Graph Processing with Pregel/Giraph

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Credits for the lecture material:
Pregel paper

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MapReduce is great!

- Adopted widely by Google and others for data analytics

- But, as it got popular user wanted more ….

Limitations of MapReduce

- Low-level abstraction for common data analysis tasks!
  - Pig [SIGMOD'10], Shark [SIGMOD'13], DryadLINQ [OSDI'08]
- Iterative algorithms
  - Haloop [VLDB'10], CIEL [NSDI '11]
- Stream processing – Low latency
  - D-stream [SOSP'13], Naiad [SOSP'13], Storm, S4
- Graph algorithms
  - Pregel [SIGMOD '10], GraphX [OSDI'14]

In today's class

1. How to do efficient graph processing?
   - Pregel/Giraph: A graph processing framework

Graphs are everywhere!

Social networks

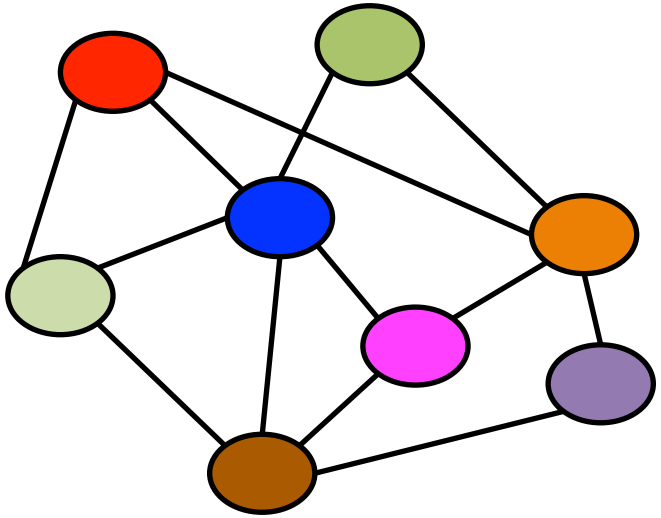
Web graph/search engine

E-commerce

Maps

Computational biology

Example: PageRank



Web graph

Example: PageRank

$$PageRank\ of\ site = \sum \frac{PageRank\ of\ inbound\ link}{Number\ of\ links\ on\ that\ page}$$

