Apache Spark GraphX

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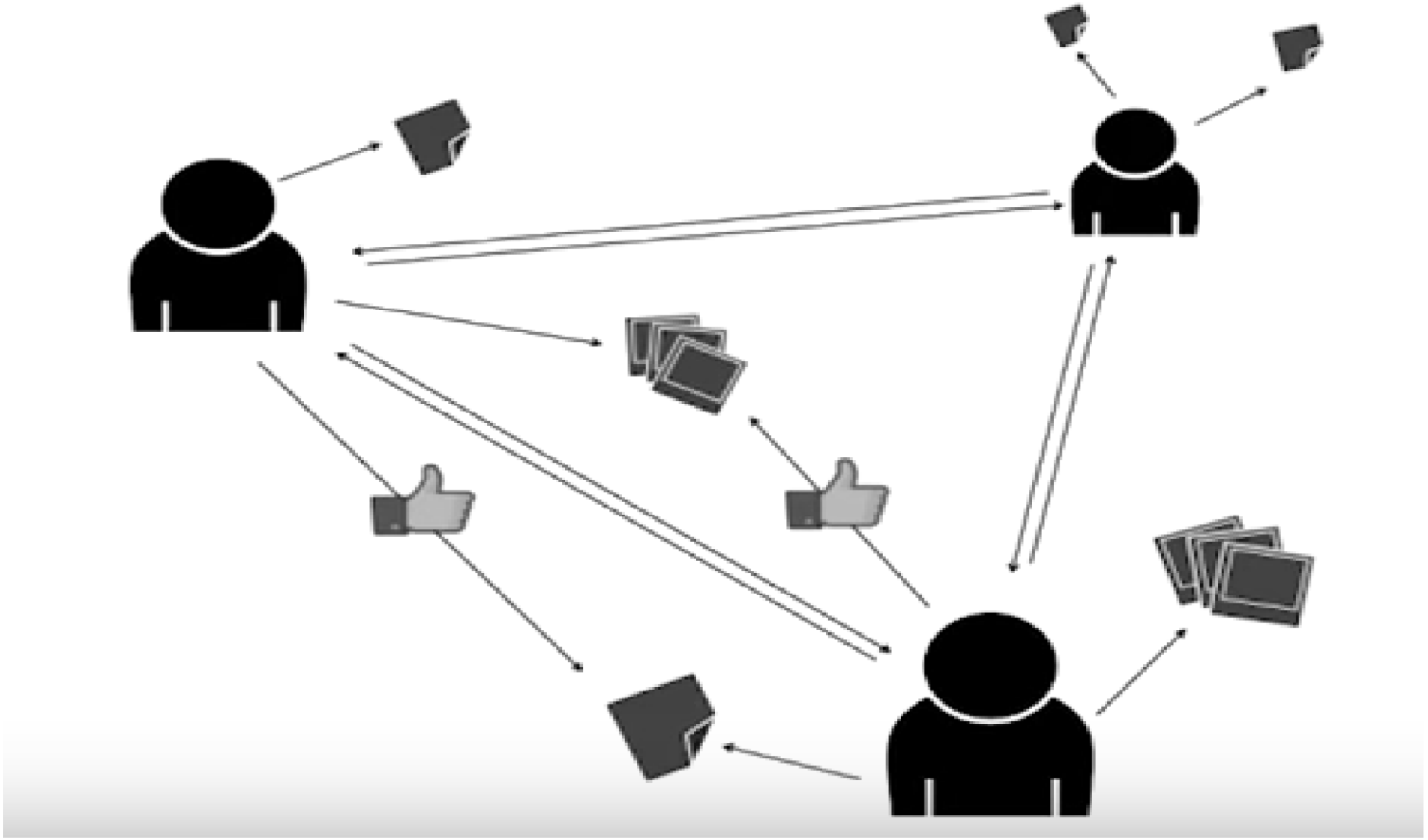
Agenda

- **An Intro to Graph Processing**
- Why GraphX?
- How (to use) GraphX?
- How GraphX Works

Graphs are Essential to Data Mining and Machine Learning

- Identify influential people and information
- Find communities
- Understand people’s shared interests
- Model complex data dependencies

Example: Social Networks



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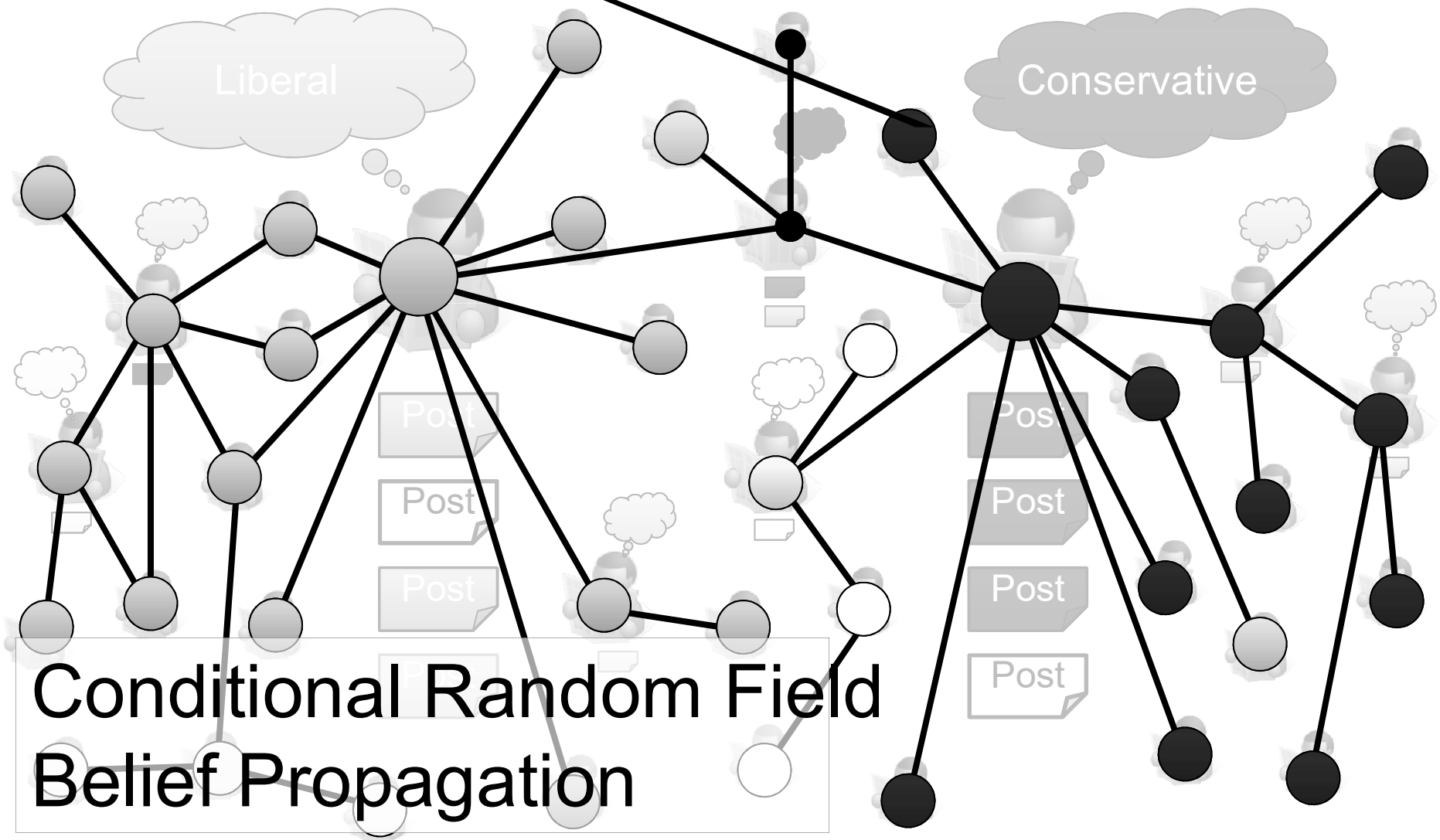
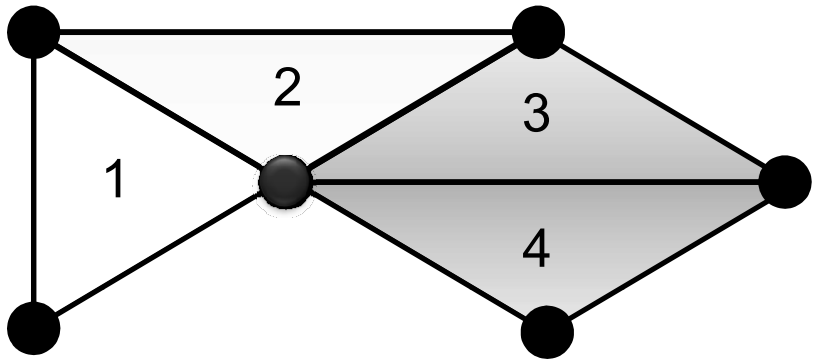


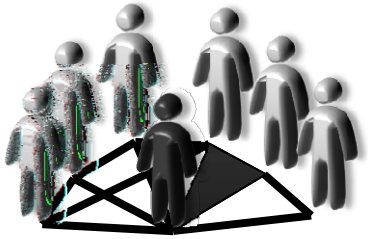
Conditional Random Field
Belief Propagation

Triangle Counting

- Count triangles passing through each vertex
- 

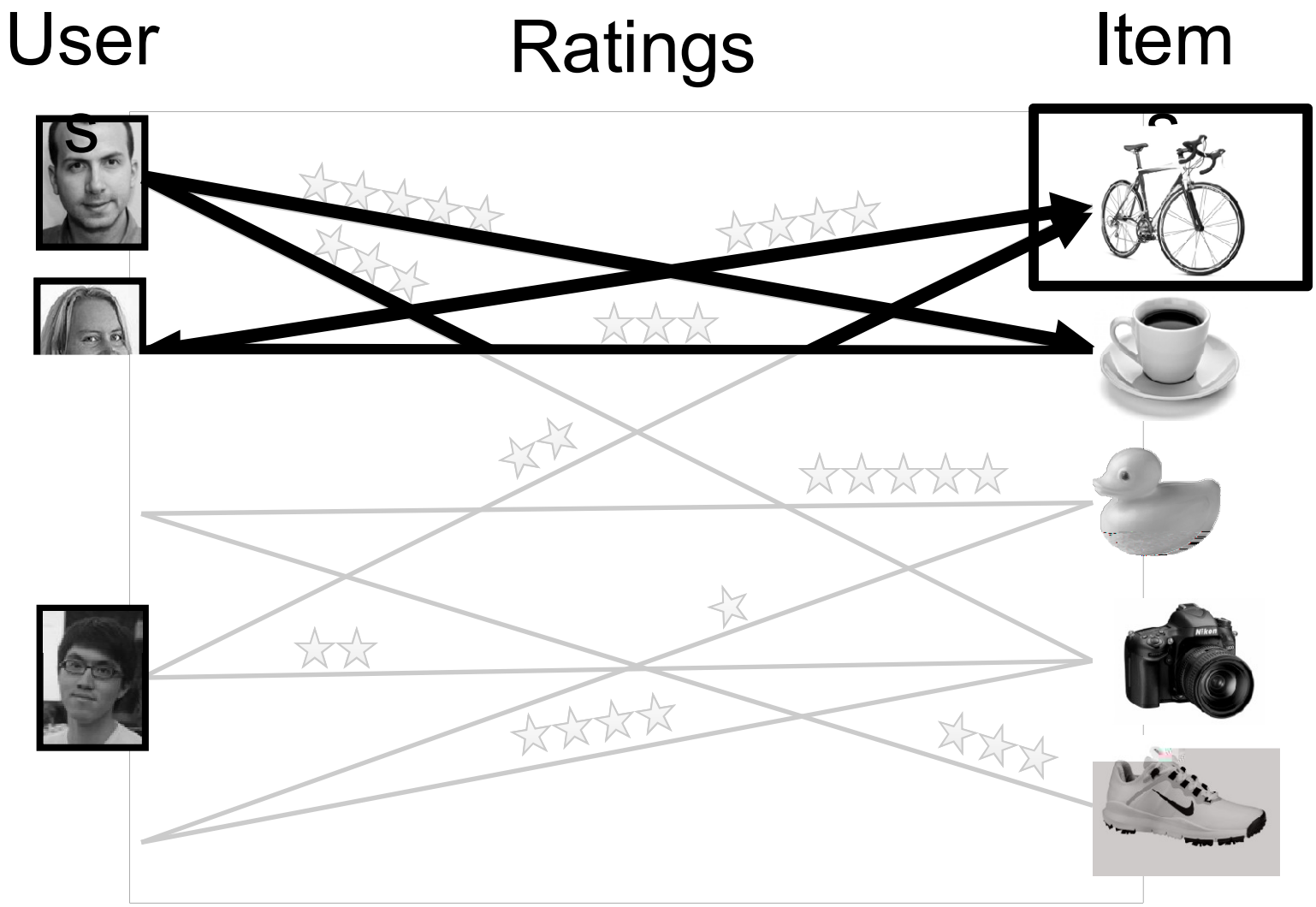
- Measures **cohesiveness** of local community

