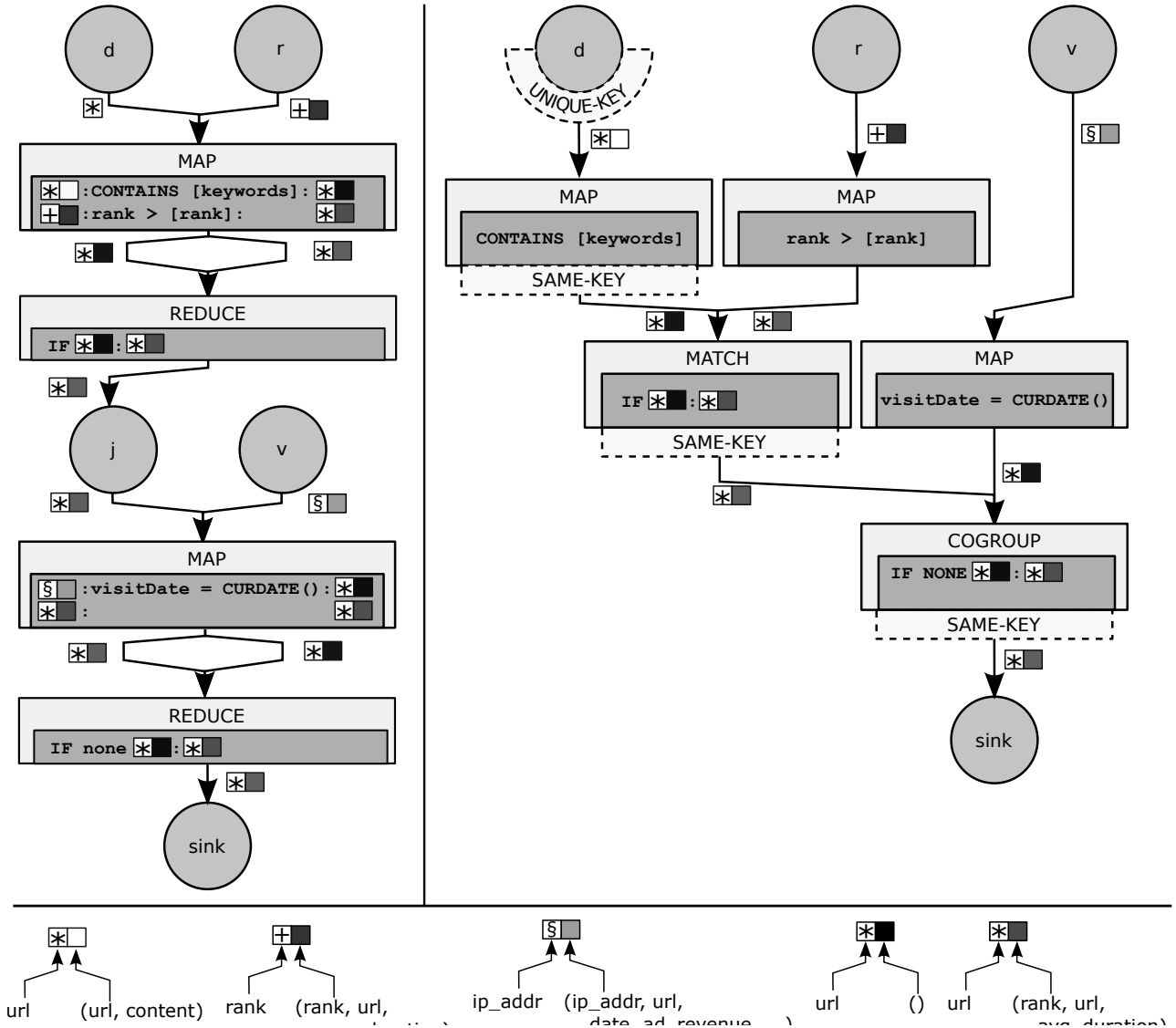
Hadoop and Stratosphere Job


```
SELECT * FROM Documents d JOIN Rankings r ON r.url = d.url
WHERE CONTAINS(d.text, [keywords]) AND r.rank > [rank]
AND NOT EXISTS (SELECT * FROM Visits v WHERE v.url = d.url
      AND v.visitDate = CURDATE());
```