OR

$$PR(u) = (1-d) + d \times \sum \frac{PR(v)}{N(v)}$$

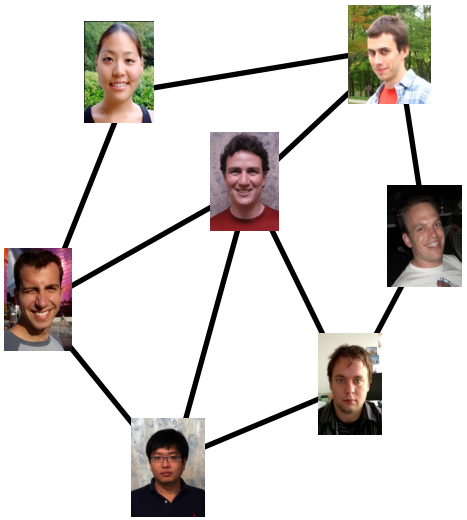
Rank of webpage *i*

Weighted sum of neighbors' ranks

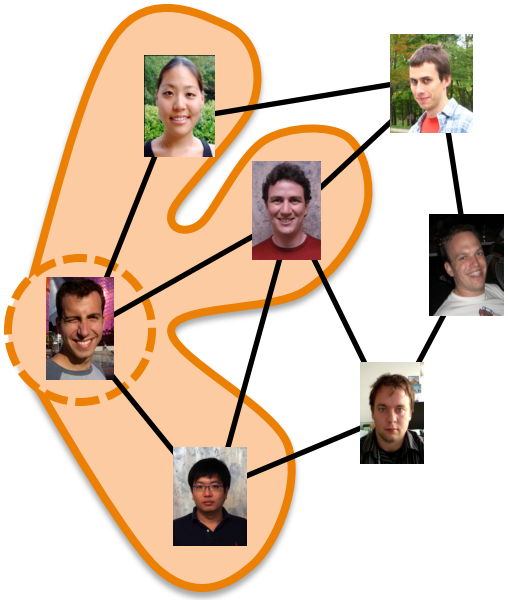
Iterate until it converges

Graph Parallel Algorithms

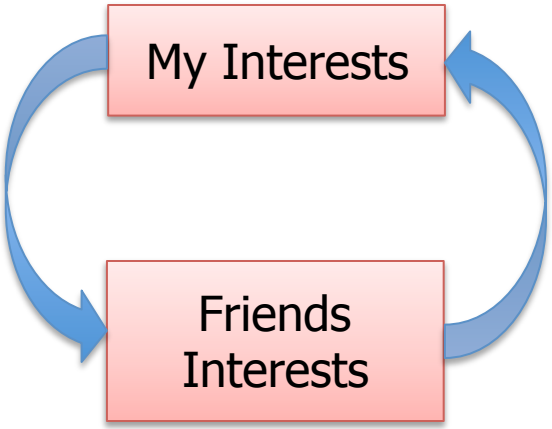
Dependency **Graph**



Local Updates



Iterative Computation