Fewer Triangles
Weaker Community



More Triangles
Stronger Community

Collaborative Filtering



Pregel

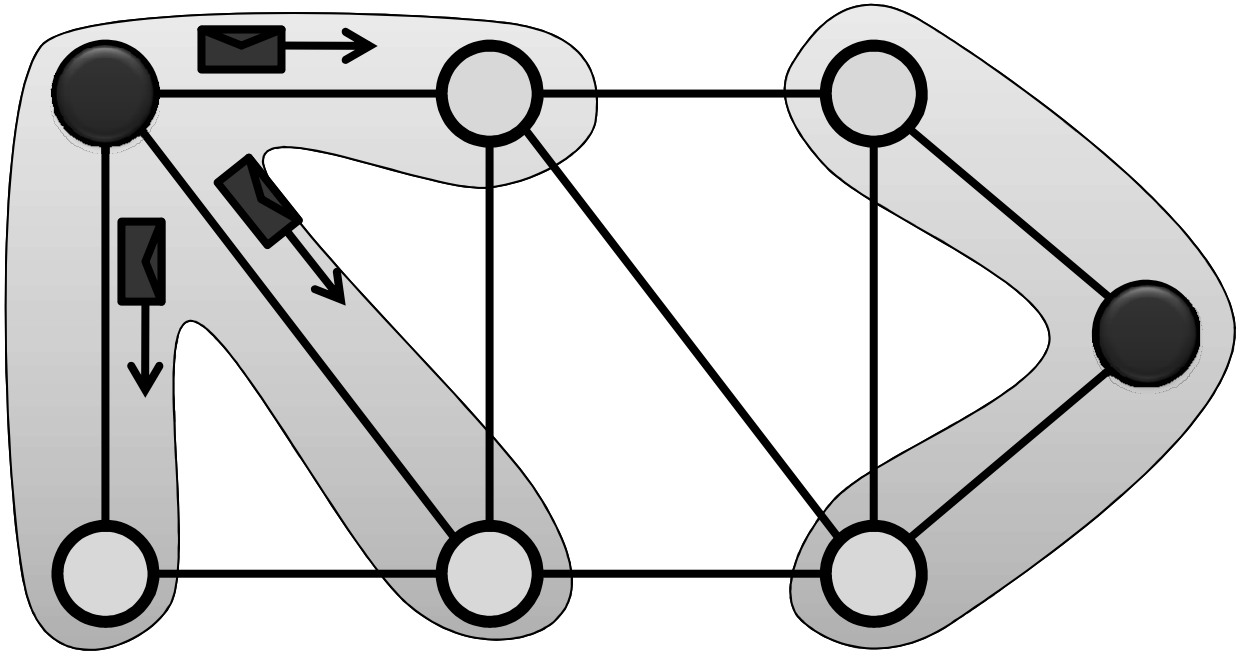
- Vertex-centric
- Runs in sequence of iterations called **super-steps**
- A vertex in super-step *a* can:
  - Read messages sent to it in super-step *a*
  - Send messages to other vertices (they will receive the messages in step *a*)
  - Modify its current state

The **Graph-Parallel** Abstraction

A user-defined **Vertex-Program** runs on each vertex

Graph constrains **interaction** along edges

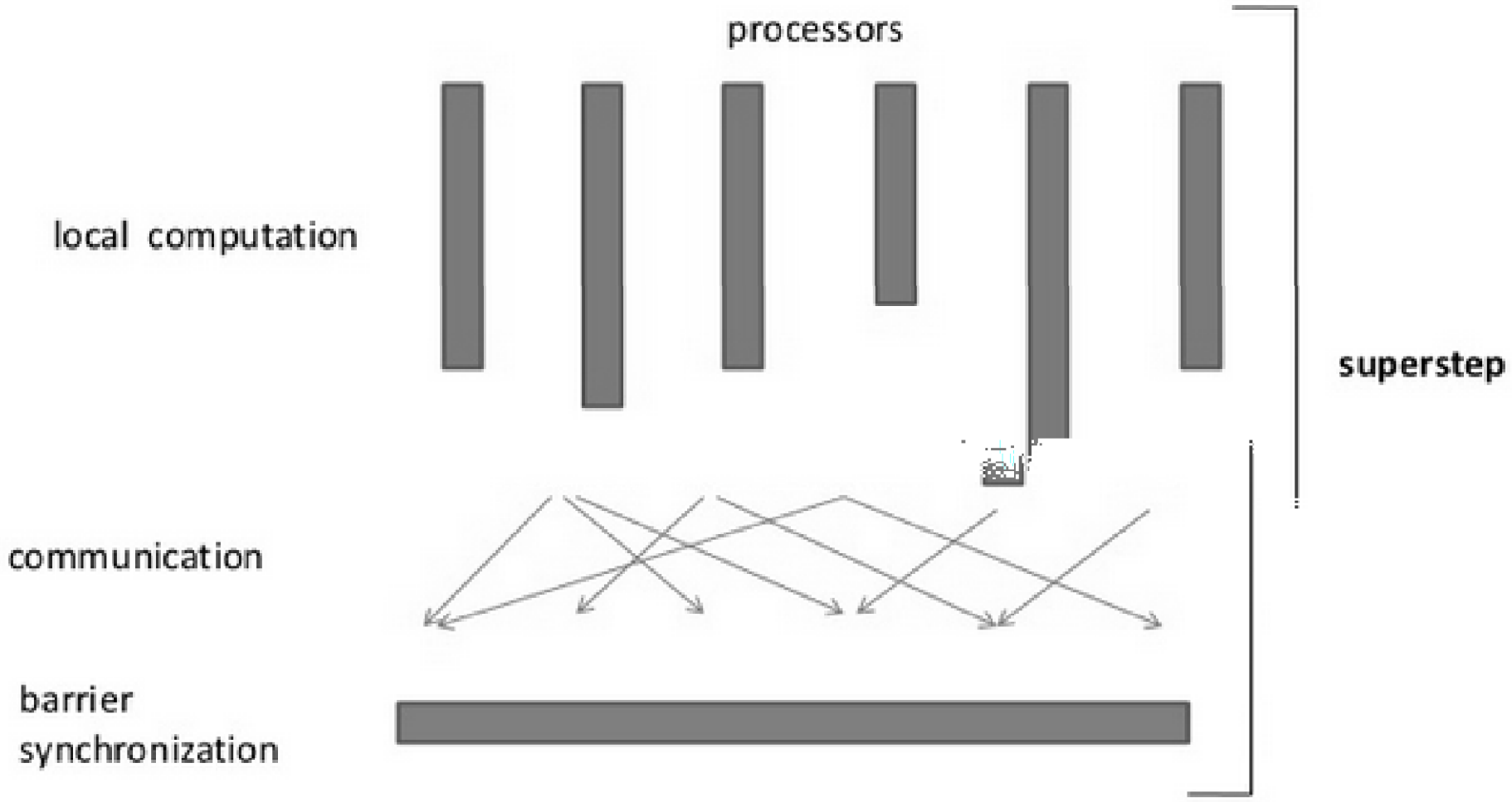
Using **messages** (e.g. **Pregel** [PODC'09, SIGMOD'10])



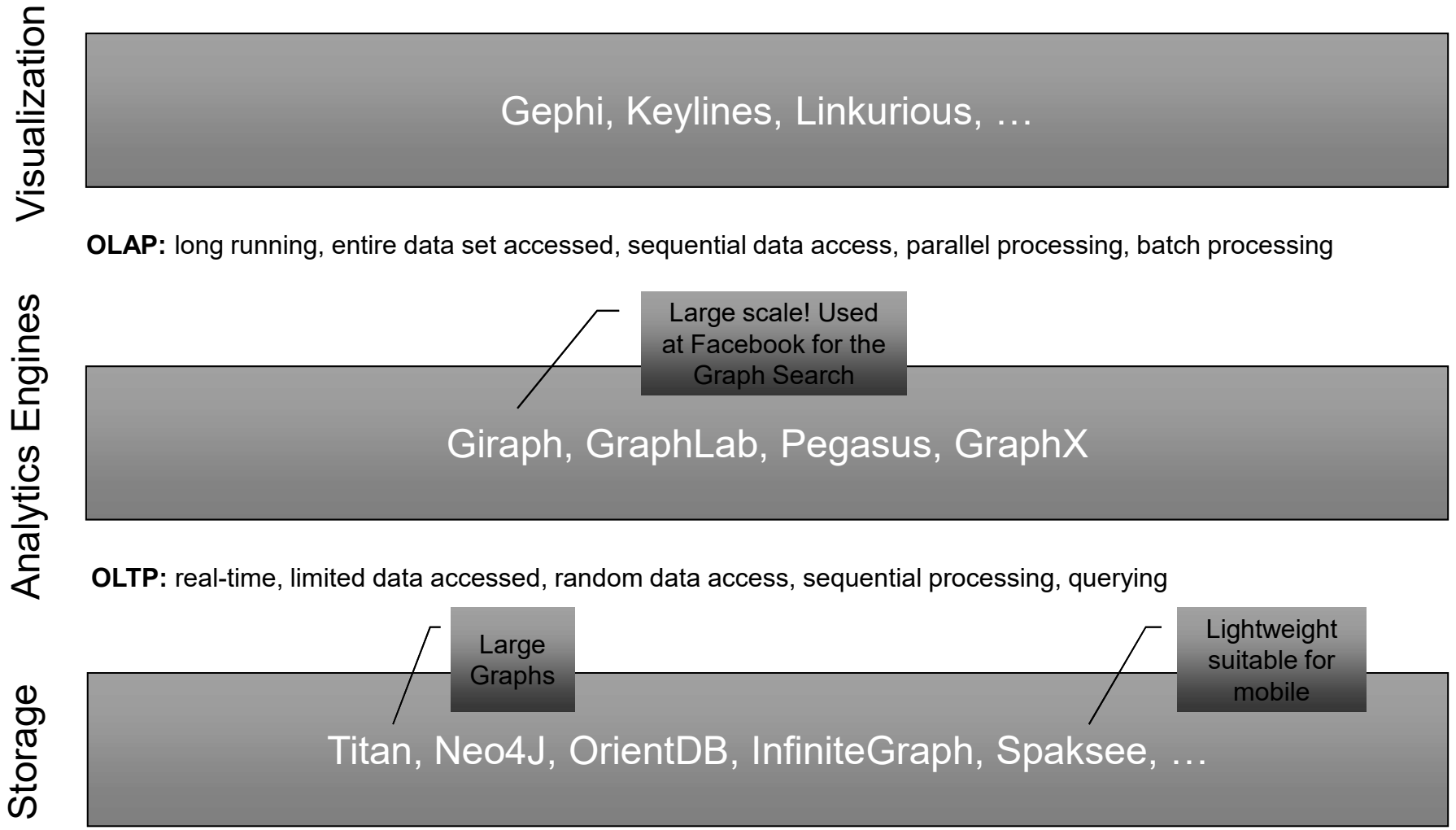
Parallelism: run multiple vertex programs simultaneously

Computing PageRank the **Pregel** way

Bulk Synchronous Parallel



Graph Technology Components



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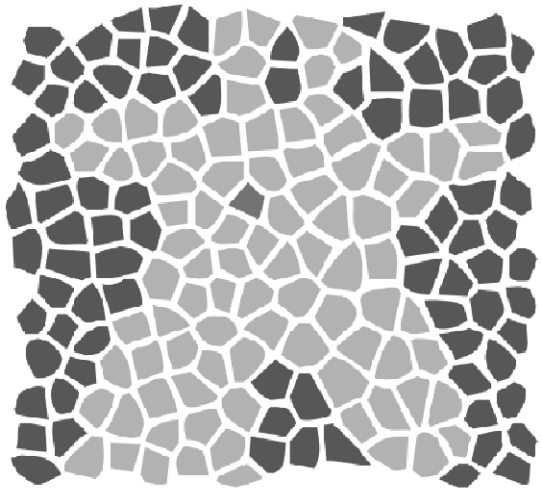
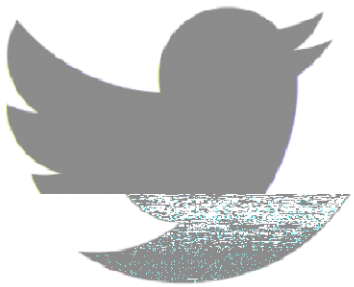
Specialized Graph Systems