- Battré et al. 2010. Nephele/PACTs: A Programming Model and Execution Framework for Web-Scale Analytical Processing

Hadoop and Stratosphere Job



Nephele

- Executes an Execution Graph
- Decides for each task how many instances are appropriate
- Assigns task instances to computation units
- Manages fault tolerance and adapts to changes

- Daniel Warneke and Odej Kao. 2009. Nephele: Efficient Parallel Data Processing in the Cloud

Sopremo and Simple

- High level language layer
- Simple = query language
- Sopremo = semi-structured data model (JSON) and operators
- Extensible operators for several use cases
- Text Mining, Data Cleansing, Data Mining

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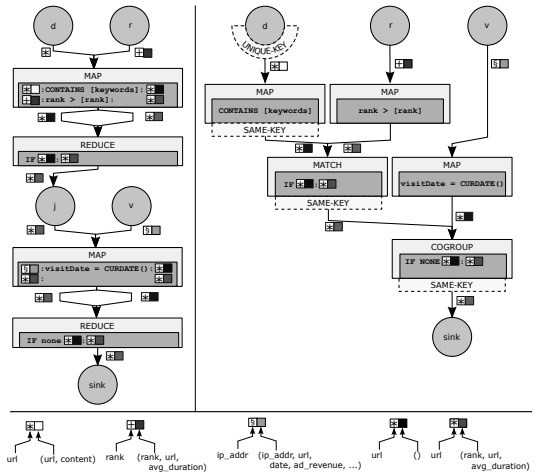
Data Analysis Program

Hadoop

- Driver program + multiple jobs
- Driver program manually connects input and outputs
- Fixed pipeline
- 1 Job = 1 Map + 1 Reduce

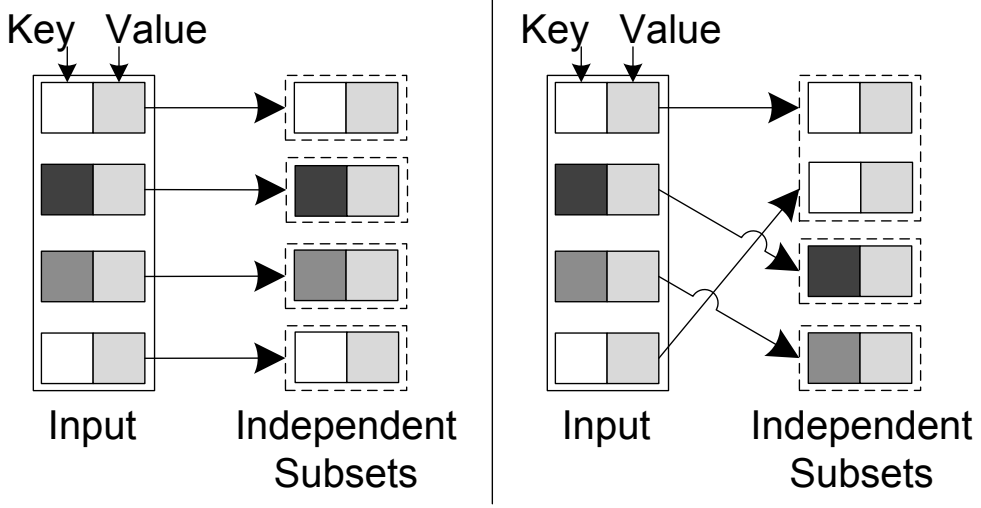
Stratosphere

- Directed acyclic graph of arbitrary Pacts
- Explicit data sources and sinks
- Pact also support two inputs (for join-like operations)



