Computational Social Choice in the Cloud

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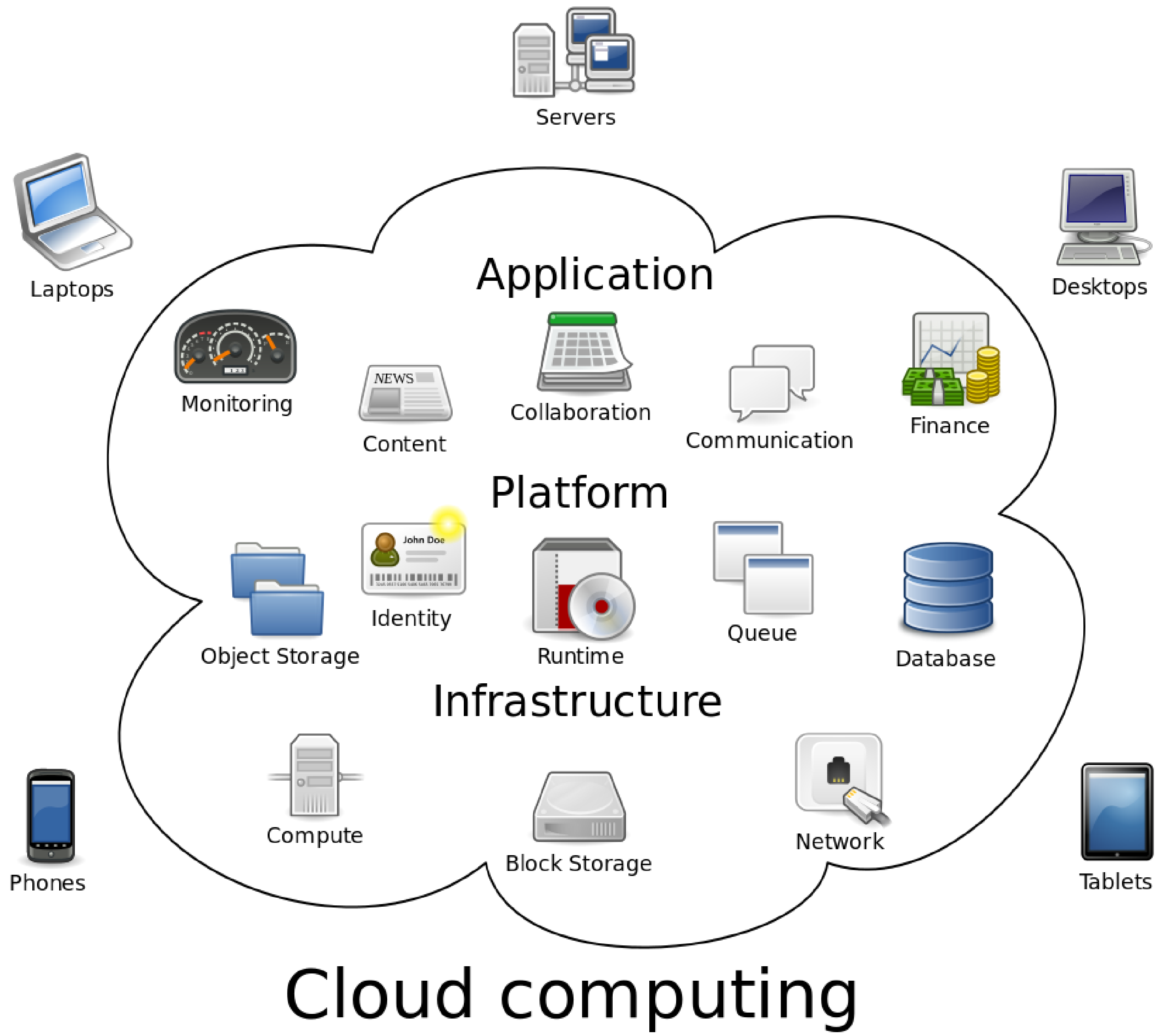
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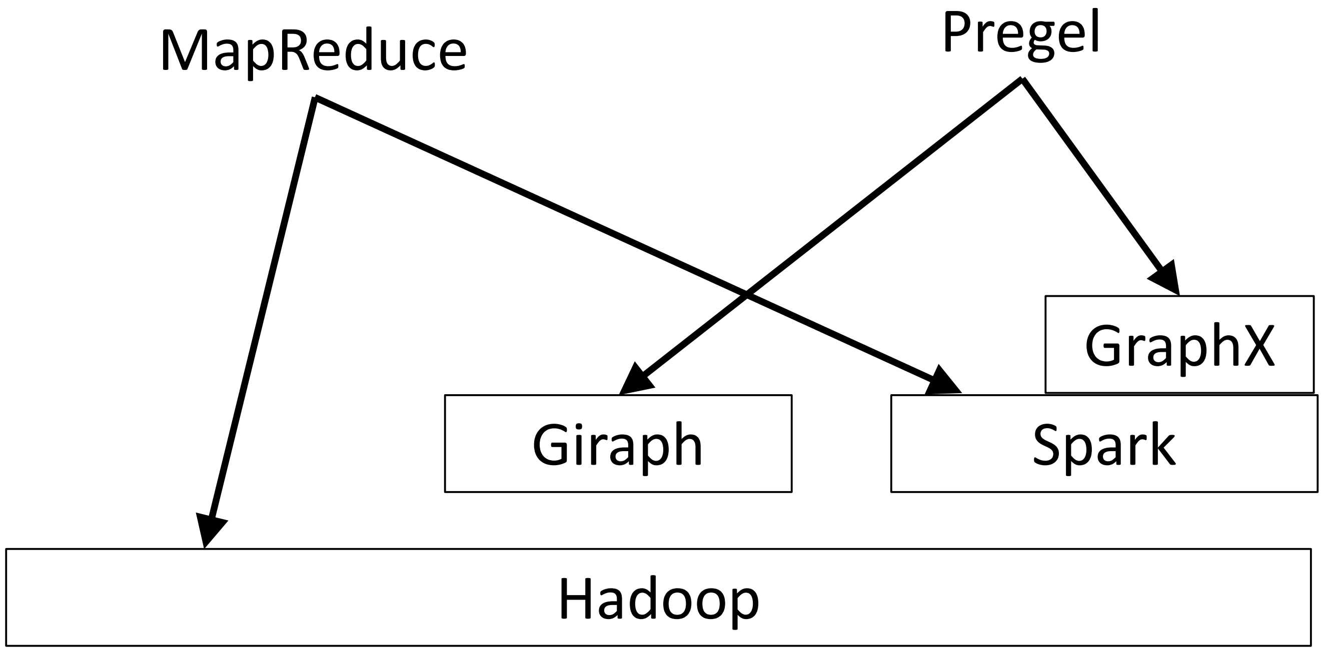
Cloud Computing Technologies