Many graph algorithms

Collaborative Filtering

- Alternating Least Squares
- Stochastic Gradient Descent
- Tensor Factorization

Structured Prediction

- Loopy Belief Propagation
- Max-Product Linear Programs
- Gibbs Sampling

Semi-supervised ML

- Graph SSL
- CoEM

Community Detection

- Triangle-Counting
- K-core Decomposition
- K-Truss

Graph Analytics

- PageRank
- Personalized PageRank
- Shortest Path
- Graph Coloring

Classification

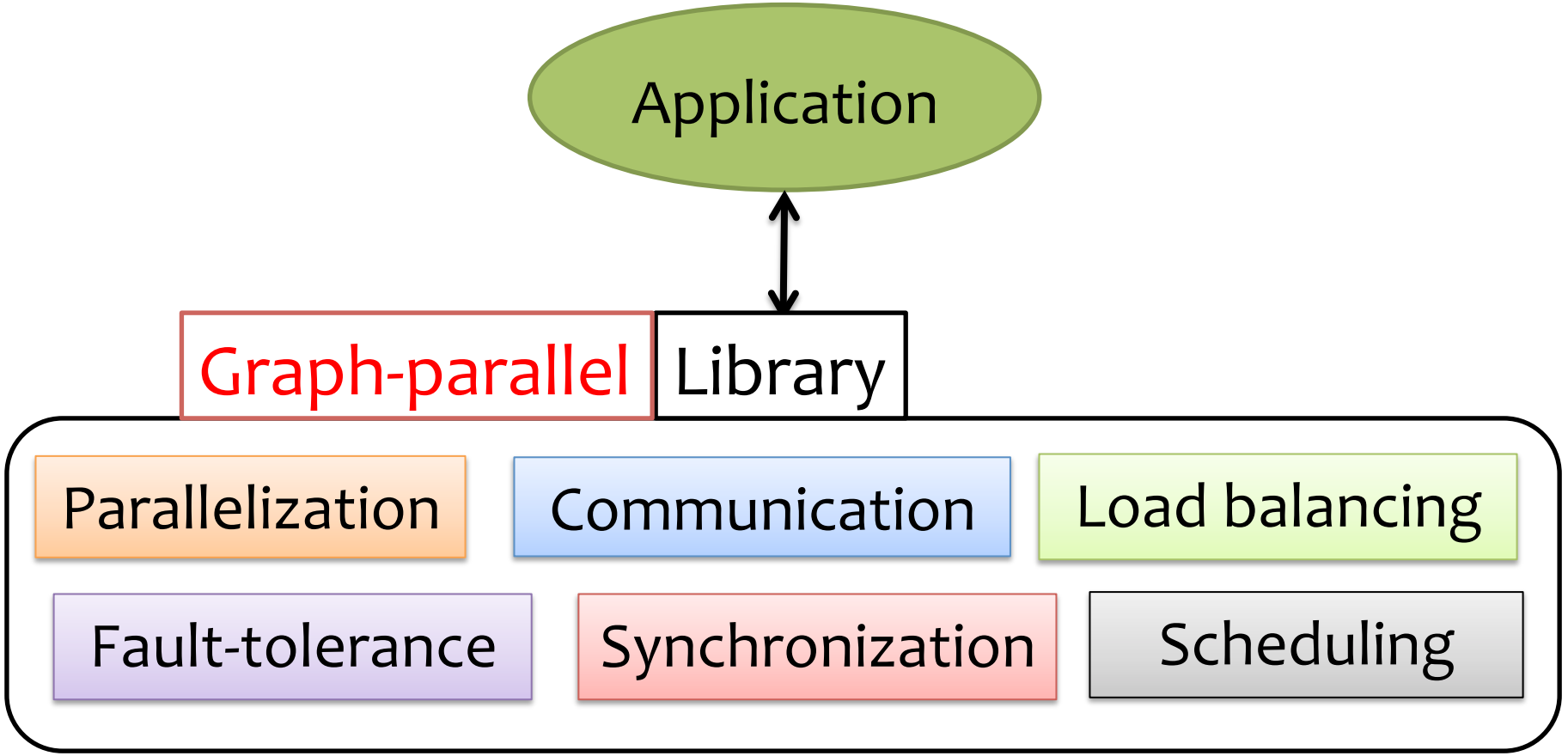
- Neural Networks

Graph processing framework

Pregel

oogle

Graph processing frameworks



Why do we need a new framework?

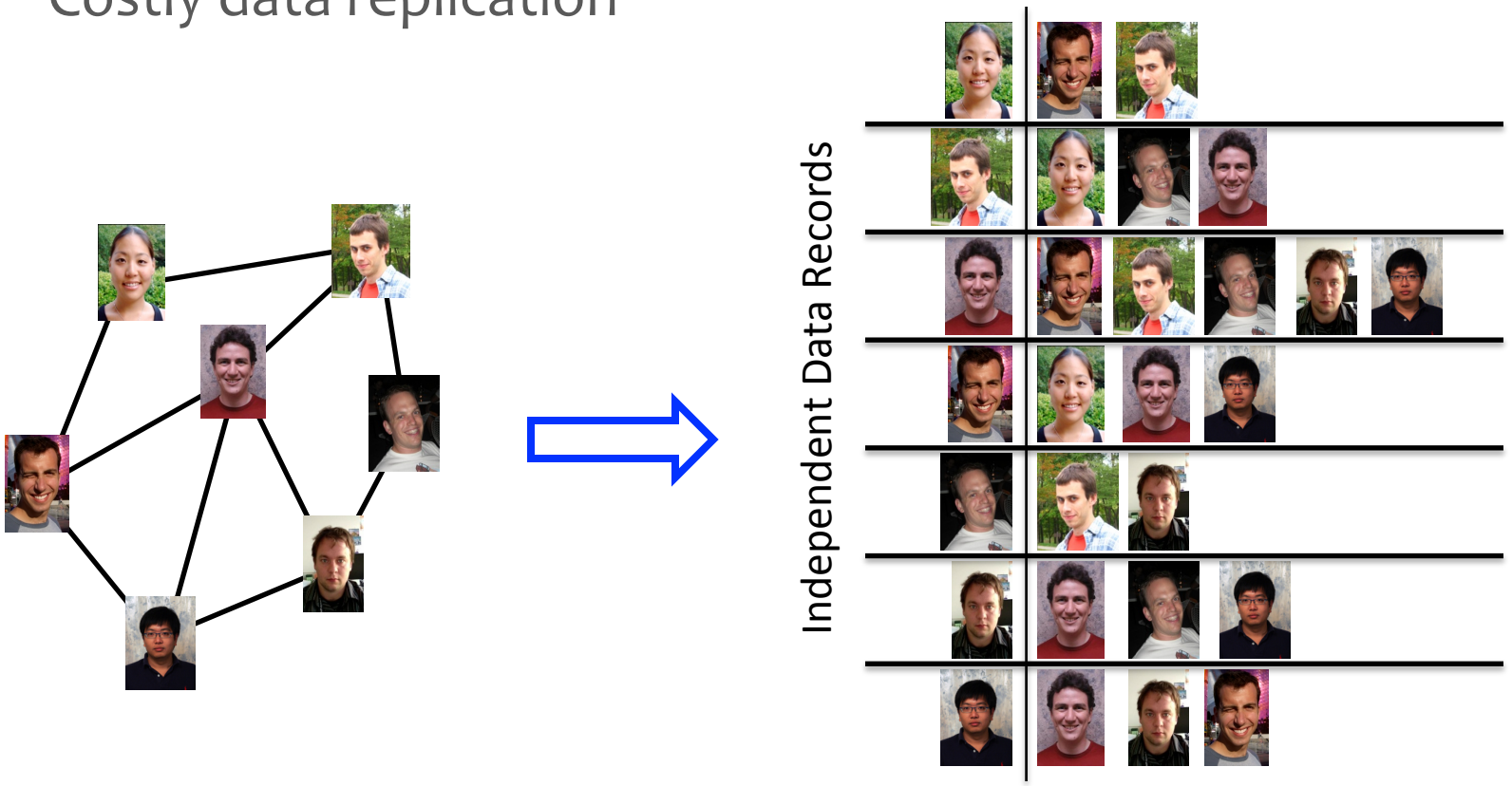
Why don't we just MapReduce?