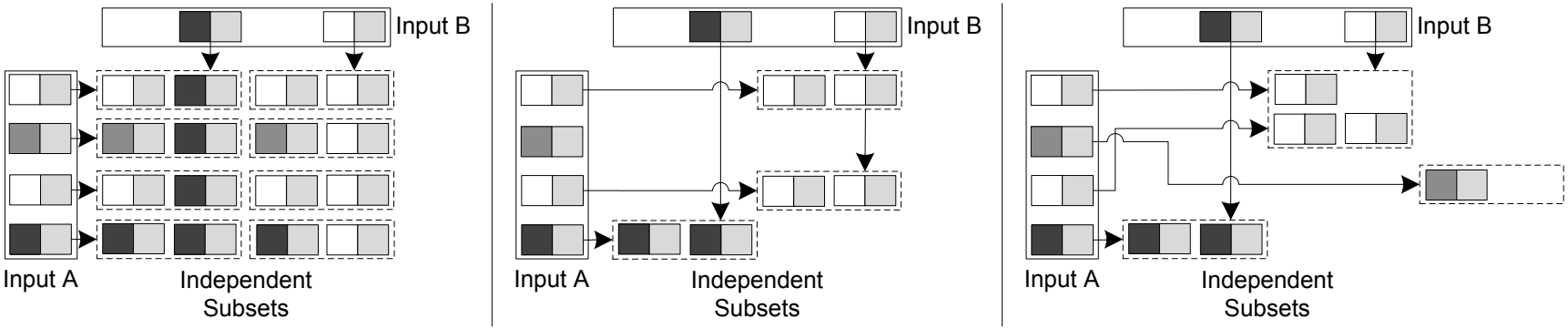
Map/Reduce in Stratosphere

- Works same as Hadoop
- But the semantics are interpreted differently
- Each Pact defines data dependencies
- Map: each tuple can be treated separately
- Reduce: tuple with same key are grouped and guaranteed to be processed by same reducer



Two Input Pacts

- Currently three additional Pacts for two inputs
- Cross: make all possible pairs
- Match: find all matching pairs
- CoGroup: group all matching tuples
- All pairs/groups are treated independently