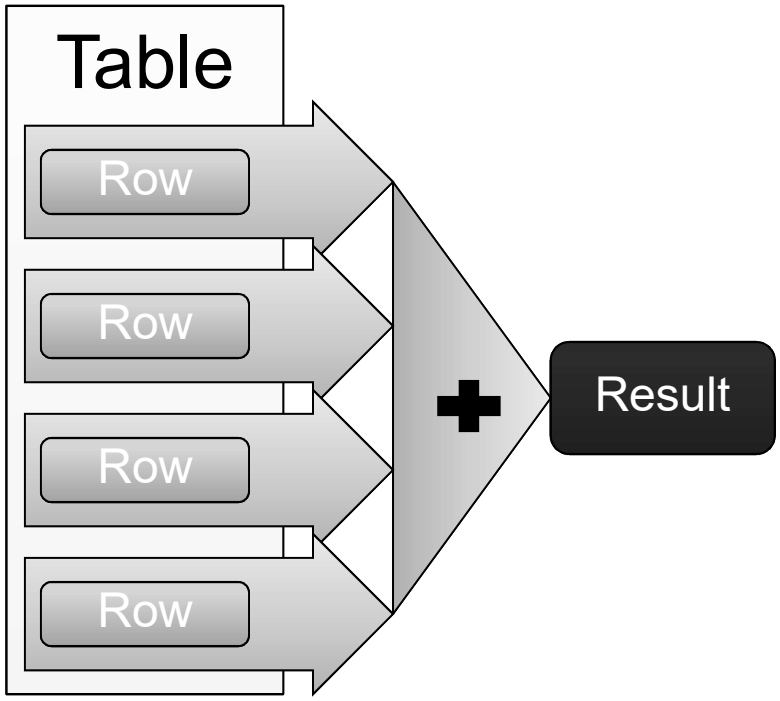




Google Pregel

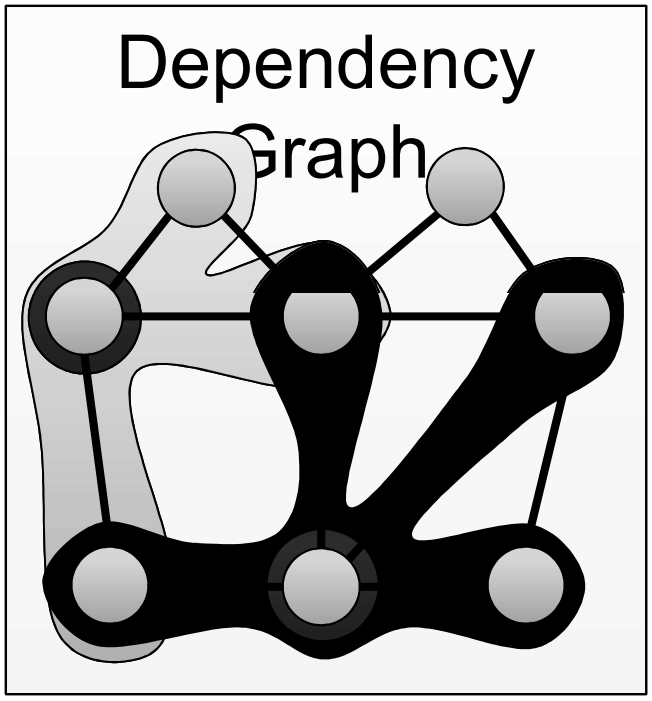
A Disconnect Between Data and Graph Processing