How would you implement Graph processing in MapReduce?

Data Dependencies are Difficult

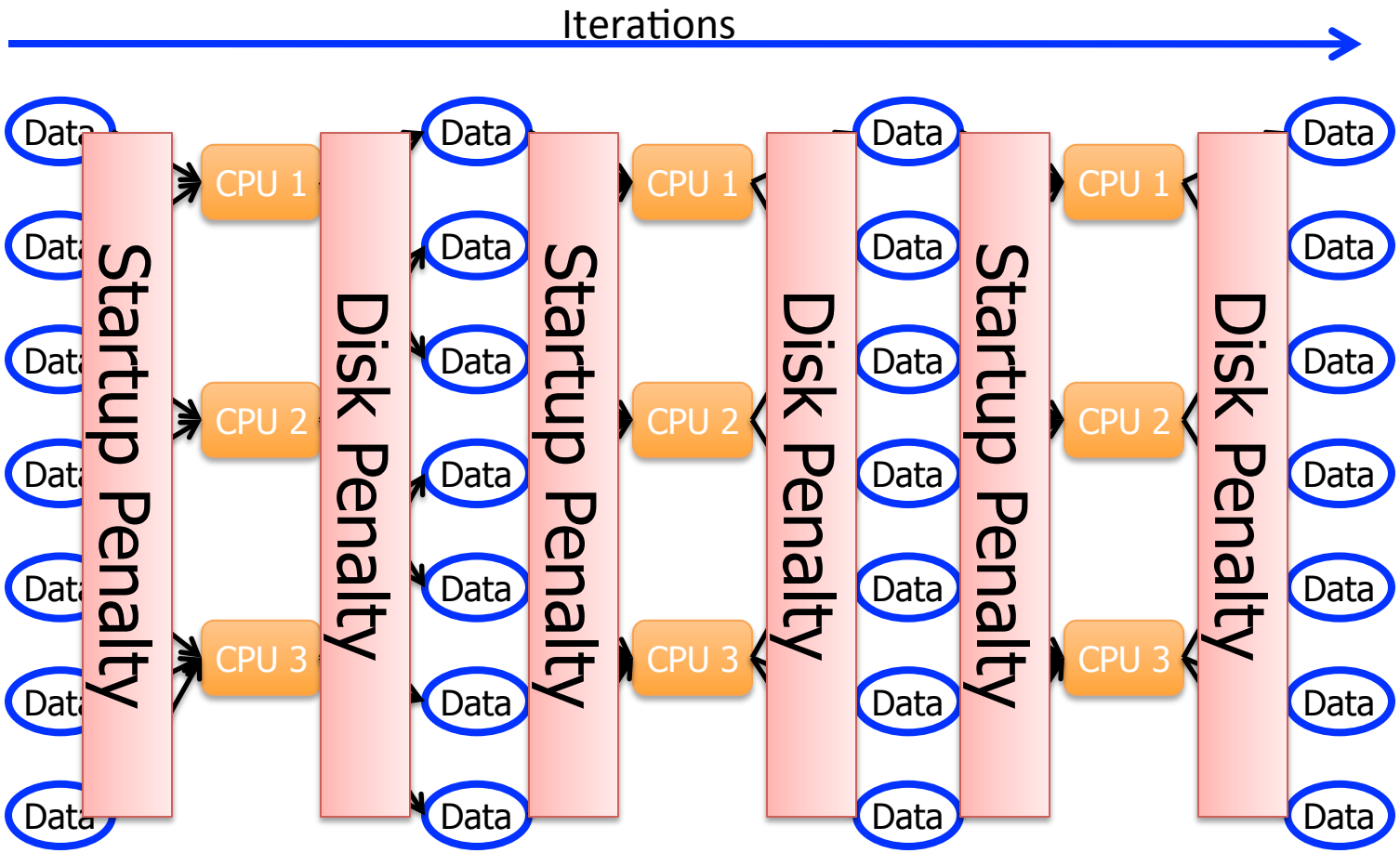
Difficult to express dependent data in MR