MapReduce

Map Phase

The input data is mapped to (key,value)-pairs

Shuffle Phase

The (key,value)-pairs are assigned to the reduce tasks

Reduce Phase

Each reduce task performs a simple calculation on all its values

What‘s an election?

Given as lists of preferences with n votes and m candidates.

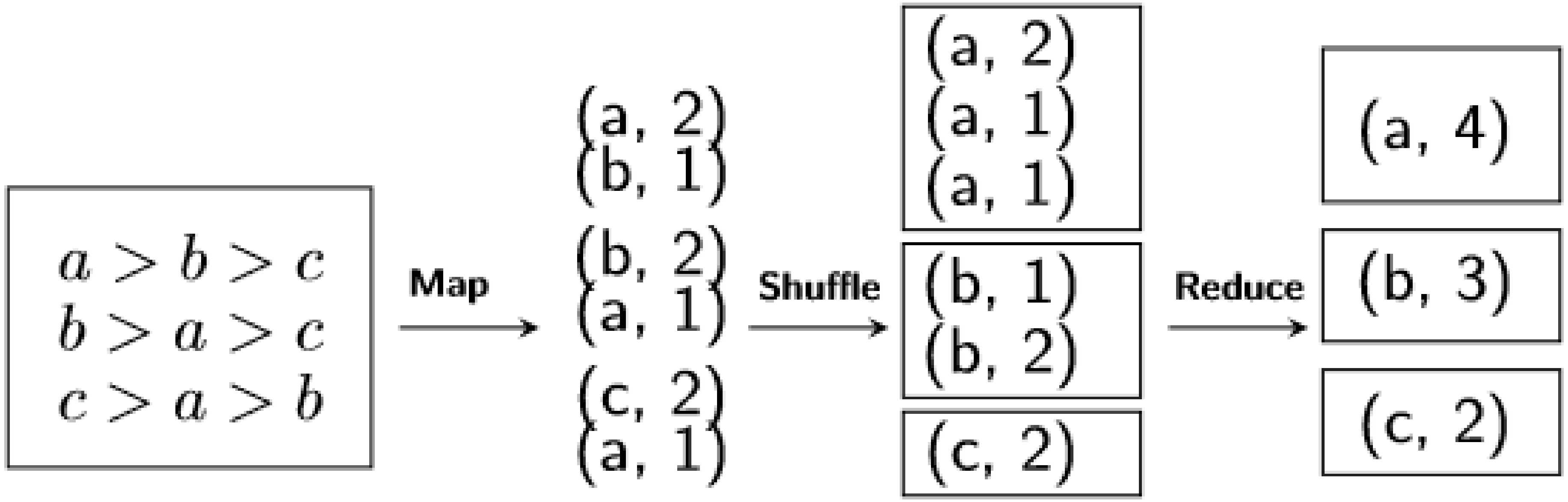
We are interested in finding the best candidate, or the set of best candidates.

