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Modeling Big Data Systems by Extending the Palladio Component Model
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Agenda

• Motivation

• Development Process and Characteristics of Big Data Systems

• Palladio Component Model (PCM) Meta-model Extension

• Related Work

• Conclusion and Future Work
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Motivation

- Various big data technologies with different characteristics
- Casado and Younas (2015) list two main techniques that are common for big data systems, namely, batch and stream processing
Motivation

• The added value of big data systems for organizations depends on the performance of such systems (Barbierato et al. 2014)

• Performance models allow for proactive evaluations of these systems

• Existing performance meta-models for big data systems, however, focus on either ...

  … one processing paradigm such as stream processing  
  e.g., Ginis and Strom (2013)  

  … or one technology such as Apache Hadoop MapReduce  
  e.g., Ge et al. (2013)

• We propose a general performance meta-model to specify shared characteristics of big data systems
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Development Process of Big Data Systems

Component developers

- Batch processing (e.g., using Apache MapReduce)

```java
public void map(Object key, Text value, ..){
    StringTokenizer itr = new StringTokenizer(value.toString());
    while (itr.hasMoreTokens()) {
        word.set(itr.nextToken());
        context.write(word, one);
    }
}
```

```java
public void reduce(Text key, Iterable<IntWritable> values,..){
    int sum = 0;
    for (IntWritable val : values) {
        sum += val.get();
    }
    result.set(sum);
    context.write(key, result);
}
```

- Stream processing (e.g., using Apache Storm)

```java
public void execute(Tuple tuple, BasicOutputCollector collector) {
    String word = tuple.getString(0);
    Integer count = counts.get(word);
    if (count == null) count = 0;
    count++;
    counts.put(word, count);
    collector.emit(new Values(word, count));
}
```
Development Process of Big Data Systems

System deployers

- Resource environment (e.g., Apache YARN)
Characteristics of Big Data Systems

• We derive the following requirements of big data systems that we propose to implement based on the finding of previous work (Kroß et al. 2015)

1. Distribution and parallelization of operations
   • Component developers specify reusable software components consisting of operations using software frameworks like Apache Spark.
   • In doing so, they may specify, but also may not know the definite number of simultaneous and/or total executions of an operation.

2. Clustering of resource containers
   • System deployers specify resource containers with resource roles (e.g., master or worker nodes), link them to a mutual network and logically group them to a computer cluster.
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PCM Meta-model Extension

Service effect specification (SEFF) actions

PCM Version 3.4.1
### PCM Meta-model Extension

#### Resource environment

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<td>- PROCESSOR_SHARING</td>
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<td>- CLUSTER</td>
</tr>
<tr>
<td></td>
<td>- MASTER</td>
</tr>
<tr>
<td></td>
<td>- WORKER</td>
</tr>
</tbody>
</table>

#### Diagram:

- **Resource Environment**
  - **ResourceContainer** (`1` to `ResourceContainer` and `0..1` to `ClusterResourceSpecification`)
  - **ProcessingResourceSpecification** (`1` to `ResourceContainer`
  - **CommunicationLinkResourceSpecification** (`1` to `ResourceContainer`

**PCM Version 3.4.1**
PCM Meta-model Extension

Service effect specification (SEFF) diagram

Service effect specification (SEFF) diagram
PCM Meta-model Extension

Resource environment diagram

Cluster

Node1
- CPU
  Scheduling: Processor Sharing
  Number of Replicas: 1
  Processing Rate: 1000
  MTTF: 0
  MTTR: 0

- Cluster Resource Specification
  Action Scheduling: -
  Resource Role: Master

Node2
- CPU
  Scheduling: Processor Sharing
  Number of Replicas: 1
  Processing Rate: 1000
  MTTF: 0
  MTTR: 0

- Cluster Resource Specification
  Action Scheduling: -
  Resource Role: Worker

Node3
- CPU
  Scheduling: Processor Sharing
  Number of Replicas: 1
  Processing Rate: 1000
  MTTF: 0
  MTTR: 0

- Cluster Resource Specification
  Action Scheduling: -
  Resource Role: Worker

- Cluster Resource Specification
  Action Scheduling: Round Robin
  Resource Role: Cluster
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Related Work

• Ginis and Strom (2013) present a method for predicting the response time of stream processes in distributed systems

• Verma et al. (2011) introduce the ARIA framework which specifies on strategy scheduling of single Apache MapReduce jobs

• Vianna et al. (2013) propose an analytical performance model which focuses on the pipeline between map and reduce jobs

• Barbierato et al. (2013) and Ge et al. (2013) present modeling techniques for Apache MapReduce which allow to estimate response times only

• Castiglione et al. (2014) use Markovian agents and mean field analysis to model big data batch applications and to provide information about performance of cloud-based data processing architectures
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Conclusion and Future Work

• We introduced a modeling approach that allows to model essential characteristics of data processing as found in big data systems

• We presented to meta-model extensions for PCM ..
  …to model a computer cluster and
  …to apply distributed and parallel operations on this cluster

• We plan to ...
  … complete extending the simulation framework SimuCom
  … fully evaluate our extensions for up- and downscaling scenarios
  … automatically derive performance models based on measurement data
References


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