Big Data and Beyond

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Outline

- Who am I?
- CEDAR Project
  - Automated Reasoning
  - Big data
- Experiments with Big Data Technologies
- Beyond Today

Who Am I?

- **30 years of RnD experience** in AI Programming (Knowledge Representation, Automated Reasoning, AI Implementation Technology)
- **Directed cutting-edge research** projects both in **Industry** (MCC, DEC, ILOG, IBM) and **Academia** (U. of Texas, SFU, UCBL)
- **Contribution**
  - **innovative mathematics** for AI, KR, CLP (OSF Constraint Logic)
  - **efficient implementations** (LogIn, LIFE, WAM)

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CEDAR research areas – Automated Reasoning

- **Semantic Web**: proposing an alternative to mainstream (both formal logic and implementation)

- Experimenting with technology for scalable and distributed reasoning

- Data-as-Constraint paradigm

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CEDAR’s Approach to Big Data

- The CEDAR project deals with theoretical and experimental research related to Big Data
- The theoretical research focuses on:
  - parallel processing of distributed queries on large-scale datasets
  - intelligent data partitioning and distribution of data within and across clusters that consist of hundreds of nodes

CEDAR research areas - Big Data

  - optimization of complex queries (composed of several tens of joins)
  - building efficient architecture for processing distributed queries on large datasets
  - developing resource models for processing queries

- Experimenting with with Big Data technologies - mainly very large triplestores and parallel architectures (*Hadoop/Mapreduce* framework)

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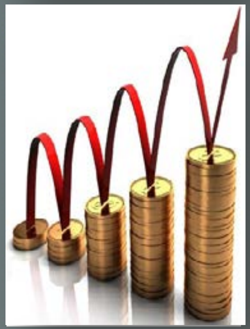
Experiments with Big Data Technologies

- For our experiments, we have focused on Hadoop/MapReduce due to its enormous popularity with Big Data processing
- For example, we experimented with two high-performance applications for processing queries on large-scale RDF datasets:
  - SHARD (BBN technologies)
  - RDFPig (U. of Amsterdam and Yahoo!)
- We used the LUBM data generator for creating datasets.



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- Experiments with Big Data Technologies
  - What did we learn?
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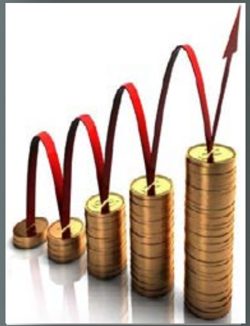
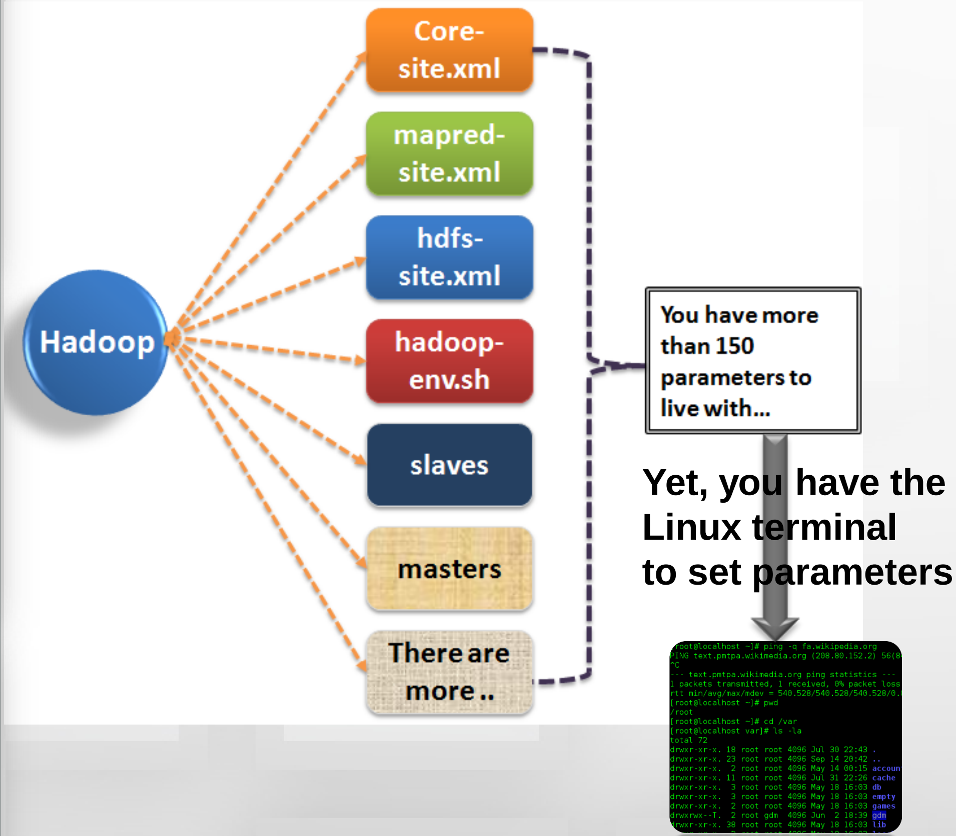