MapReduce and Elections by Example

Given a set of $m = 3$ candidates a,b,c and n voters. Each voter provides a ranking of candidates, e.g.: $a > b > c$

Borda Scoring Rule: The candidate ranked first receives $m-1$ points, the second $m-2$ points, etc.

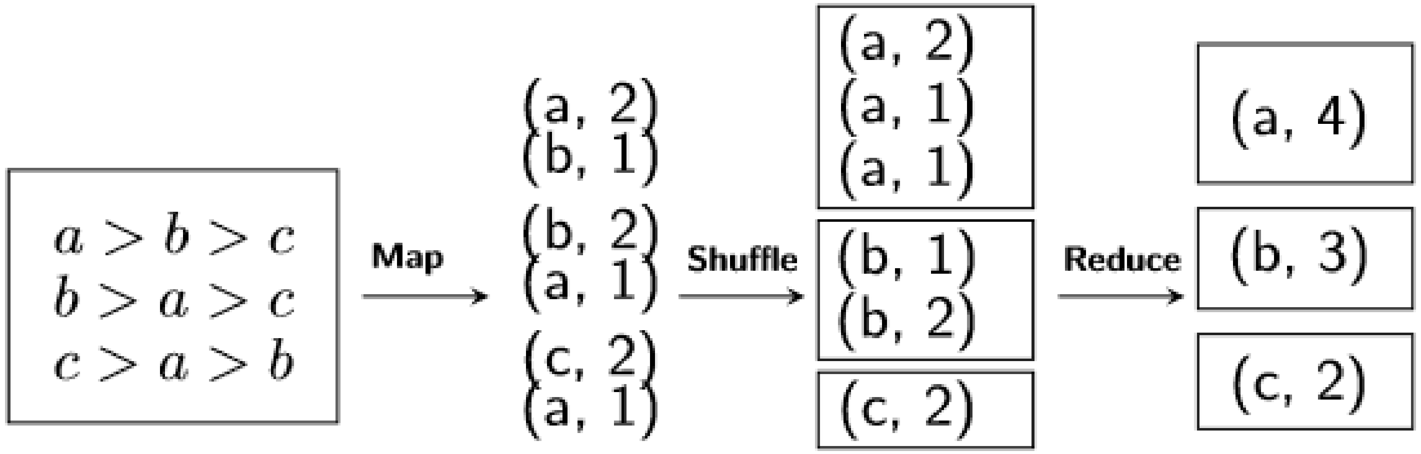
MapReduce and Elections by Example – Borda Scoring Rule



Performance Analysis of a Mapreduce Computation

- data replication rate (rr)
- number of MapReduce rounds
- number of keys / reduce tasks
- wall clock time (wct): the maximum time consumed by a single computation path in the parallel execution of the algorithm
- total communication cost (tcc): number of values transferred during the computation.

Performance –Borda Scoring Rule



The scores of all candidates given a scoring rule can be computed using MapReduce with the following characteristics:
rr = 1, # rounds= 1, # keys = m, wct ≤ n, and tcc ≤ mn.