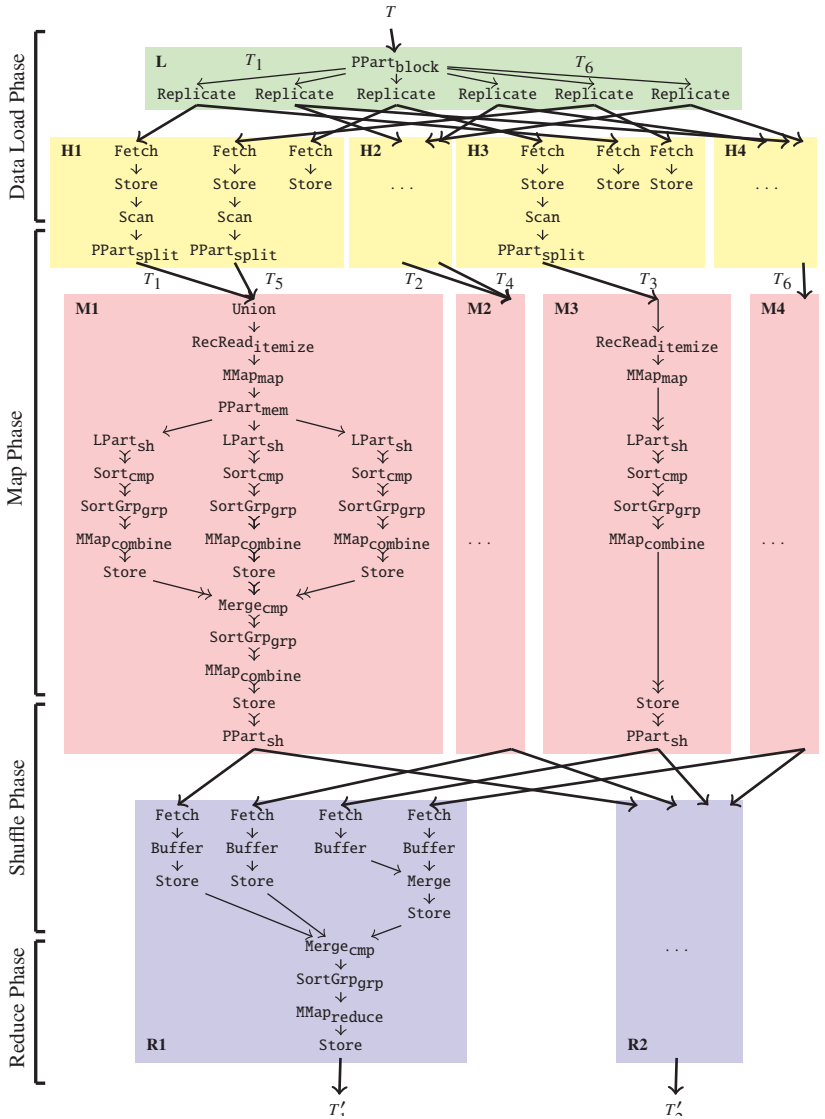


Comparison

Hadoop

- Often workarounds necessary in a complex M/R program
- Error-prone, re-occurring manual data partitioning
- Pattern evolved for joins etc. (Data mining book)
- Fixed pipeline allows fine-grain tweaks (exploits)

Comparison


Data Load Phase
Map Phase
Shuffle Phase
Reduce Phase
T
L
T1
PPartblock
T6
Replicate
H1
H2
H3
H4
Fetch
Store
Scan
PPartsplit
M1
M2
M3
M4
Union
RecReaditemize
MMapmap
PPartmem
LPartsh
Sortcmp
SortGrpgrp
MMapcombine
Mergecmp
PPartsh
Buffer
Merge
MMapreduce
R1
R2
T'

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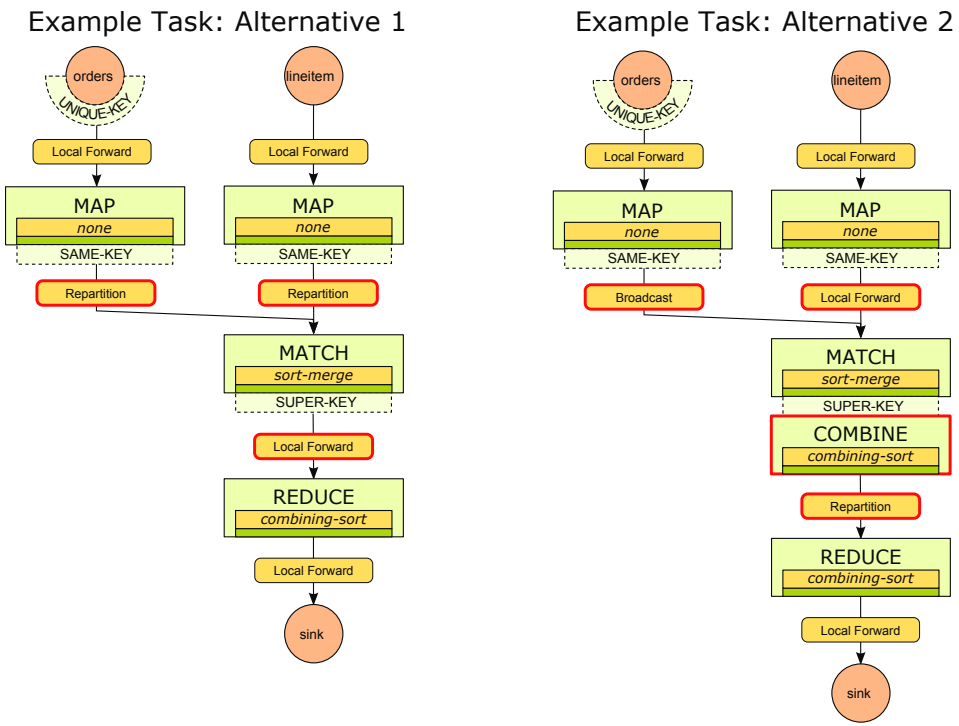
Stratosphere