Experiments with Big Data Technologies

- We discovered that Hadoop:
  - can provide a scalable infrastructure for processing Big Data
  - can be deployed on commodity hardware which is cost-effective
- But… Hadoop:
  - is not a “magic wand” to increase performance (tricky to get optimal # of nodes per cluster)
  - does not give the user much freedom to customize the data distribution process
  - is very slow in reading data from secondary storage

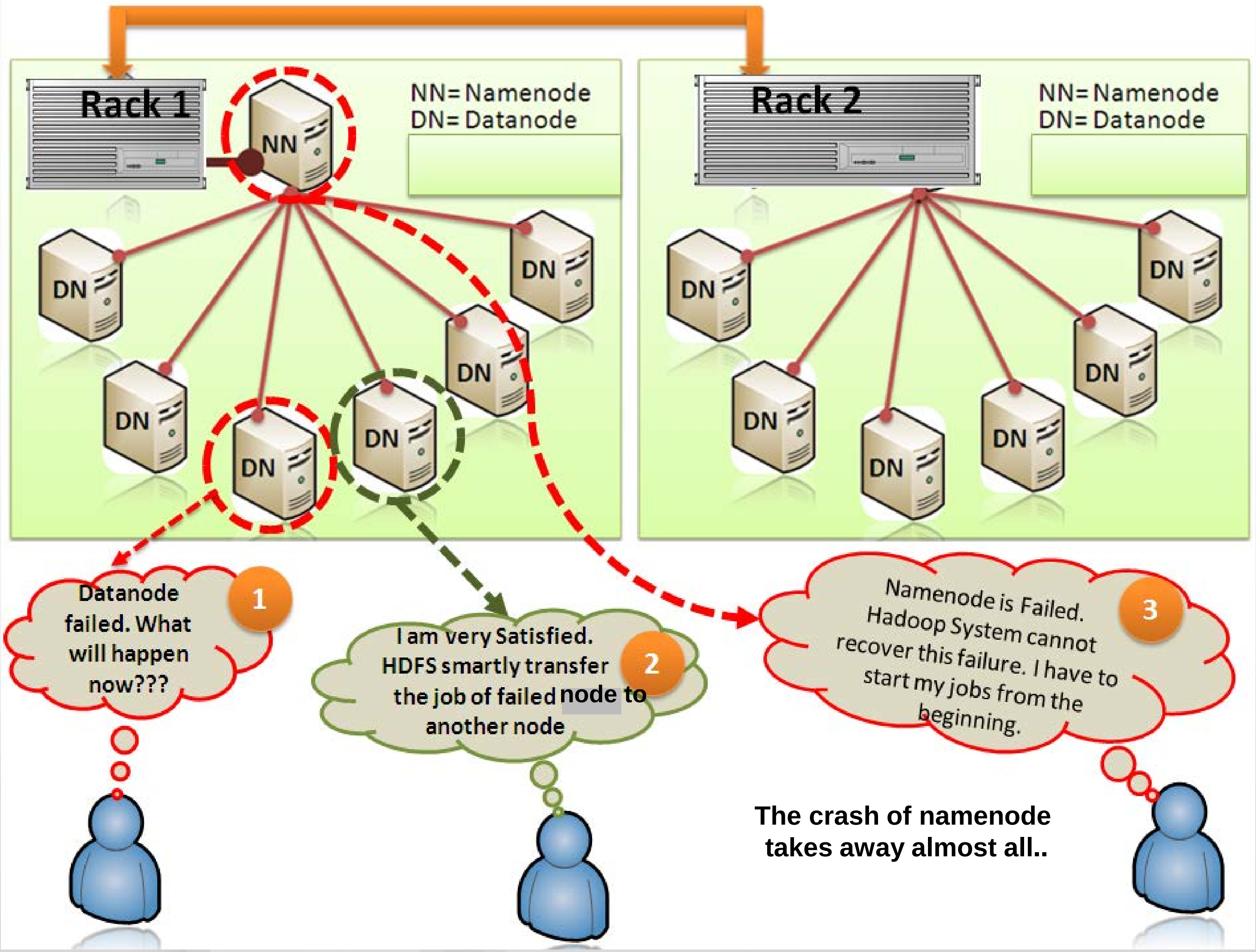
Experiments with Big Data Technologies



Our Painful Experience

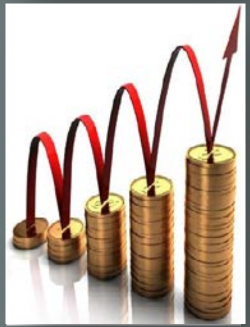
- The 20-node Hadoop cluster configuration with basic parameters on LIRIS-Cloud took 24 hours of exhausting work
- For 100-node clusters, we spent more than four weeks!
- The configuration tasks was more painful than we expected when data nodes crashed
- Datanodes crash **very often!**
- This means that data reloading due to crashes of data nodes must be redone all the time!

Experiments with Big Data Technologies



ERGO:

Big Data processing is in dire need of innovative, efficient, effective, and flexible architectures and techniques



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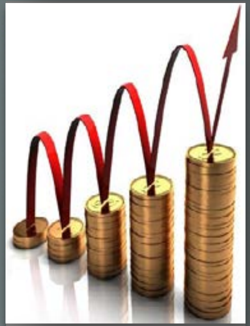
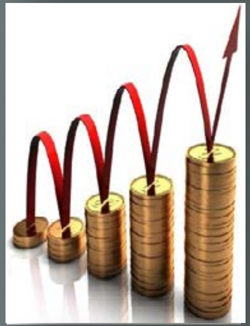