- Substantial data transformations
- User managed graph structure
- Costly data replication

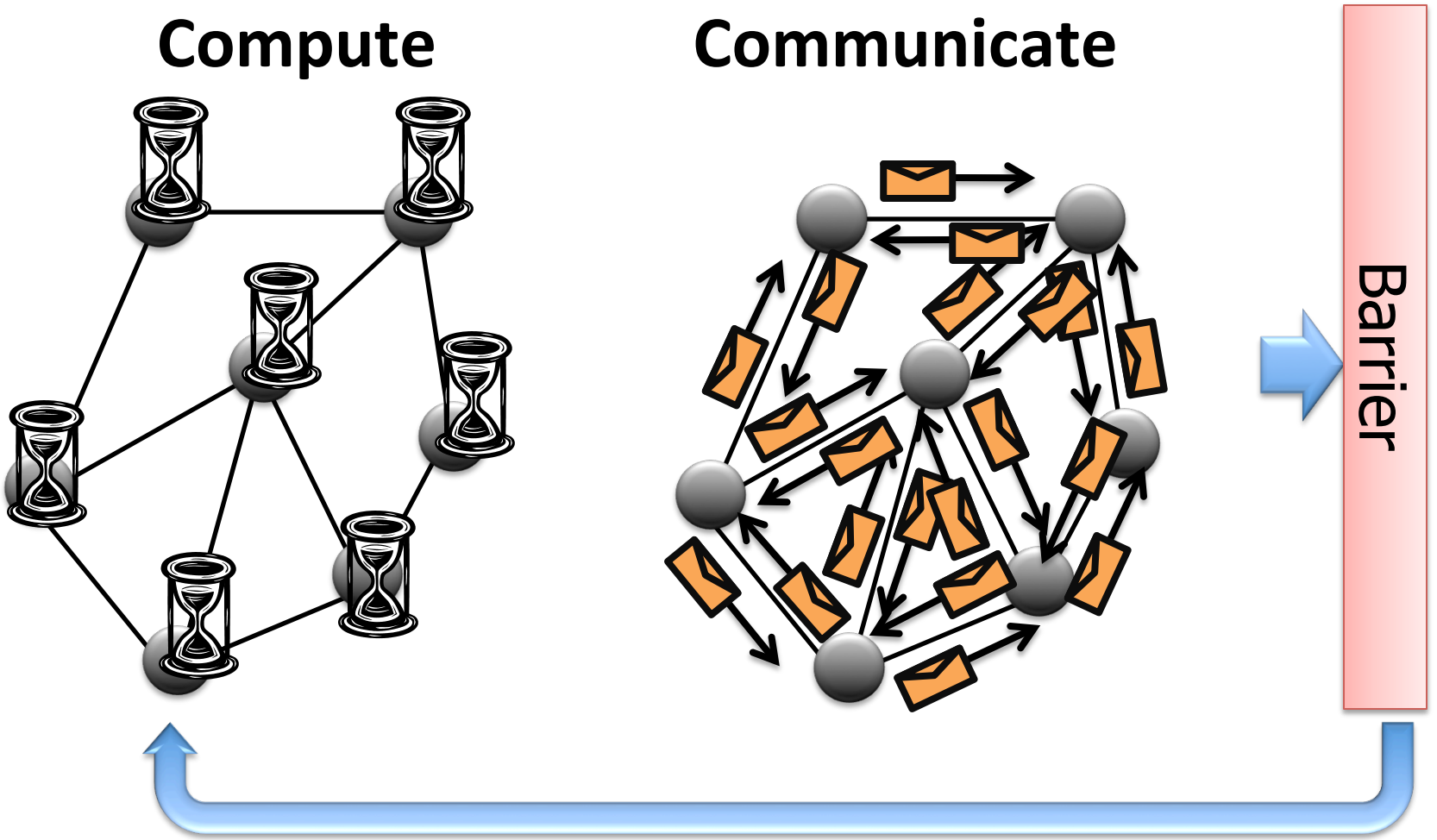


Iterative Computation is Difficult

System is not optimized for iteration:



Pregel: Bulk Synchronous Parallel



http://dl.acm.org/citation.cfm?id=1807184

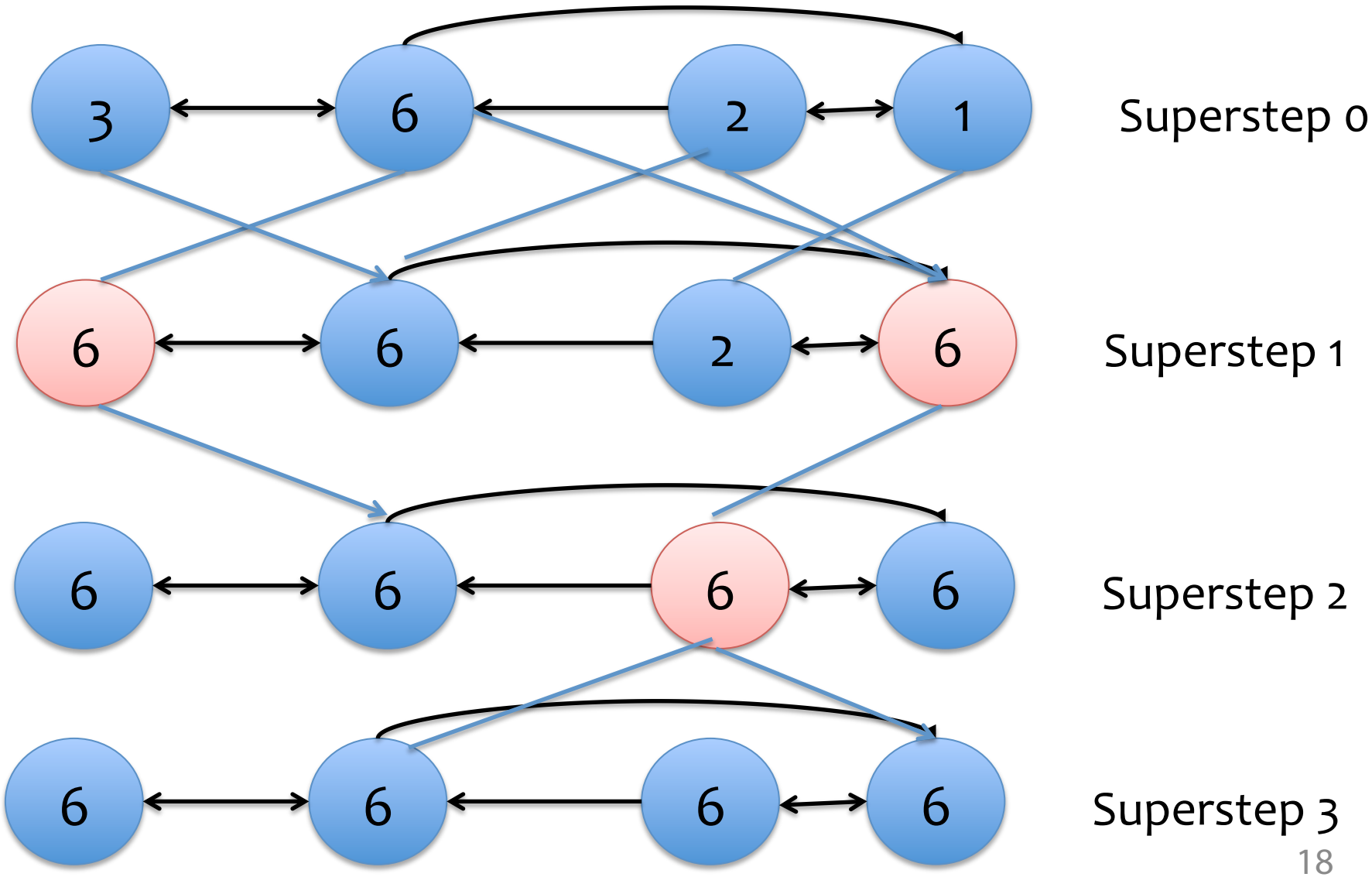
Vertex centric API

Programming API

```
Class Vertex{
    //Main methods
    Compute(MessageIterator *msgs);
    SendMsgTo(dest, msg);
    VoteToHalt();

    //Auxiliary methods
    GetValue();
    MutableValue();
    GetOutEdgeIterator();
    SuperStep();
}
```