- More expressiveness for complex data operations
- Maintains dataflow semantics to some degree
- Allows optimization and different shipping strategy
- Less hooks than Hadoop

Optimization

- Inspired by traditional query optimization
- Choose best join/shipping strategy for plan



- Reorder Pacts

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Switch to Tuple-based Model

- Bleeding Edge! Check pact-examples subproject
- Typical Hadoop job:
  - Map: transforms/filters data, sets key
  - Reduce: combines data, unsets key
- Preceding maps limit reordering

Switch to Tuple-based Model

- Bleeding Edge! Check pact-examples subproject
- Typical Hadoop job:
  - Map: transforms/filters data, sets key
  - Reduce: combines data, unsets key
- Preceding maps limit reordering

- Stratosphere uses tuples instead of k/v-pairs
- User should set keys as soon as possible for ALL Pacts
- Each Pact is annotated to define the "key"

Reduce Example


```
1  public static class CountWords extends ReduceStub {
2    public void reduce(Iterator<PactRecord> records,
         Collector out){
3      PactRecord element = null;
4      int sum = 0;
5      while (records.hasNext()) {
6        element = records.next();
7        PactInteger count =
8          element.getField(1, PactInteger.class);
9        sum += count.getValue();
10     }
11
12     element.setField(1, new PactInteger(sum));
13     out.collect(element);
14   }
15 }
16 ...
17 ReduceContract reducer = new ReduceContract(
18     CountWords.class, // <-- UDF
19     PactString.class, // <-- key class
20     0, // <-- key index
21     mapper); // <-- input
```

PactRecords Semantics

- List of fields = keys or values
- Fields that are used as keys need to implement Key
- Maintains serialized form as long as possible, lazy deserialization
  - Fields are only deserialized when read
  - Serializes only written fields
  - Needs type of field to deserialize
- Very efficient storage of null values
- $\Rightarrow$ Use a separate field for each key in your code

Word Count Example

- Wrap Pact Stubs in Pact Contracts
- All pacts except source specify their input

```
1  String dataInput = ...;
2  FileDataSource source = new FileDataSource(
3      LineInFormat.class, dataInput, "Input Lines");
4  MapContract mapper = new MapContract(
5      TokenizeLine.class, source, "Tokenize Lines");
6  ReduceContract reducer = new ReduceContract(
7      CountWords.class, PactString.class, 0, mapper,
8      "Count Words");
9  FileDataSink out = new FileDataSink(
10     WordCountOutFormat.class, output, reducer,
11     "Word Counts");
```

Word Count Example

- Input format needs to be parsed in any case
- Here we could already split lines and omit map
- In this case, we emit a PactRecord with 1 field
- Reuse objects to minimize garbage collection

```
1  public static class LineInFormat extends
       DelimitedInputFormat {
2    private final PactString string = new PactString();
3
4    public boolean readRecord(PactRecord record, byte[] line,
         int numBytes) {
5      this.string.setValueAscii(line, 0, numBytes);
6      record.setField(0, this.string);
7      return true;
8    }
9  }
```

Word Count Example

- Implicit semantic of fields

```
1  public static class TokenizeLine extends MapStub {
2    private final PactRecord outputRecord = new PactRecord();
3    private final PactString string = new PactString();
4    private final PactInteger integer = new PactInteger(1);
5
6    private final AsciiUtils.WhitespaceTokenizer tokenizer =
7            new AsciiUtils.WhitespaceTokenizer();
8
9    @Override
10   public void map(PactRecord record, Collector collector) {
11     // get the first field (as type PactString)
12     PactString str = record.getField(0, PactString.class);
13
14     // tokenize the line
15     this.tokenizer.setStringToTokenize(str);
16     while (tokenizer.next(this.string)) {
17       // we emit a (word, 1) pair
18       this.outputRecord.setField(0, this.string);
19       this.outputRecord.setField(1, this.integer);
20       collector.collect(this.outputRecord);
21     }
22   }
23 }
```