Beyond Today

Design “*HadoopGnX*” to meet the demands of twenty-first century’s users by building tomorrow’s technologies that are innovative, intelligent, reliable, secure, efficient, scalable, and easy to use and maintain

Beyond Today

- **Query Processing and Optimization**
  - Aggregated search algorithm
  - Adaptive search algorithm
  - Hybrid approach (composition of static and dynamic) for optimization of complex queries on big datasets

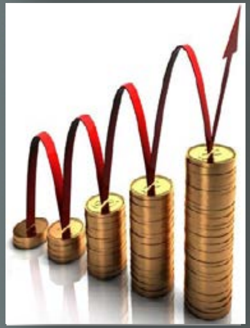


Beyond Today

- **Knowledge Discovery**
  - develop learning algorithms (*e.g.* Deep neural networks) for knowledge discovery in large-scale structured and semi-structured datasets
  - algorithm for high-quality information retrieval from unstructured data
- **System Architecture**
  - optimize computation power with minimum hardware
  - optimize CPU and memory utilization for multi-threaded job processing

Beyond Today

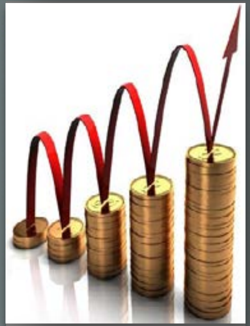
- **File System**
  - develop faster data reading from secondary storage
- **Resource Scheduling**
  - scheduling algorithms for efficient resource allocation
- **Resource Management**
  - dynamic data management within and across clusters of computation nodes
  - dynamic memory management for processing jobs (*e.g.* queries)