Example: maximum value



Example: PageRank

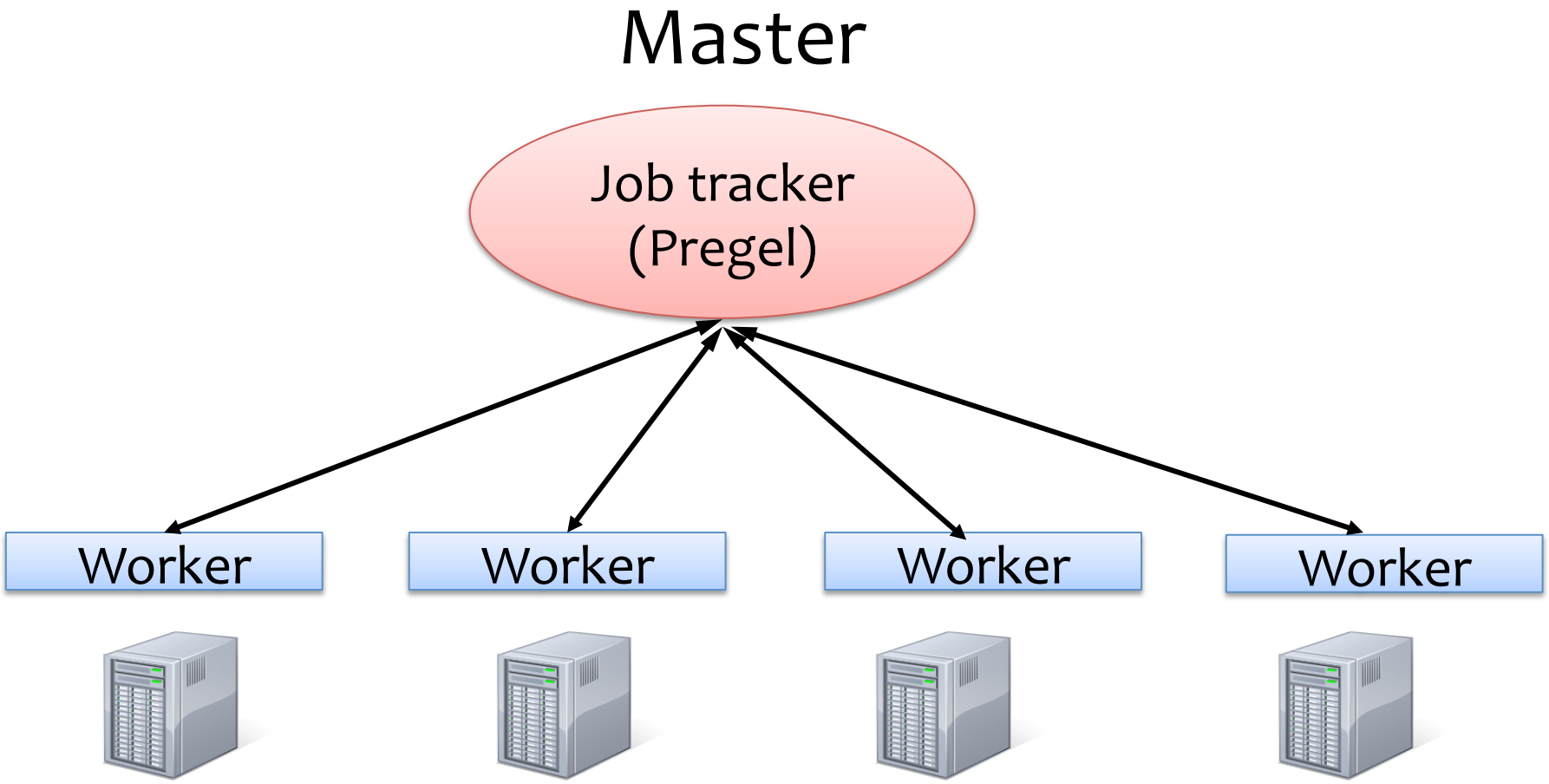
```
class PageRankVertex
    : public Vertex<double, void, double> {
 public:
  virtual void Compute(MessageIterator* msgs) {
    if (superstep() >= 1) {
      double sum = 0;
      for (; !msgs->Done(); msgs->Next())
        sum += msgs->Value();
      *MutableValue() =
          0.15 / NumVertices() + 0.85 * sum;
    }

    if (superstep() < 30) {
      const int64 n = GetOutEdgeIterator().size();
      SendMessageToAllNeighbors(GetValue() / n);
    } else {
      VoteToHalt();
    }
  }
};
```

Additional features

- Combiners
- Aggregators
- Topology mutations
  - Partial ordering (removal then addition, edges first)
  - Handlers
- Input/output
  - File, GFS, BigTable, etc.

Implementation



Fault tolerance

- Achieved through checkpointing
- At the beginning of a super-step, master instructs the workers to take a check-point
- When a worker fails --- the master re-asssigns the partition to a new worker, and restarts from the latest checkpoint

References for Graph processing

- Pregel [VLDB'10]
  - Pregel paper
- GraphX [OSDI'14]
  - Graph processing framework built on top Spark
- GraphLab [OSDI'12]
  - Edge-centric graph processing framework

Summary

- Graph processing with Pregel/Giraph
  - Bulk Synchronous Programming (BSP) model

- Resources:
  - Giraph: http://giraph.apache.org/
  - GraphX: https://spark.apache.org/graphx/
  - GraphLab: http://graphlab.org/
  - Okapi: http://grafos.ml/

Thanks!

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