Data-Parallel



hadoop

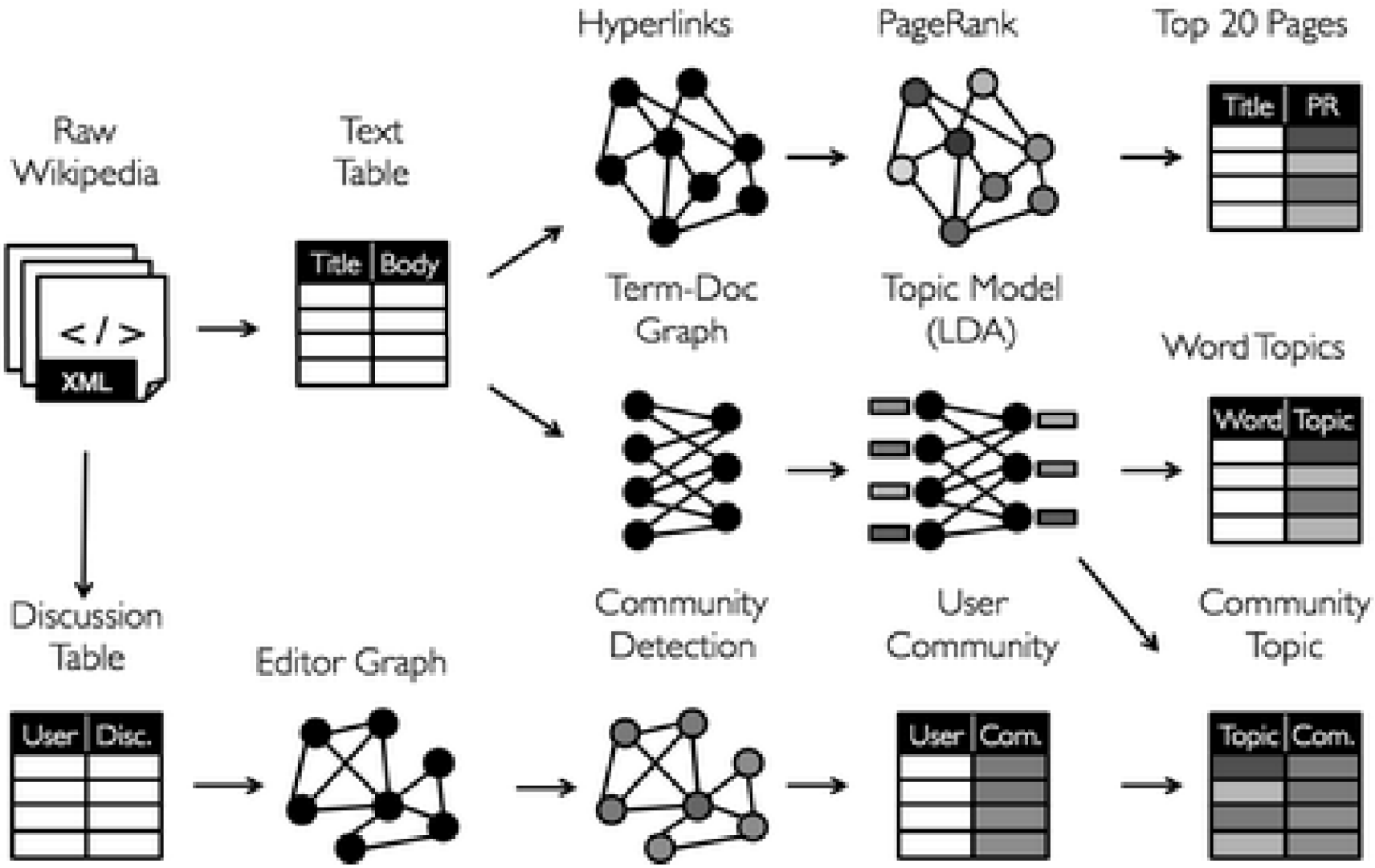
Graph-Parallel



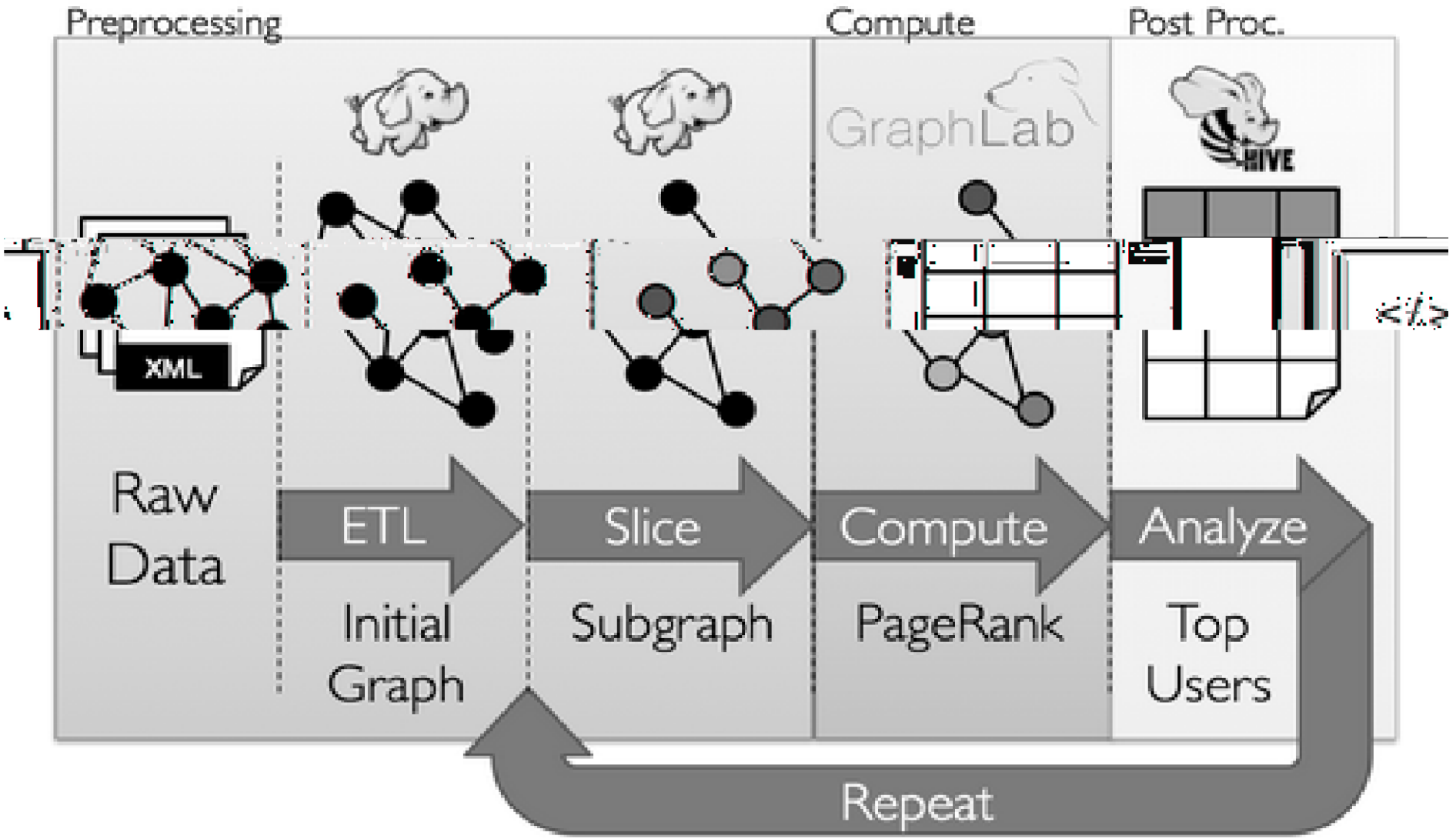
Pregel

GraphLab

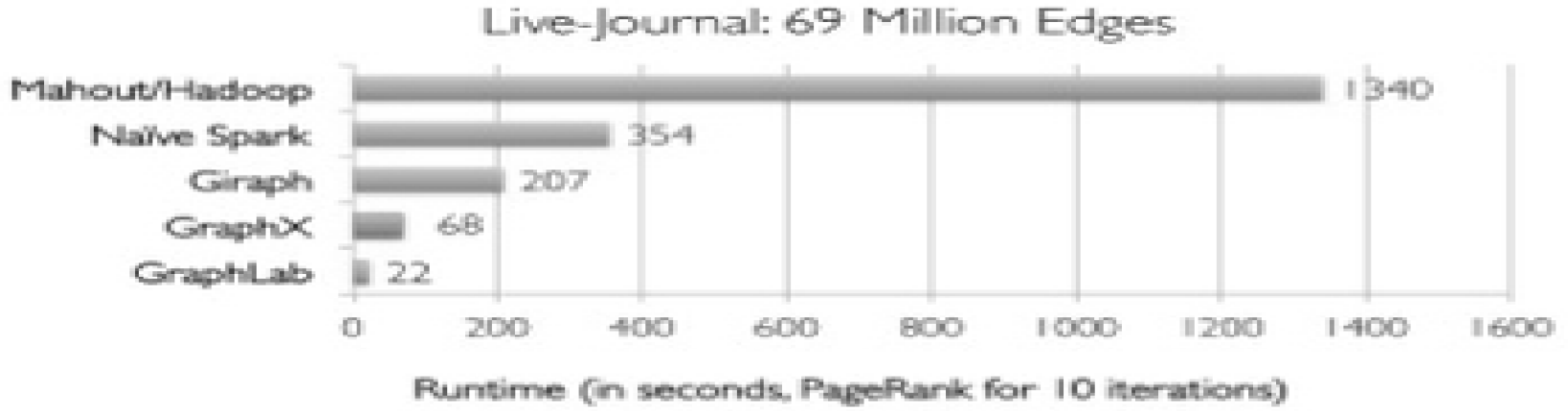
Typical Graph Processing Pipeline

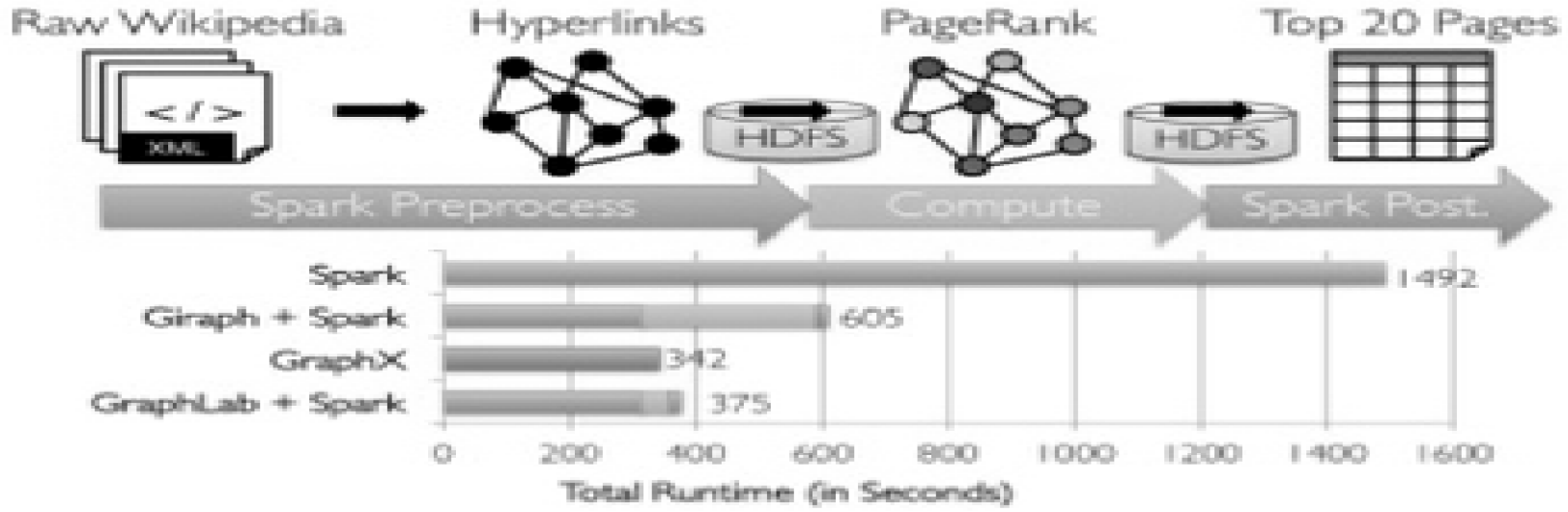


An Example of this Pipeline



Runtime Comparisons





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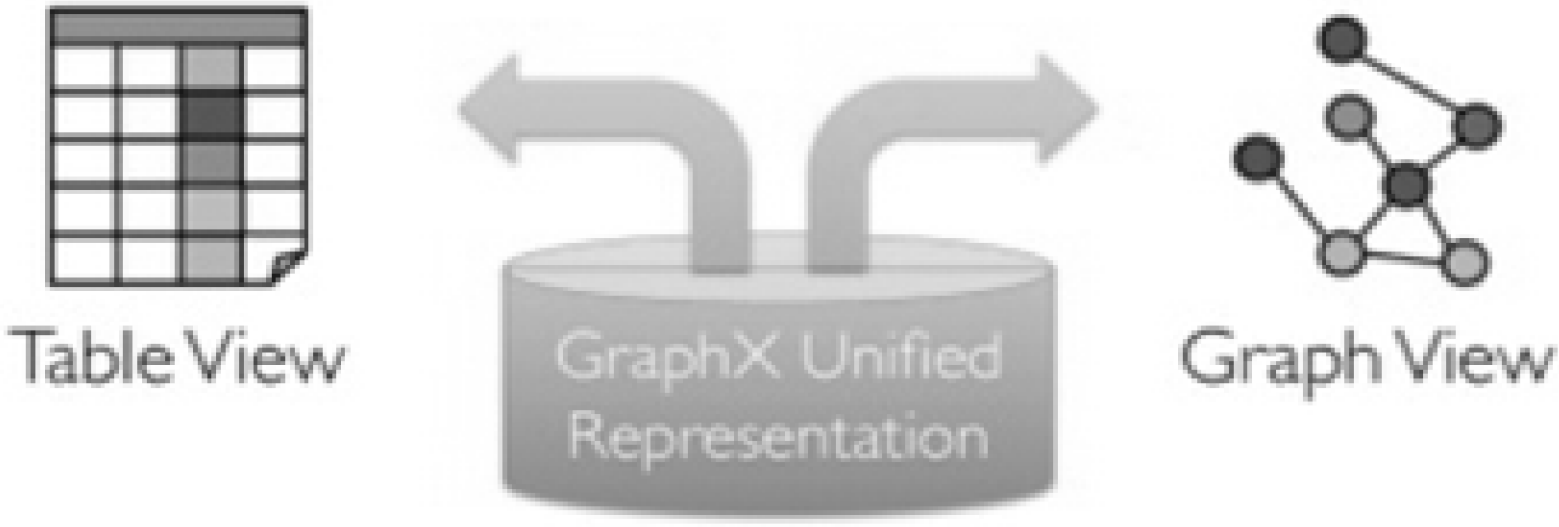
GraphX Design Goals

- Blur distinction between tables & graphs
- Unify data & graph parallel processing
- Implement on top of Spark

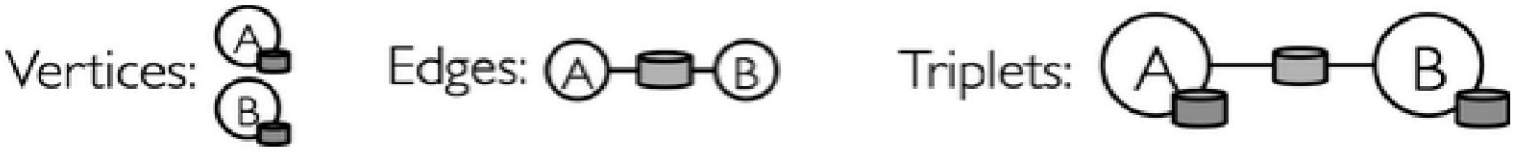
GraphX Key Idea

- Tables & Graphs are composable views of the same physical data
- View support operations that exploit semantics of the view to achieve efficient execution



GraphX Structure

- VertexRDD maps IDs to vertex content
- EdgeRDD are of the form (ID1, ID2, ET)
- Triplets are a combination of Vertex & Edge RDDs



*** Some graph frameworks assume that the edges of a single vertex can fit in a single machine --- GraphX does not make this assumption!**

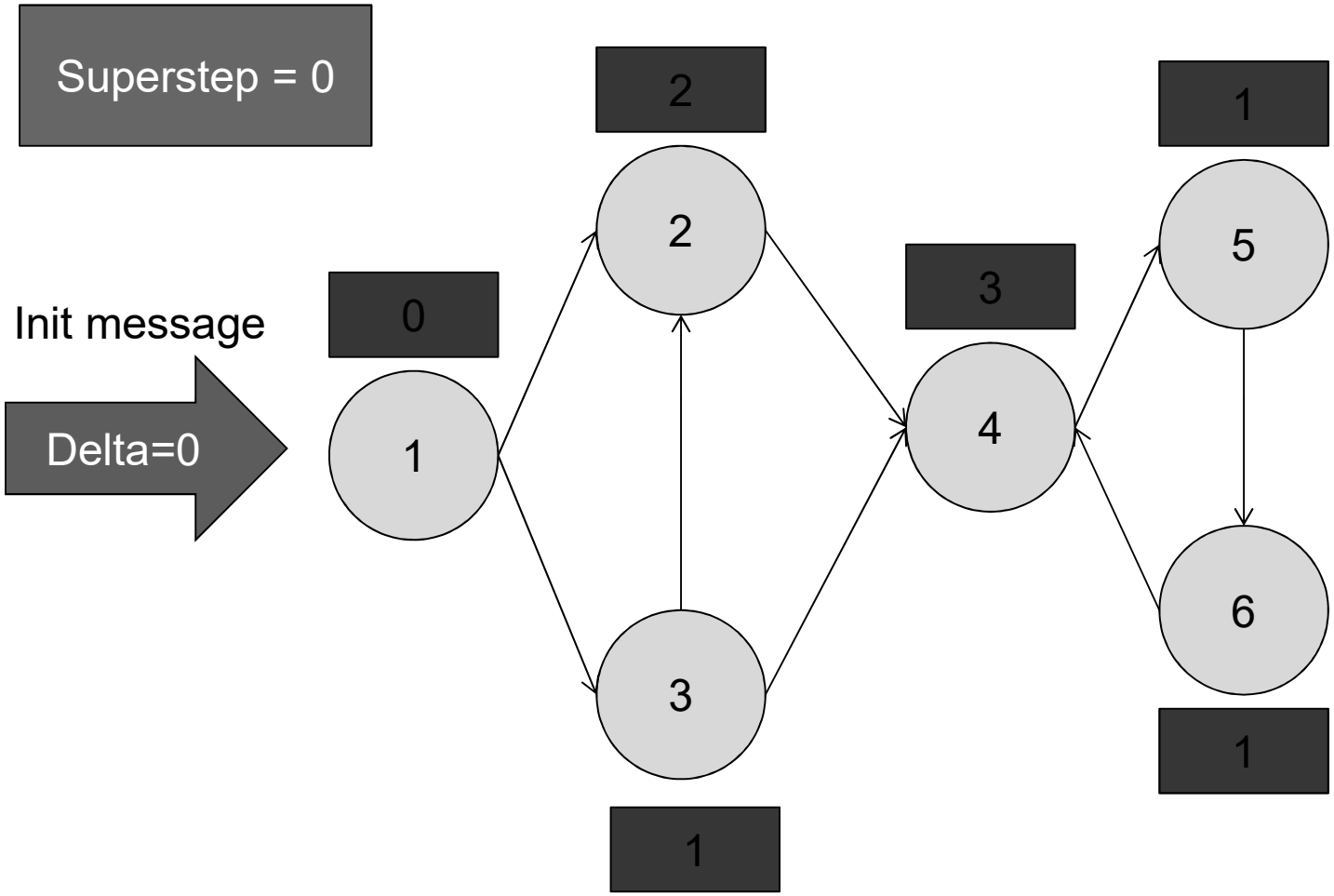
GraphX Structure

```
// Vertex collection
class VertexRDD[VD] extends RDD[(VertexId, VD)]

// Edge collection
class EdgeRDD[ED] extends RDD[Edge[ED]]
case class Edge[ED](srcId: VertexId = 0, dstId: VertexId = 0,
                    attr: ED = null.asInstanceOf[ED])

// Edge Triple
class EdgeTriplet[VD, ED] extends Edge[ED]
```