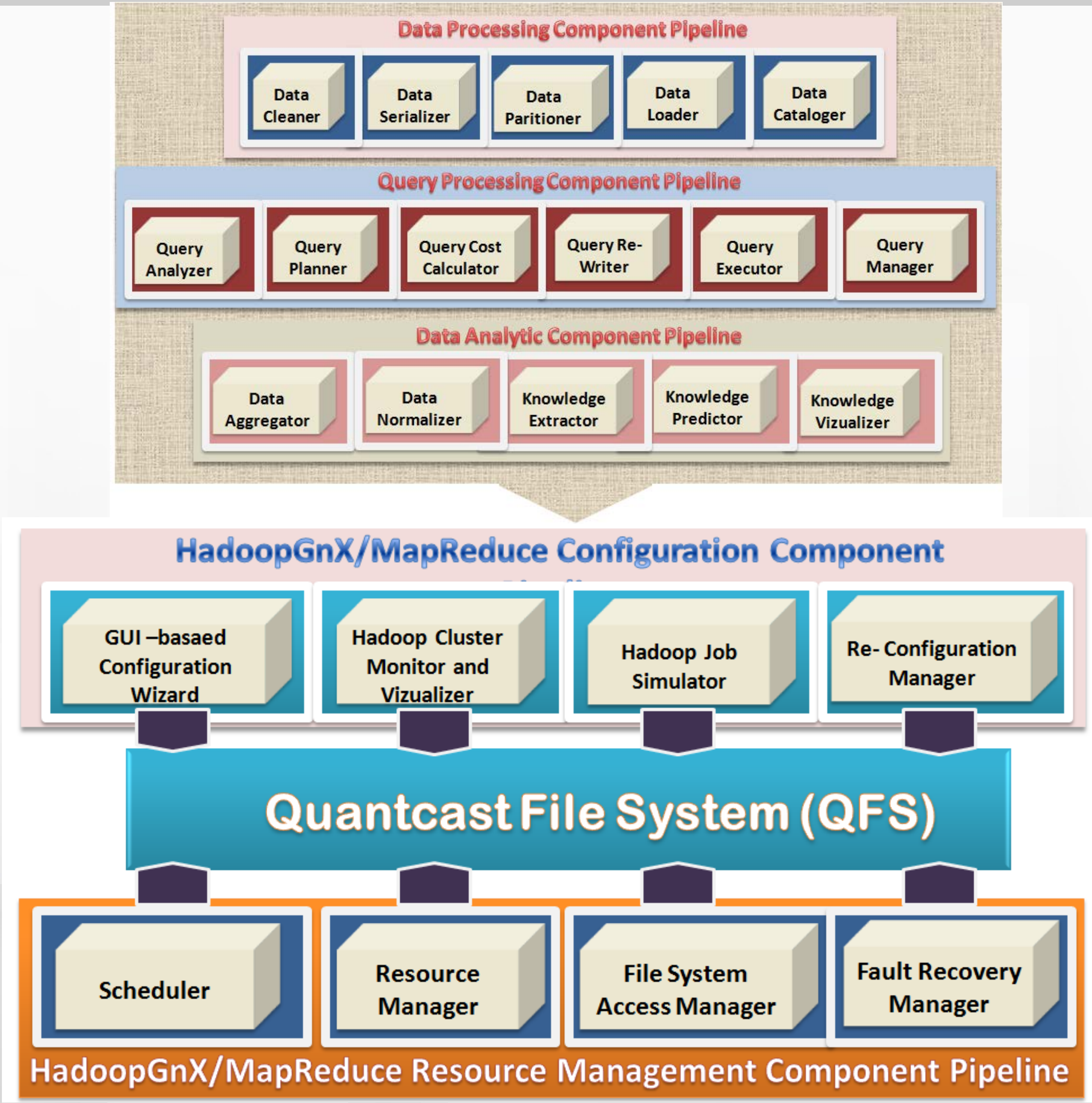


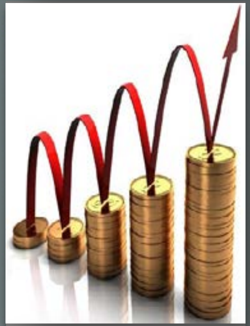
Beyond Today

- **Platform Configuration**
  - mathematical model for predicting required resources to build infrastructure (*e.g.* clusters) for deploying big data solutions
  - simulation of complex job processing on large and distributed datasets
  - user-friendly application environment for cluster configuration
  - dynamic reconfiguration of clusters to adapt various system architectures