Winner Determination in Elections

- **Scoring Rules:** Borda Scoring Rule, …
- **Copeland Set:** The Copeland set is based on Copeland scores. The Copeland score of candidate a is defined as $|\{b \in C : a > b\}| - |\{b \in C : b < a\}|$. The Copeland set is the set of candidates that have the maximum Copeland score.
- The **Smith set** is the (unique) smallest set of candidates that dominate all outside candidates.
- The **Schwartz set** is the union of minimal sets that are not dominated by outside candidates.

Winner Determination in Elections
Input Data

Preference-Lists (Scoring Rules)

- Number of Lists / Number of Votes
- Length of Votes / Number of Candidates

Dominance Graph (Smith Set, Copeland Set, Schwartz Set)

- Number of Candidates

Smith Set

Definition
Candidate a is in the Smith set if and only if for every candidate b there is a path from a to b in the weak dominance graph.

Brandt,Fischer and Harrenstein (2009) show that in the weak dominance graph a vertex t is not reachable from a vertex s if and only if there exists a vertex v such that D2(v) = D3(v), s ∈ D2(v), and t / ∈ D2(v).

→ In other words: We only need paths of length 3 to find the Smith Set

Smith Set Algorithm-sketch

- Preprocessing step (create needed datastructure)
- 2 MR-Rounds: to find paths of length 2 und 3 (or 4)
- Postprocessing: find vertices contained in the Smith set

Smith Set – Vertex Datastructure „Think like a vertex“

Each vertex saves three sets storing information on incoming and outgoing edges for a vertex a as follows:

- the set **old** stores all vertices that have been found previously to be reachable from a;
- the set **new** stores all vertices that have been found in the last map-reduce round to be reachable from a;
- the set **reachedBy** stores all vertices known to reach a;

Vertex Data Structure – in action

MapVertex

Input	Output
Vertex A	
new = {B}	(A,({B},"old"))
old = {}	
rB = {}	
Vertex B	(B,({C},"old"))
new = {C}	(B,({A},"rB"))
old = {}	(C,({A},"rB"))
rB = {A}	(A,({C},"new"))
Vertex C	
...	...

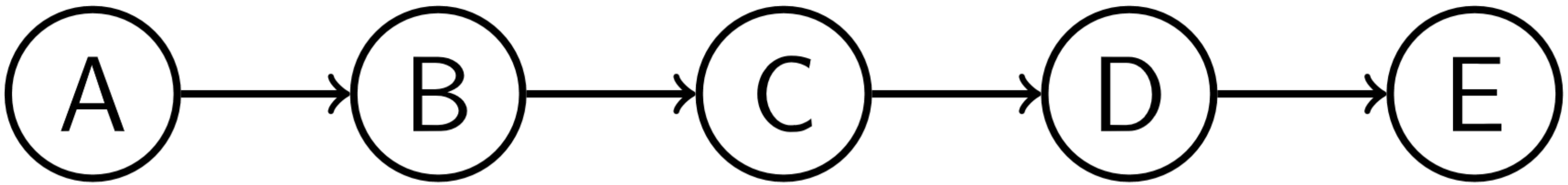
ReduceVertex A

Input	Output
(A,({B},"old"))	Vertex A
(A,({C},"new"))	new = {C}
	old = {B}
	rB = {}

ReduceVertex B

Input	Output
(B,({C},"old"))	Vertex B
(B,({A},"rB"))	new = {D}
(B,({D},"new"))	old = {C}
	rB = {A}

...



Experimental Design

- Mapreduce Java Implementation
  github.com/theresacsar/bigvoting
- Amazon Web Services (AWS) – Elastic Compute Cloud
- Synthetic Datasets
  - with varying number of candidates and edges in the dominance graph (m=7000 candidates and m2/10 edges)
  - up to 128 EC2 instances

Future Work – Exploring other Technologies

- Pregel (Giraph, GraphX) „Think like a vertex“
  - Pregel-like systems are better suited for iterative Graph computations
- Spark
  - Interactivity
  - Data is loaded in memory

Future Work

- Other Technologies
- Using real word data
  - Results from search engines
- Other Rules for Winner Determination

Thank you for listening!

ask questions now or send me an email csar@dbai.tuwien.ac.at ☺