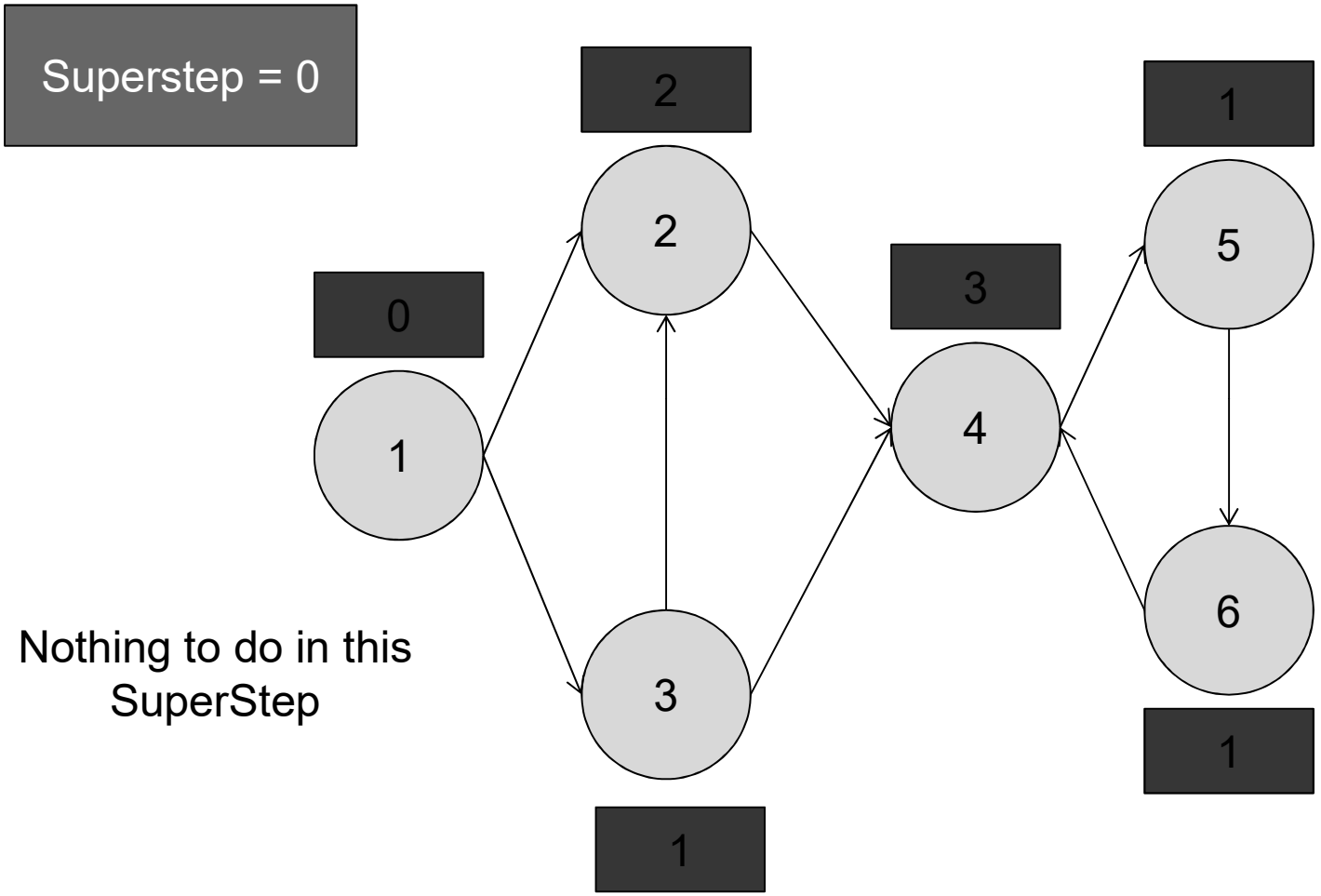
GraphX Example

```
val sc: SparkContext

// Create an RDD for the vertices
val users: VertexRDD[(String, String)] = sc.parallelize(
    Array((3L, ("rxin", "student")), (7L, ("jgonzal", "postdoc")),
          (5L, ("franklin", "prof")), (2L, ("istoica", "prof"))))

// Create an RDD for edges
val relationships: EdgeRDD[String] = sc.parallelize(
    Array(Edge(3L, 7L, "collab"),    Edge(5L, 3L, "advisor"),
          Edge(2L, 5L, "colleague"), Edge(5L, 7L, "pi")))

// Define a default user in case there are relationship with missing user
val defaultUser = ("John Doe", "Missing")

// Build the initial Graph
val userGraph: Graph[(String, String), String] =
    Graph(users, relationships, defaultUser)
```

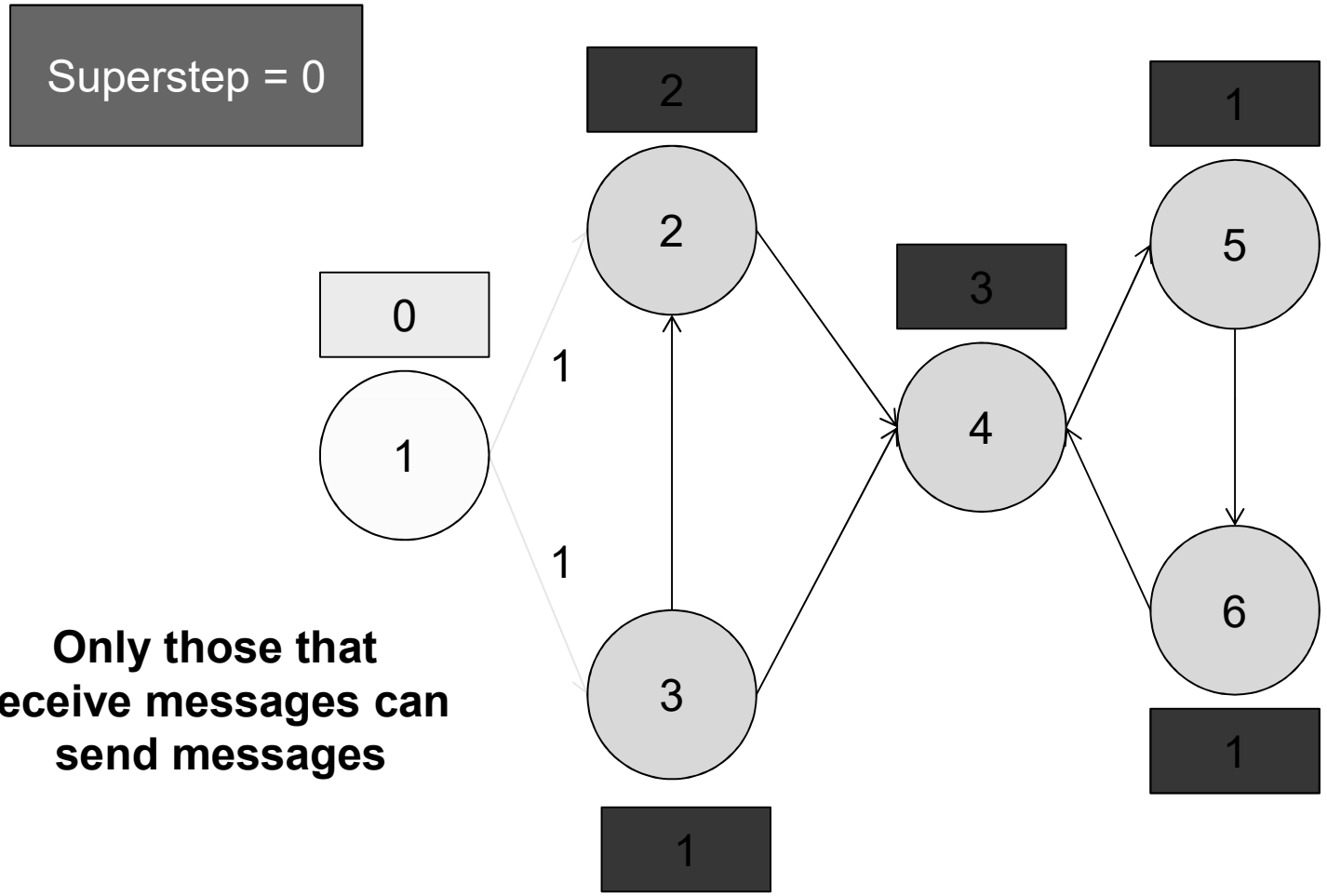
Is DAG Pregel Example



Is DAG Pregel: **vprog**

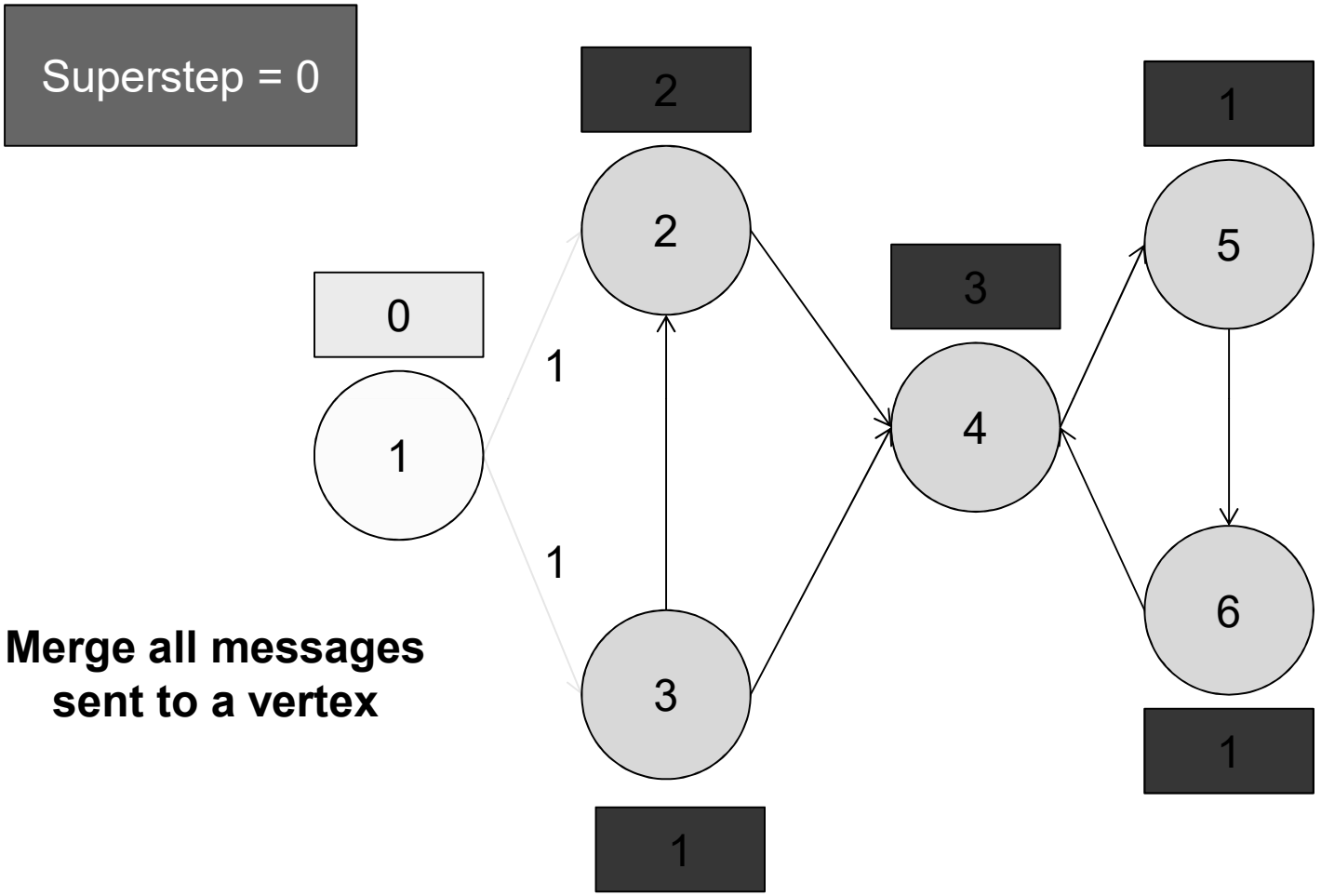


Is DAG Pregel: **sendMsg**



Only those that receive messages can send messages

Is DAG Pregel: **mergeMsg**



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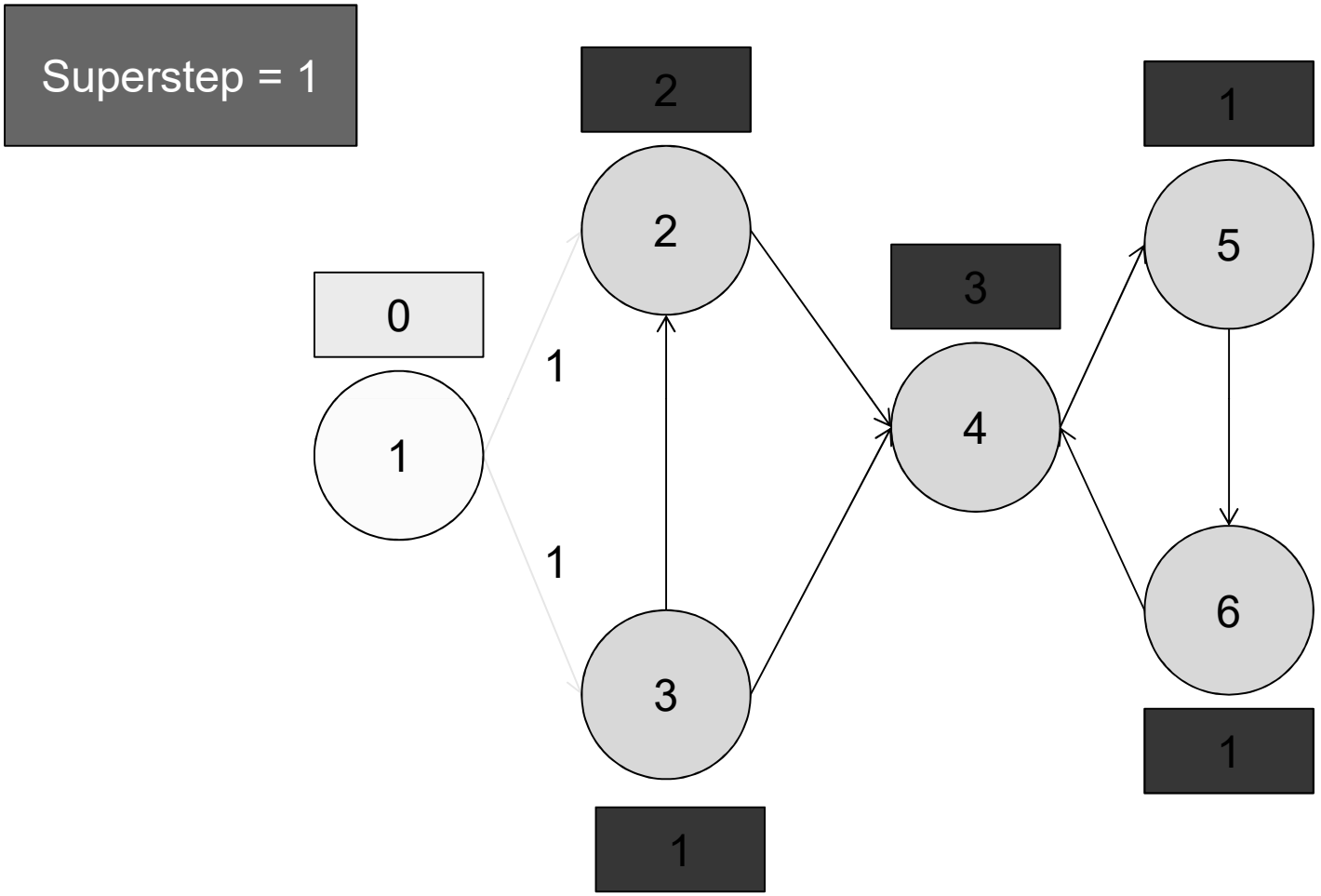