Beyond Today – Product Pipeline







Beyond Today – Product Pipeline

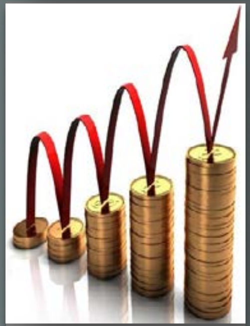
- **Quintcast File System (QFS)**
  - QFS is an open source distributed file system for large-scale batch processing improving on HDFS: data compression, faster disk reads, “Reed-Solomon error correction”, …
  - Adopt QFS in HadoopGnX instead of HDFS since it is faster

Beyond Today – Product Pipeline

- **Reengineering QFS:**
  - storage of structured, semi-structured and unstructured data
  - customize job execution environment (*e.g.*, different sizes of data blocks distributed in nodes across clusters)
  - compress data to minimize the size of the dataset
  - handle real-time workloads
  - build multi-layer Hadoop clusters to increase parallel execution of *jobs* rather than *tasks within jobs* as in the classical Hadoop

Beyond Today – Product Pipeline

- **Scheduler**
  - Follow a **"scheduling on-demand"** for HadoopGnX
  - Scheduler made of two modules:
    - **Job Scheduler**
    - **Resource Scheduler**



Beyond Today – Product Pipeline

- **Scheduler** (ctd.)

  - **Fair Scheduling**: resource-scheduling method for assigning resources to application so that all applications receive an equal share of resources (in particular main memory)
  - **Complex-Level Priority Scheduling** : scheduling resources for jobs by their level of complexity in particular: jobs with higher complexity level receive more resources
  - **Longest Processing Time Task First**
  - **Higher-ordered Tasks first Scheduling**

Beyond Today – Product Pipeline

- **Resource Manager**
  - Implement a resource manager that allocates resources specifically the data for Hadoop jobs
  - Implement an *interactive*, *self-managed*, and *flexible* Hadoop (*e.g.*, dynamic resource allocation)

- **Explore other processor layouts**
  - **Data Diffusion Machine** (DDM): scalable virtual shared memory architecture - (COMA, NUMA)
  - **Skewed-Associative Memory**: efficient memory indexing using several hash functions (speeds up data finding and therefore job processing)

Beyond Today – Product Pipeline

- **Fault-Handling Manager**
  - Self-healing architecture using a fault-handling manager capable of recovering the cluster in case of node failure
  - Flexible **multi-master/no-master** policy to prevent the loss of failing master node failure
  - Adopt the **Disruptor** job-scheduling pattern to build multi-master layouts
    - **Disruptor** enables assigning a new master node automatically upon failure of the running (current) one.

Beyond Today – Product Pipeline

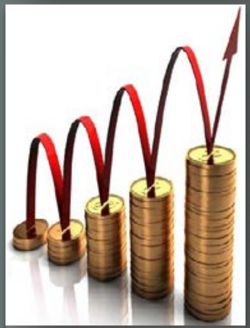
- **Data Processing Application**:
  - **Data Cleaner**: cleans data specifically if found redundant in the dataset
  - **Data Serializer**: converts data from one format to another
  - **Data Partitioner**: splitting data heuristics beyond *predicate-splitting, and object-splitting* (*e.g.*, skew-joins)
  - **Data Loader**: customize data-loading into distributed storage (thus taking the burden off Hadoop)
  - **Data Cataloger**: create a data catalog after loading data into storage

Beyond Today – Product Pipeline

- **Query Processing Application:**
  - **Query Analyzer**: clean up redundant data
  - **Query Cost Calculator**: estimate query evaluation costs
  - **Query Planner**: efficient distributed querying
  - **Query Rewriter**: query rewriting using the planned strategy
  - **Query Executor**: evaluate a given query across the nodes of clusters
  - **Query Manager**: manage queries during their lifetime

Beyond Today – Product Pipeline

- **Data Analytics Application:**
  - **Data Aggregator**: collect data from multiple sources for analysis
  - **Knowledge Extractor**: discover knowledge such as business knowledge from a large datasets
  - **Knowledge Predictor**: summarize prediction of operational and business knowledge
  - **Knowledge Visualizer**: display information on a dashboard that provides a comprehensive view of data