Word Count Example


```
1  @Combinable
2  public static class CountWords extends ReduceStub {
3    private final PactInteger theInteger = new PactInteger();
4
5    @Override
6    public void reduce(Iterator<PactRecord> records,
         Collector out) throws Exception {
7      PactRecord element = null;
8      int sum = 0;
9      while (records.hasNext()) {
10       element = records.next();
11       PactInteger i =
12         element.getField(1, PactInteger.class);
13       sum += i.getValue();
14     }
15
16     this.theInteger.setValue(sum);
17     element.setField(1, this.theInteger);
18     out.collect(element);
19   }
20 }
```

Word Count Example


```
1  public static class WordCountOutFormat extends
       FileOutputFormat {
2    private final StringBuilder buffer = new StringBuilder();
3
4    @Override
5    public void writeRecord(PactRecord record) throws
         IOException {
6      this.buffer.setLength(0);
7      this.buffer.append(
8        record.getField(0, PactString.class));
9      this.buffer.append('␣');
10     this.buffer.append(
11       record.getField(1, PactInteger.class).getValue());
12     this.buffer.append('\n');
13
14     byte[] bytes = this.buffer.toString().getBytes();
15     this.stream.write(bytes);
16   }
17 }
```

Composite Keys

- Reduce, CoGroup, and Match use keys
- May be composed of more than one field
- Useful for block identifier: separate row and column

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- Reduce, CoGroup, and Match use keys
- May be composed of more than one field
- Useful for block identifier: separate row and column

- Assuming a block is a three-tuple (row, column, data):

```
1  ReduceContract reducer = new ReduceContract(MergeBlocks.
       class,
2      new Class[] { PactInteger.class, PactInteger.class },
           // <-- key classes
3      new int[] { 0, 1 }, // <-- key indizes
4      mapper); // <-- input
```

Comparison to Key/Value-Pairs

- Key/value-pairs easier to understand
- May use generic syntax to check compatibility
- Implicit type specification through generics

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- Tuple-based is more flexible, especially for optimization
- Pays quickly off in more complex tasks
- More convention based, field semantic less clear
- UDF more verbose, especially when reusing objects
  $\Rightarrow$ Work on class mapping, HLL uses schema inference
- Generalization of k/v-pairs, may simulate k/v

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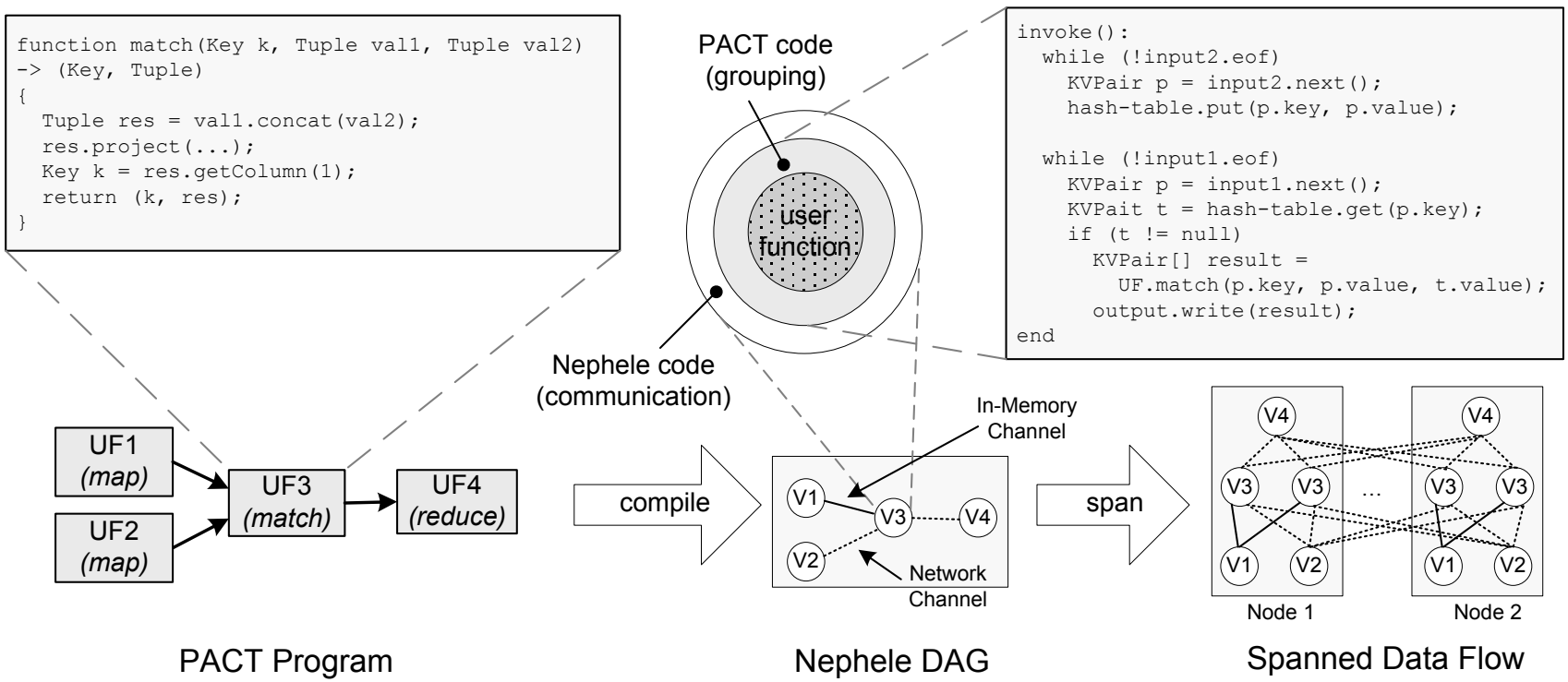
Separate Execution Engine