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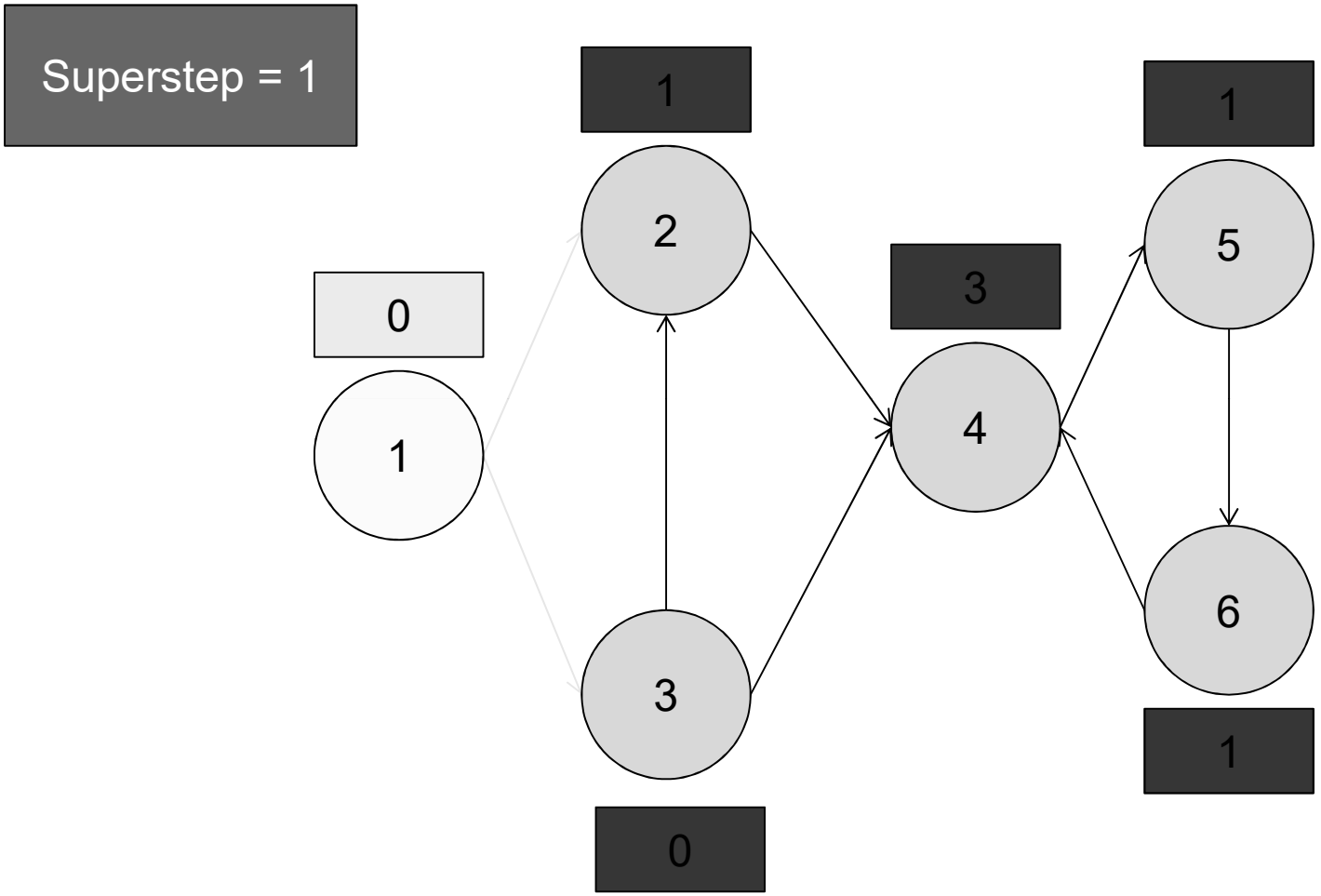
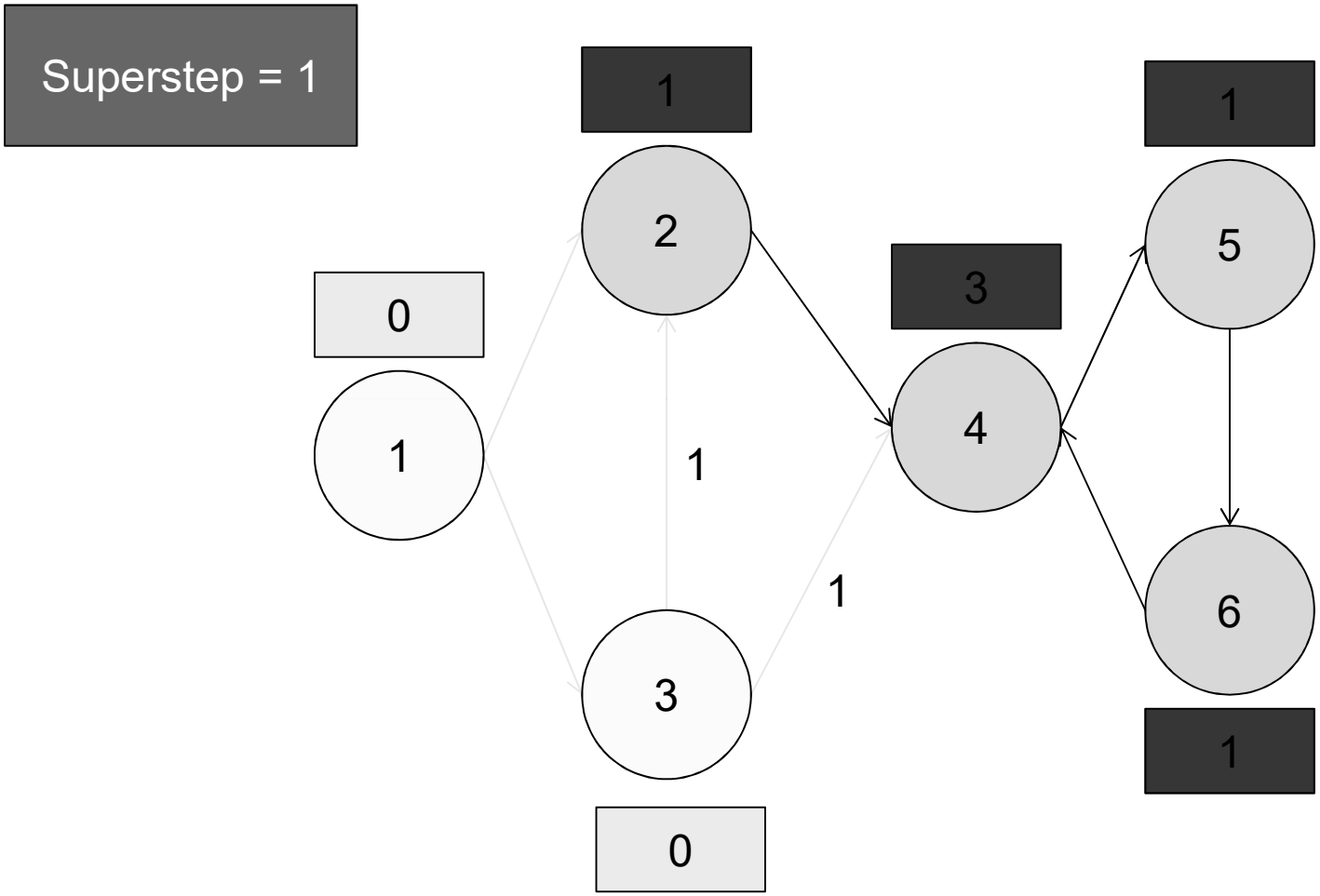
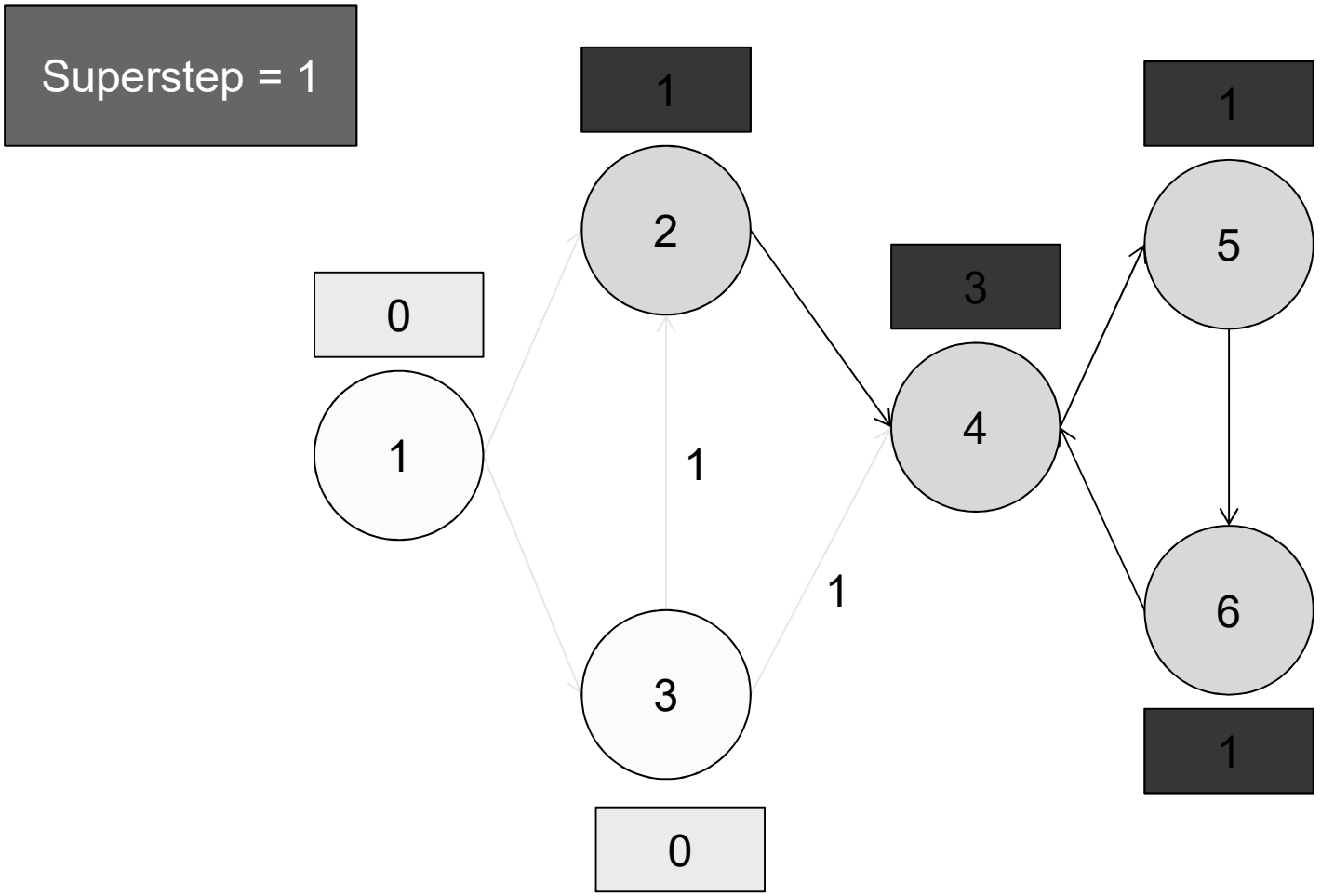