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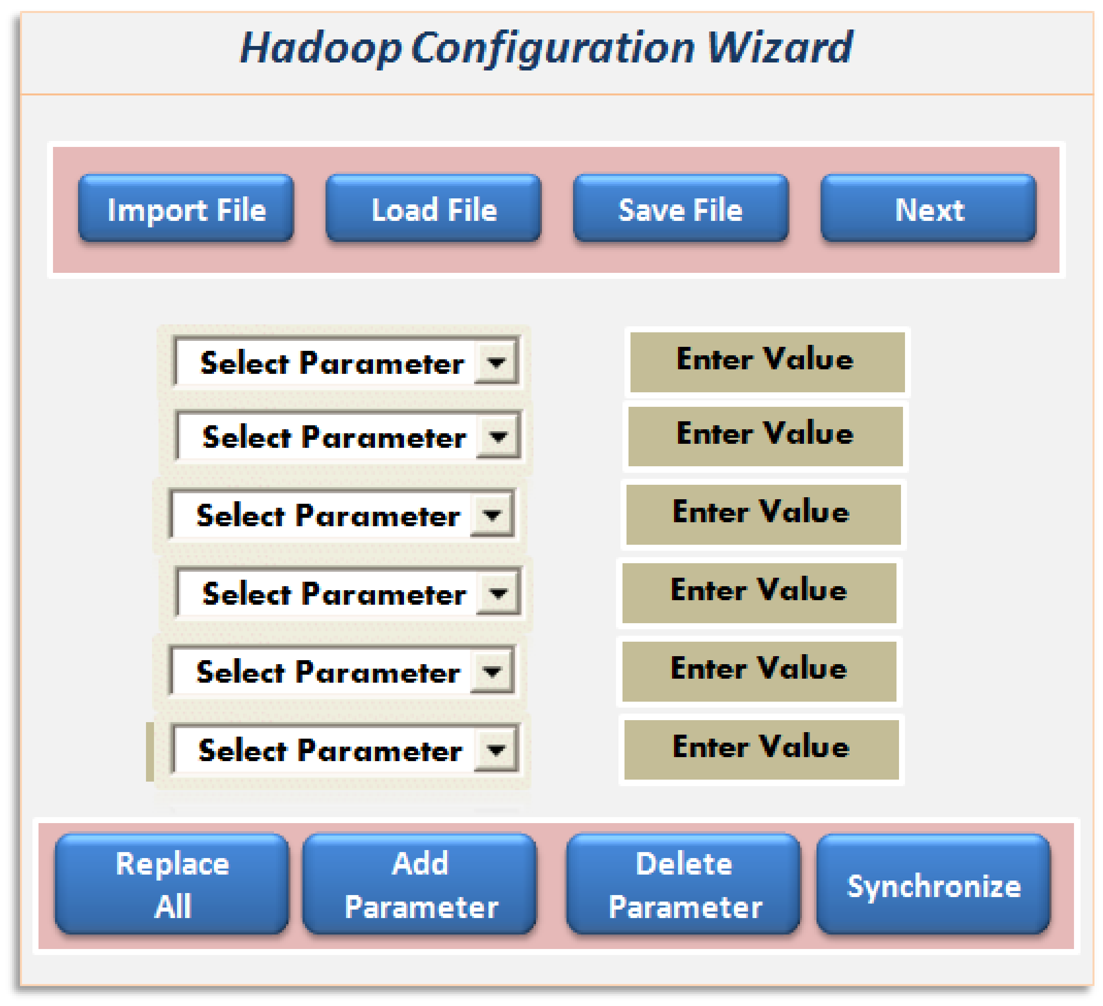
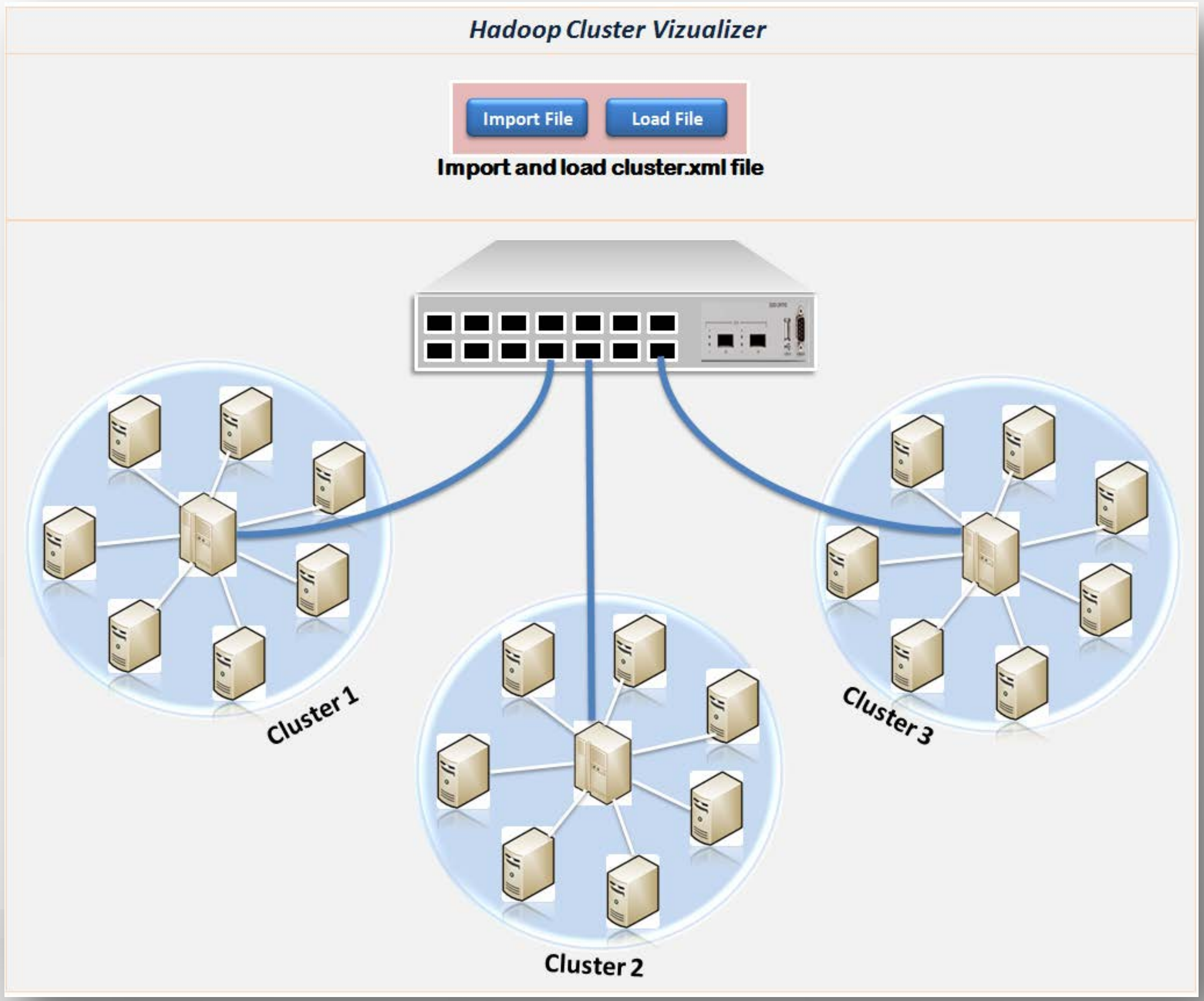