- Nephele and Pact together are equivalent to Hadoop
- Nepehle may be used by itself for fine-grain data management
- However, decoupling may loose some optimization potential

Separate Execution Engine

- Nephele and Pact together are equivalent to Hadoop
- Nepehle may be used by itself for fine-grain data management
- However, decoupling may loose some optimization potential
- UDF is wrapped in Pact and Nephele code



Dynamic Resource Allocation

- Hadoop works best on cluster environment
- Stratosphere also targets a true cloud environment
- Computation units may be dynamically booked and released

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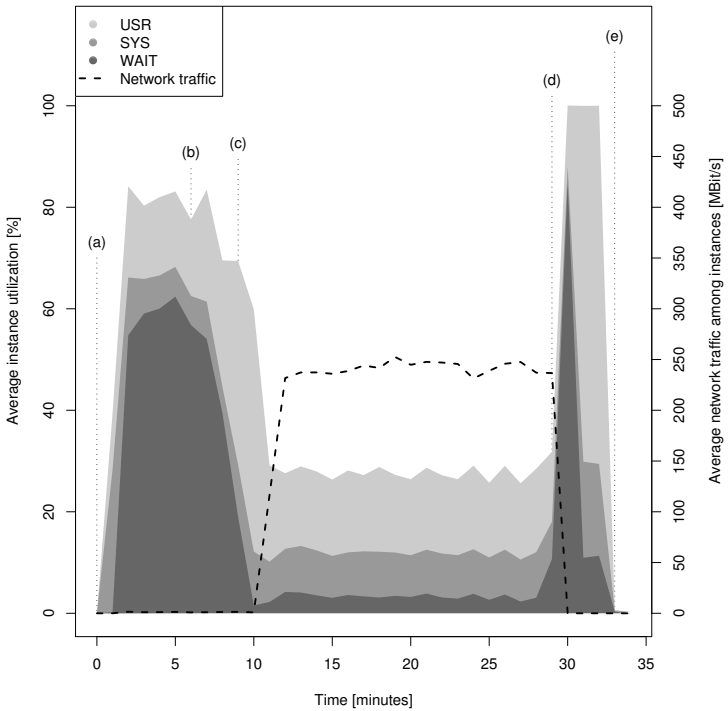
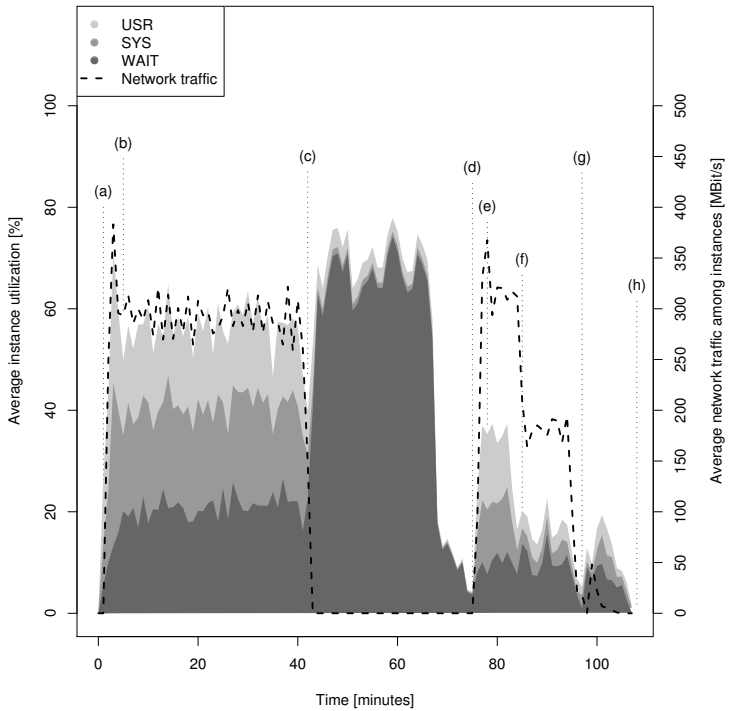
- Hadoop works best on cluster environment
- Stratosphere also targets a true cloud environment
- Computation units may be dynamically booked and released
- Aggregate the smallest 20% numbers, Nephele (l), Hadoop (r)





Continuous Reoptimization

- Stratosphere wants to optimize plans
- However, environment (cloud or cluster) is not stable
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- Start with **robust** initial plan
- Adapt and optimize during **runtime**

Smart Checkpointing

- (Work in Progress)
- Hadoop materializes all results
- Very good for fault-tolerance
- A crashed computation unit may be immediately replaced

Smart Checkpointing

- (Work in Progress)
- Hadoop materializes all results
- Very good for fault-tolerance
- A crashed computation unit may be immediately replaced
- However, often bad for runtime performance

- Stratosphere materializes only data when meaningful