Is DAG Pregel: **sendMsg**



Is DAG Pregel: **mergeMsg**



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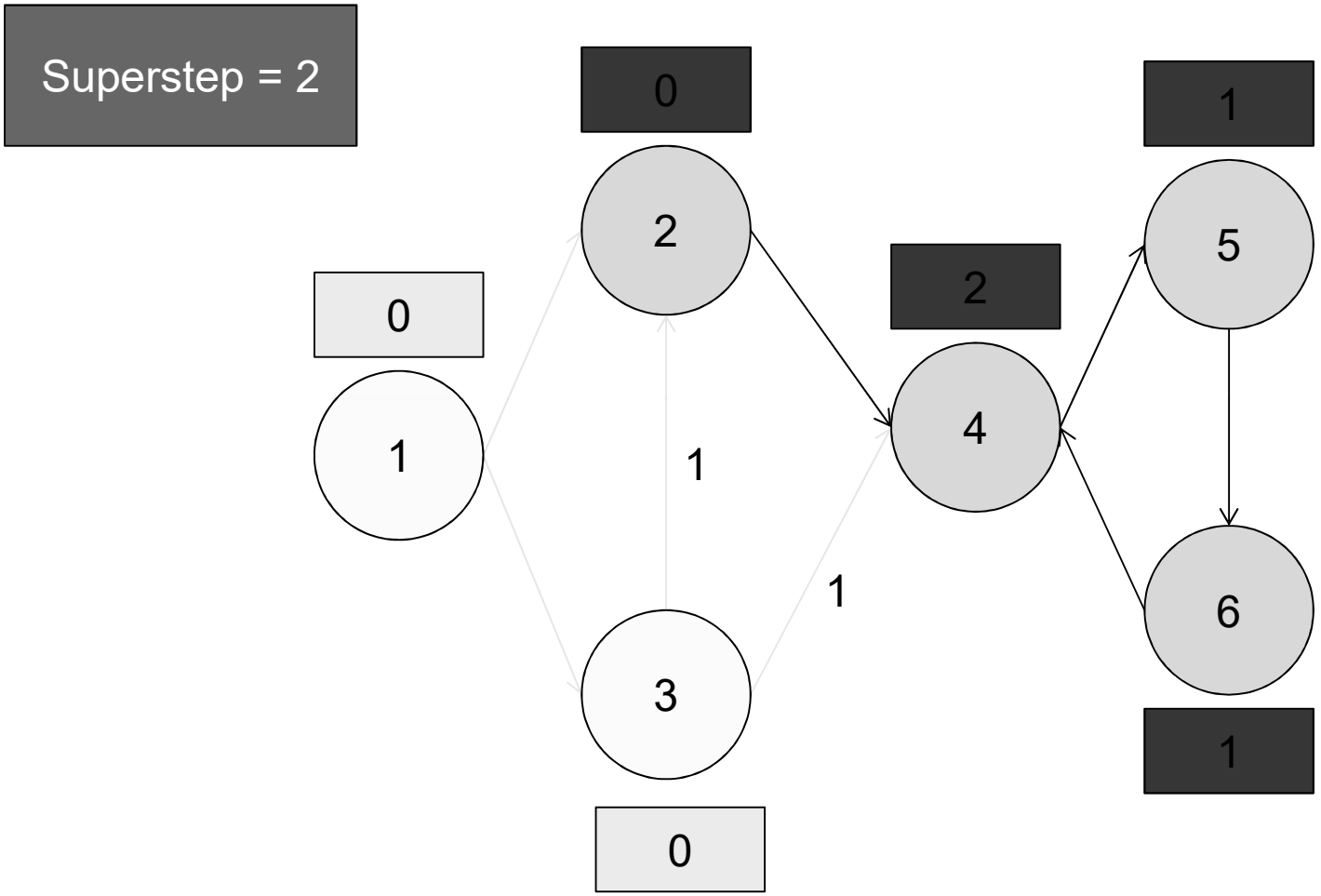
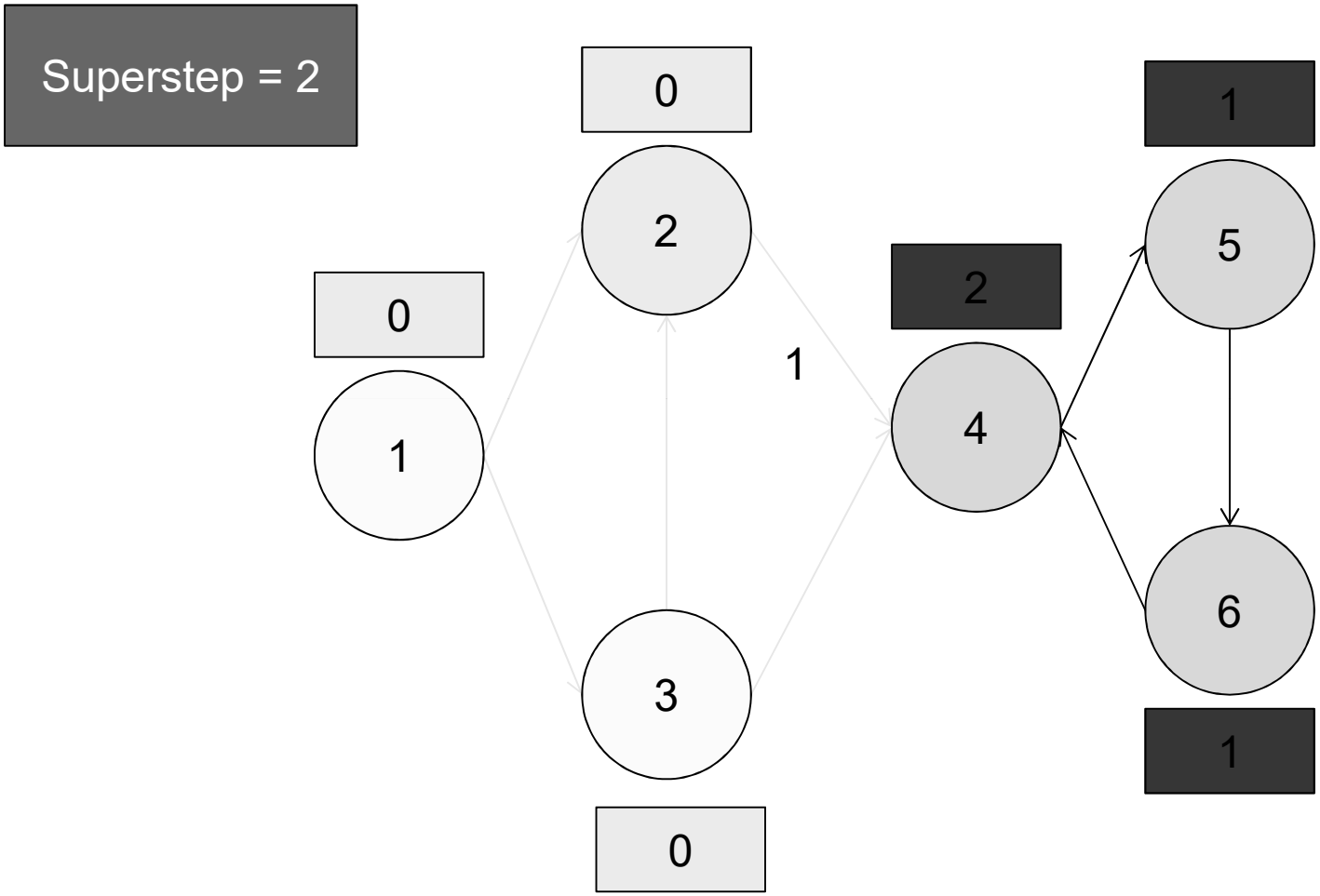


Is DAG Pregel: **sendMsg**



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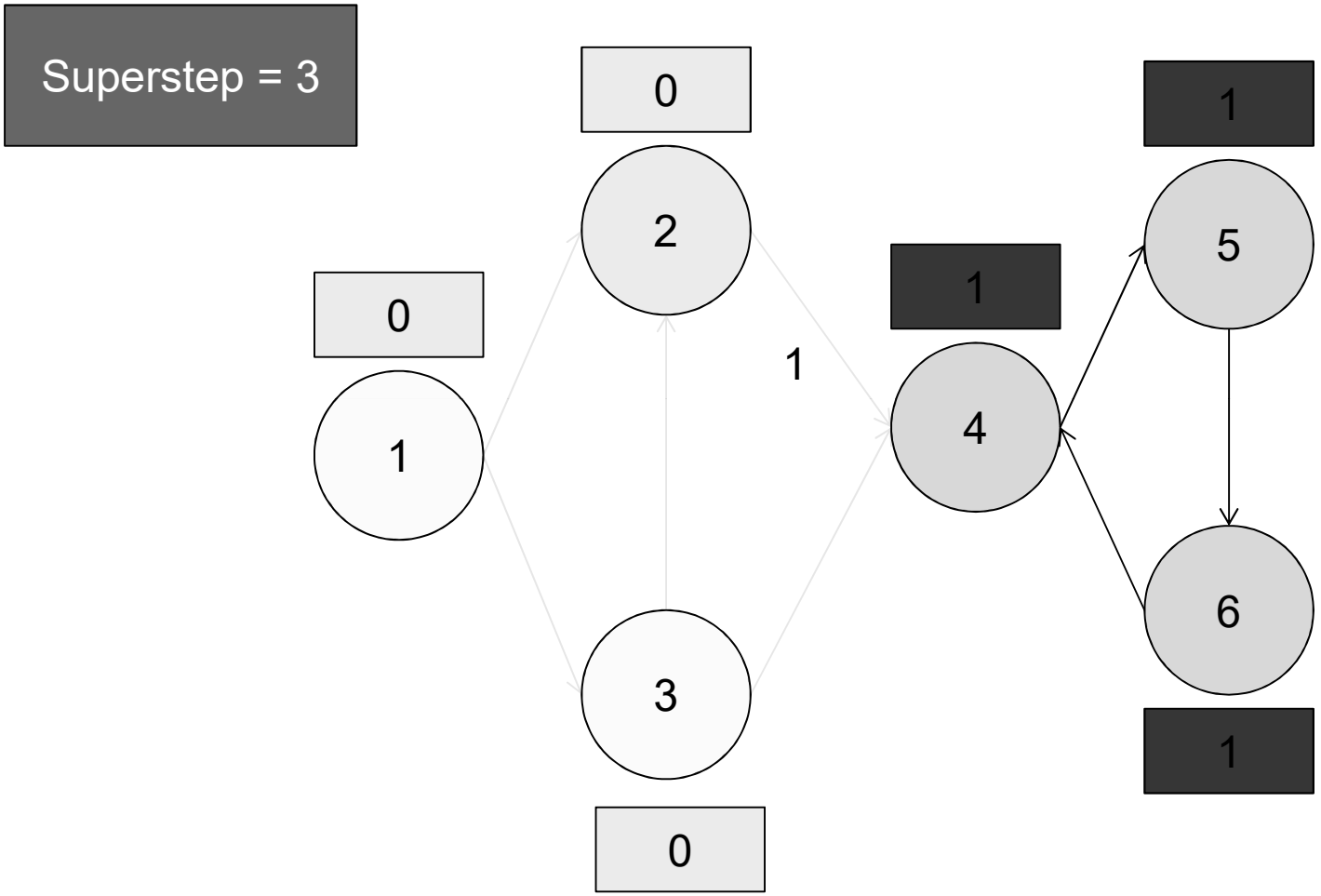