A sample of Hadoop configuration wizard

Beyond Today – Product Pipeline



A sample of Hadoop cluster vizualizer

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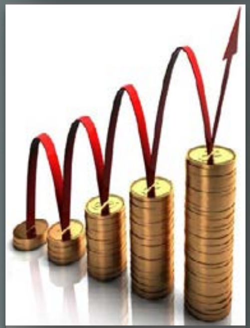

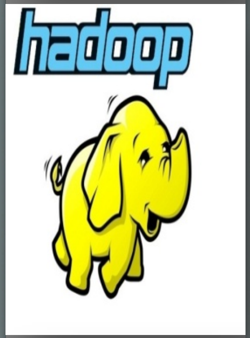

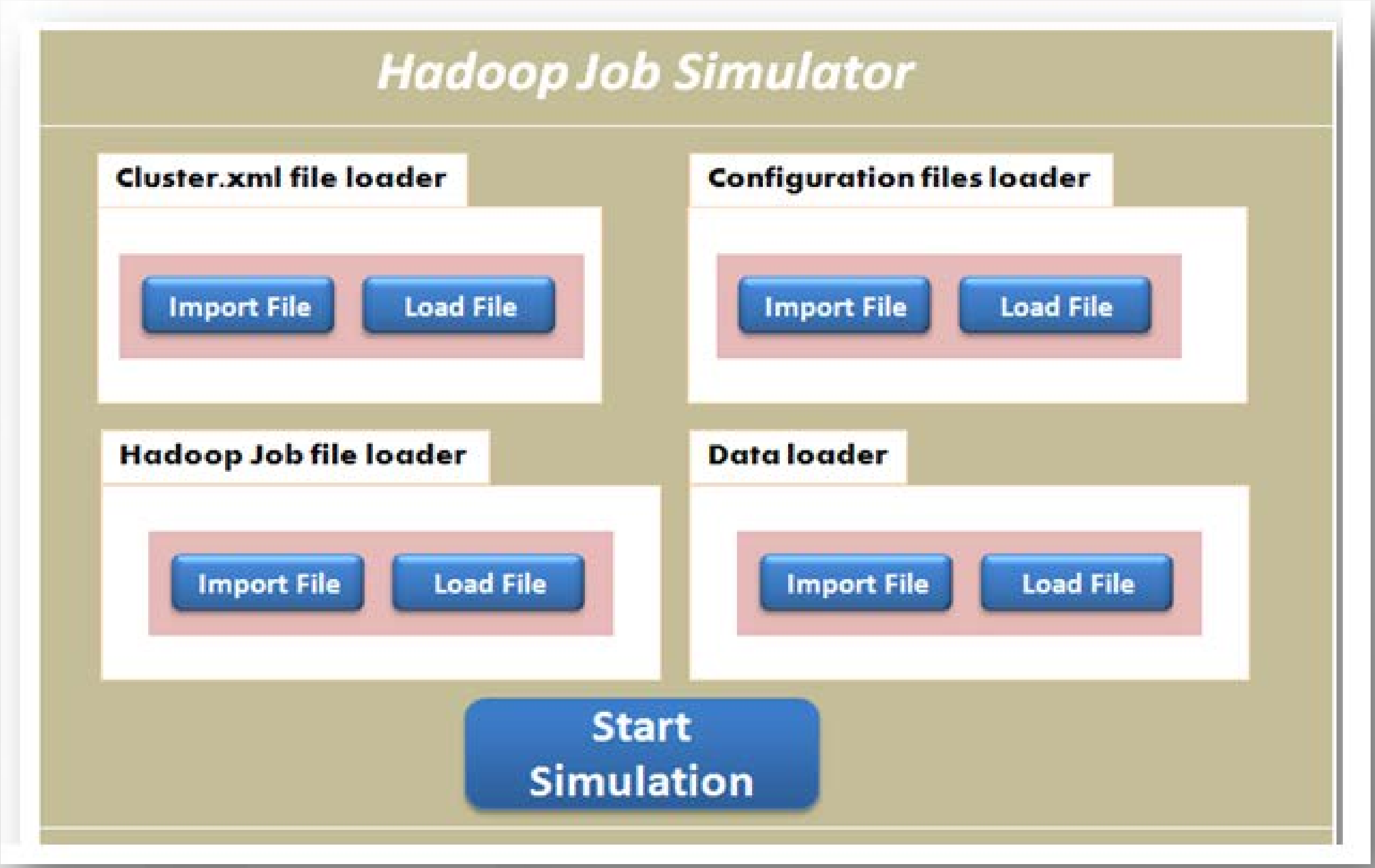

Example of Hadoop job simulator

Challenges

- **Need resources**: world-class theoretical computer scientists, applied computer scientists (mathematicians and implementers)
- **Leverage human network** of top quality scientists and engineers from all over the world.
- **France's potential**: excellence of research centers (LIX, ENS, INRIA, CNRS)

Our Strengths

- Through CEDAR, we have built a **solid foundation on Big Data** state of the art
- This has enabled us to **identify some critical issues and think up solutions** that are not available in the market
- The experience of CEDAR has comforted us in defining a **winning strategy for Big Data** research and applications

Conclusion

We are living exciting times!

- **Big Data** – sure! – **Big Knowledge too…**
- **Analytics and Reasoning:** the next step
- **Don’t follow the crowd:** Innovation is the key
- **We have many ideas** … but time is of the essence!

Links

- **CEDAR:**
  - **http://cedar.liris.cnrs.fr/**
- **PetaSky:**
  - **http://com.isima.fr/Petasky**

Thank You Very Much!