- Mostly, when materialization is cheaper than recalculation
  - Will materialize result of computation-intensive taks
  - Will not materialize cartesian products

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Get Stratosphere Running

- `https://www.stratosphere.eu/register/register`
- Write me email to be unlocked for stage1
- Install git and maven2
- `mkdir/cd stratosphere`
- `git clone https://stratosphere.eu/git/stage1.git .`
- `git checkout -b version02 remotes/origin/version02`
- `mvn install`
- `http://www.stratosphere.eu/projects/Stratosphere/wiki/GettingStarted`
- Start local mode
- Get word count running

Port Hadoop to Stratosphere

- Meeting on 01/10/2012
- Conceptual port should be completed
- Implementation started
- Write email when troubled
- Write tickets if bug was found
- Help other teams, write to sdaa mailinglist

- Who uses joins, composite keys?

Cluster Times

- Proposal: for the next 6 weeks, every group gets a fixed day
- Thursday 6pm – Monday 6pm
- Time slots are flexibly tradable
- Announce start/end on cluster mailinglist

Final presentations

- May be rescheduled if everybody agrees
- First part should be similar to Hadoop talk
- Second part should include detailed benchmark and comparison
- State what you will additionally evaluate until report

Report

- Two column format (sig-alternate.cls)
- 6–8 pages, max. 2 appendix
- How did you change the original algorithms?
- Which design decisions did you make?
- Focus on important, interesting evaluations
- What results did you get? Are they making sense?
- How would you improve the algorithm for better runtime/results?
- No code, only conceptional