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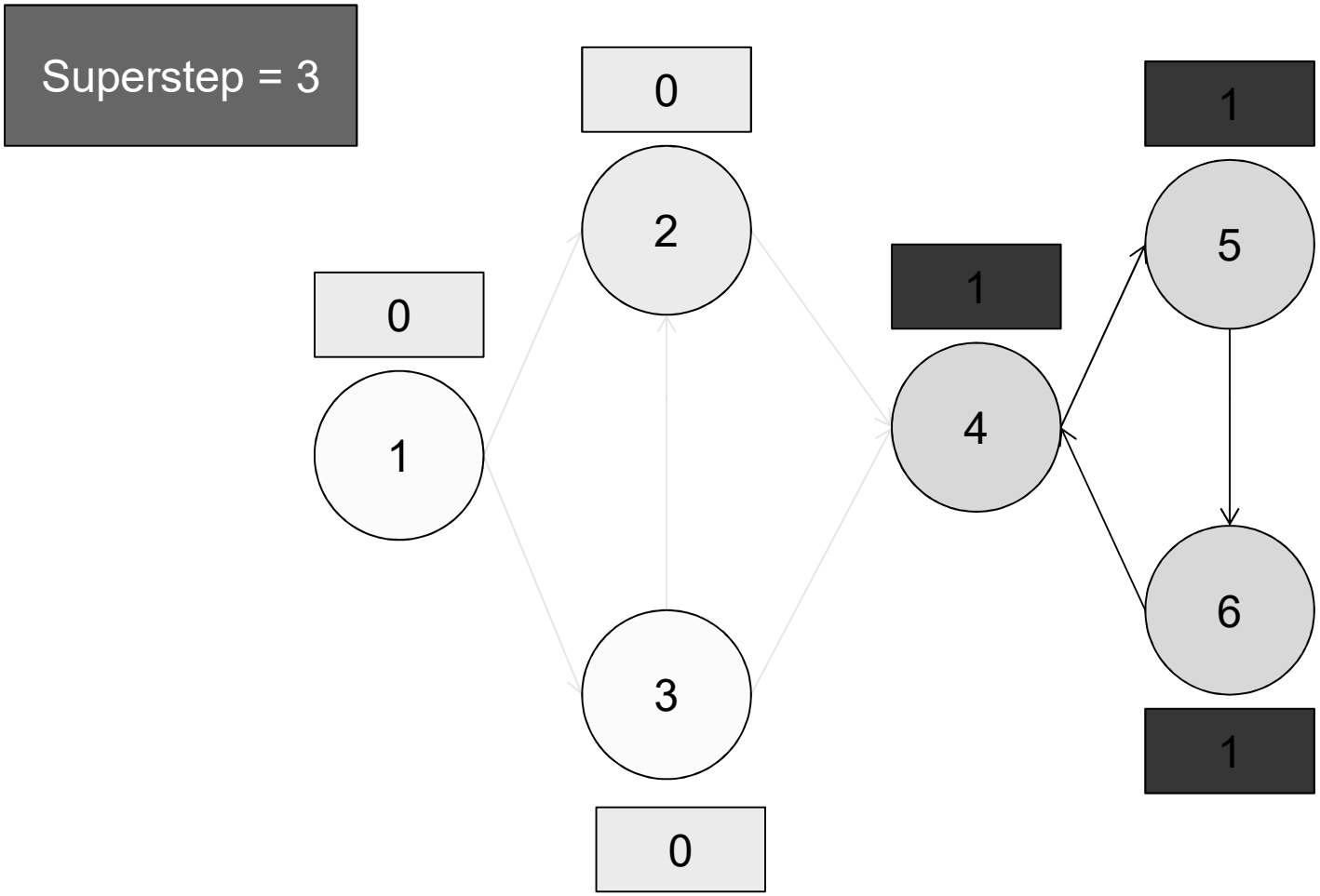


Final (non-pregel) Step

- Is a DAG iff all vertex incounts are zero
- This requires something like:
  - **filter(_.deg != 0).isEmpty**

Looking at the Code

```
def isDag(): Boolean = {
  val dag = g.outerJoinVertices(g.inDegrees){
    case(vid, vt, oInDeg) => oInDeg.getOrElse(0)
  }

  import IsDagUtil._

  val resG = dag.pregel(
      initialMsg = -1,
      maxIterations = Int.MaxValue,
      activeDirection = EdgeDirection.Out
  )(vprog, sendMsg, mergeMsg)

  resG.vertices.filter(_._2 > 0).isEmpty
}
```

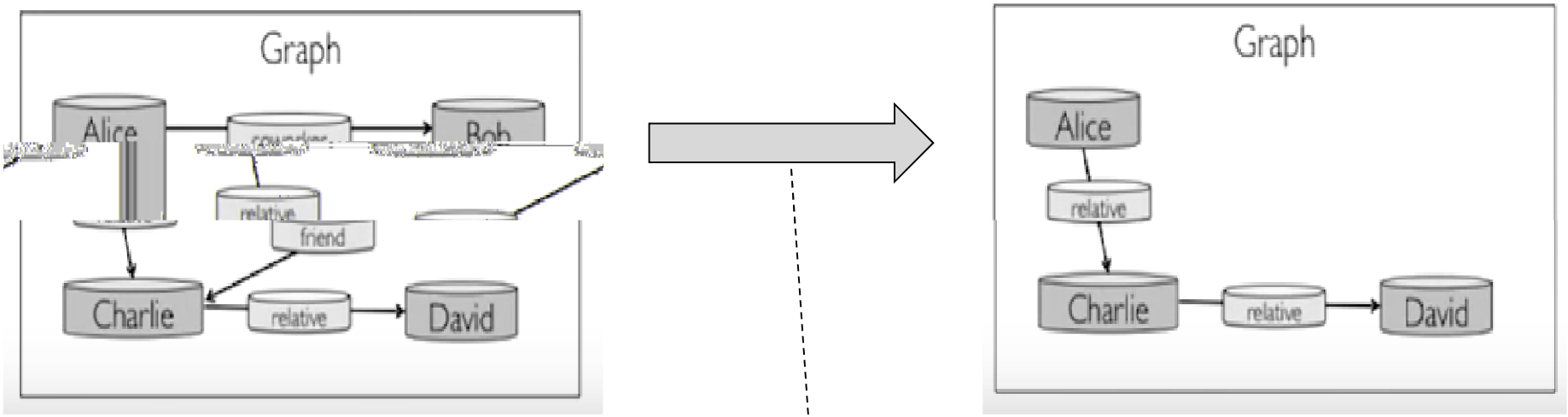
GraphX APIs

GraphX APIs

```
def mapVertices[VD2](map: (VertexId, VD) ⇒ VD2): Graph[VD2, ED]
def mapEdges[ED2](map: (Edge[ED]) ⇒ ED2): Graph[VD, ED2]
def mapTriplets[ED2](map: (EdgeTriplet[VD, ED]) ⇒ ED2): Graph[VD, ED2]


def reverse: Graph[VD, ED]
def subgraph(
    epred: (EdgeTriplet[VD, ED]) ⇒ Boolean,
    vpred: (VertexId, VD) ⇒ Boolean): Graph[VD, ED]
def mask[VD2, ED2](other: Graph[VD2, ED2]): Graph[VD, ED] // subgraph based on other
def groupEdges(merge: (ED, ED) ⇒ ED): Graph[VD, ED] // merge parallel edges
```

Example: subgraph



graph.subgraph(vpred = (_, name) => name != "Bob")

GraphX APIs

```
def outerJoinVertices[U, VD2](
    other: RDD[(VertexId, U)])
    (mapFunc: (VertexId, VD, Option[U]) ⇒ VD2): Graph[VD2, ED]
def aggregateMessages[A](
    sendMsg: (EdgeContext[VD, ED, A]) ⇒ Unit,
    mergeMsg: (A, A) ⇒ A): VertexRDD[A]
```

Age Of Oldest Follower

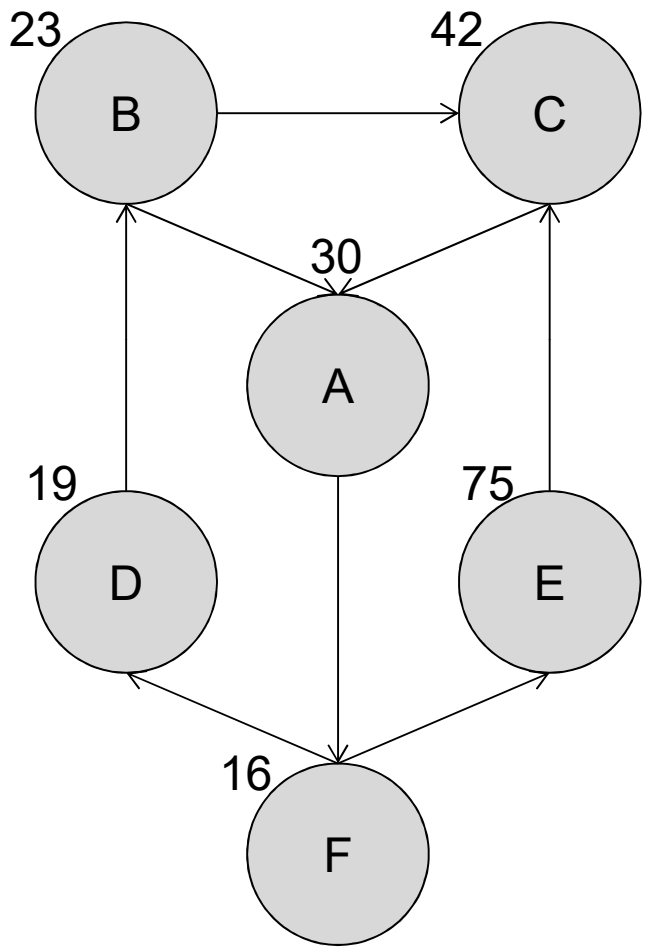
```
val oldestFollowersAge: VertexRDD[Int] =
  graph.aggregateMessages(
        ctx => ctx.sendToDst(ctx.srcAttr),
        (c1, c2) => Math.max(c1, c2)
  )
```

```
class EdgeContext[VD, ED, A] {
        def attr: ED

        def srcAttr: VD
        def dstAttr: VD

        def srcId: VertexId
        def dstId: VertexId

        def sendToDst(msg: A): Unit
        def sendToSrc(msg: A): Unit
}
```



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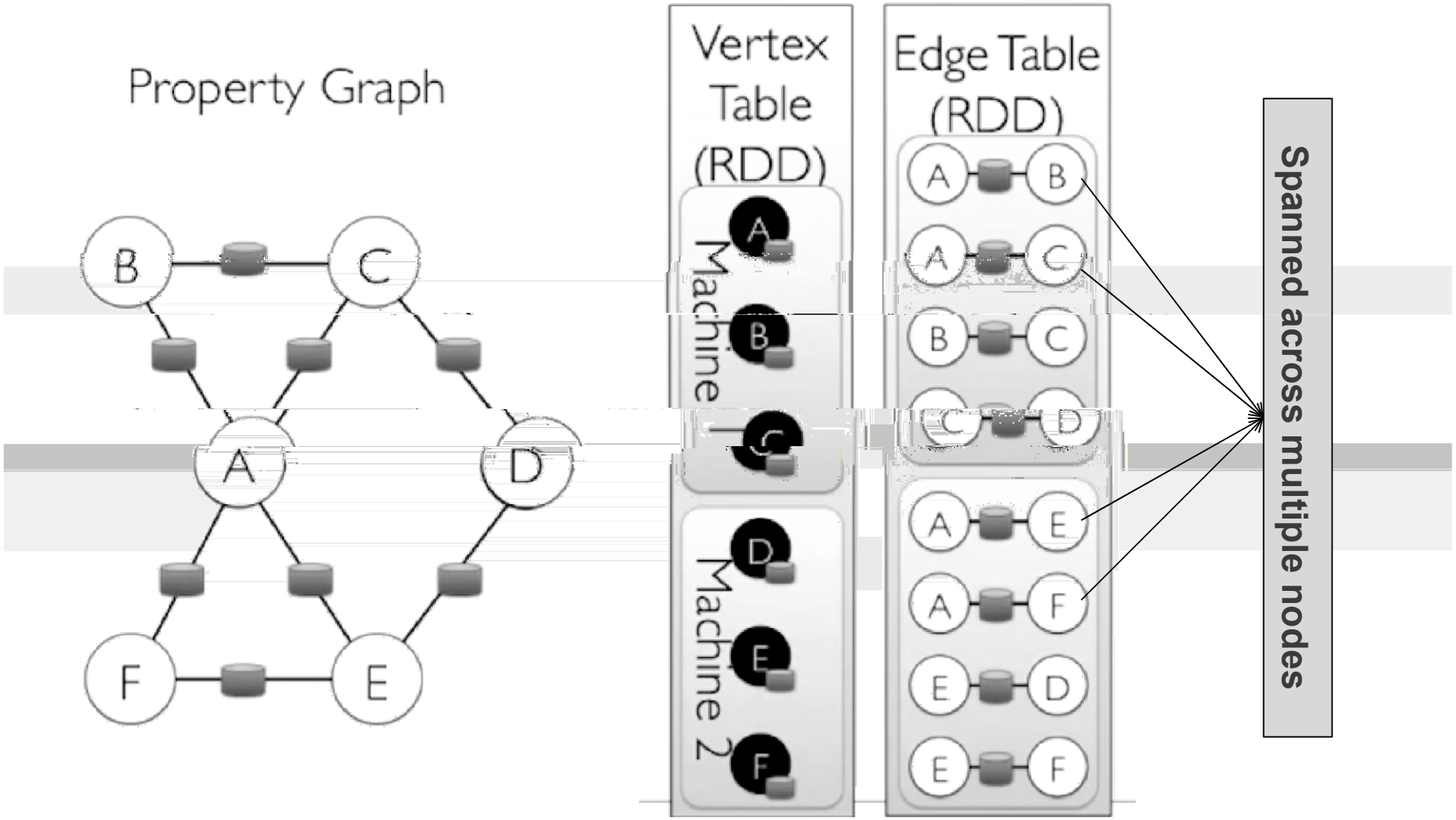
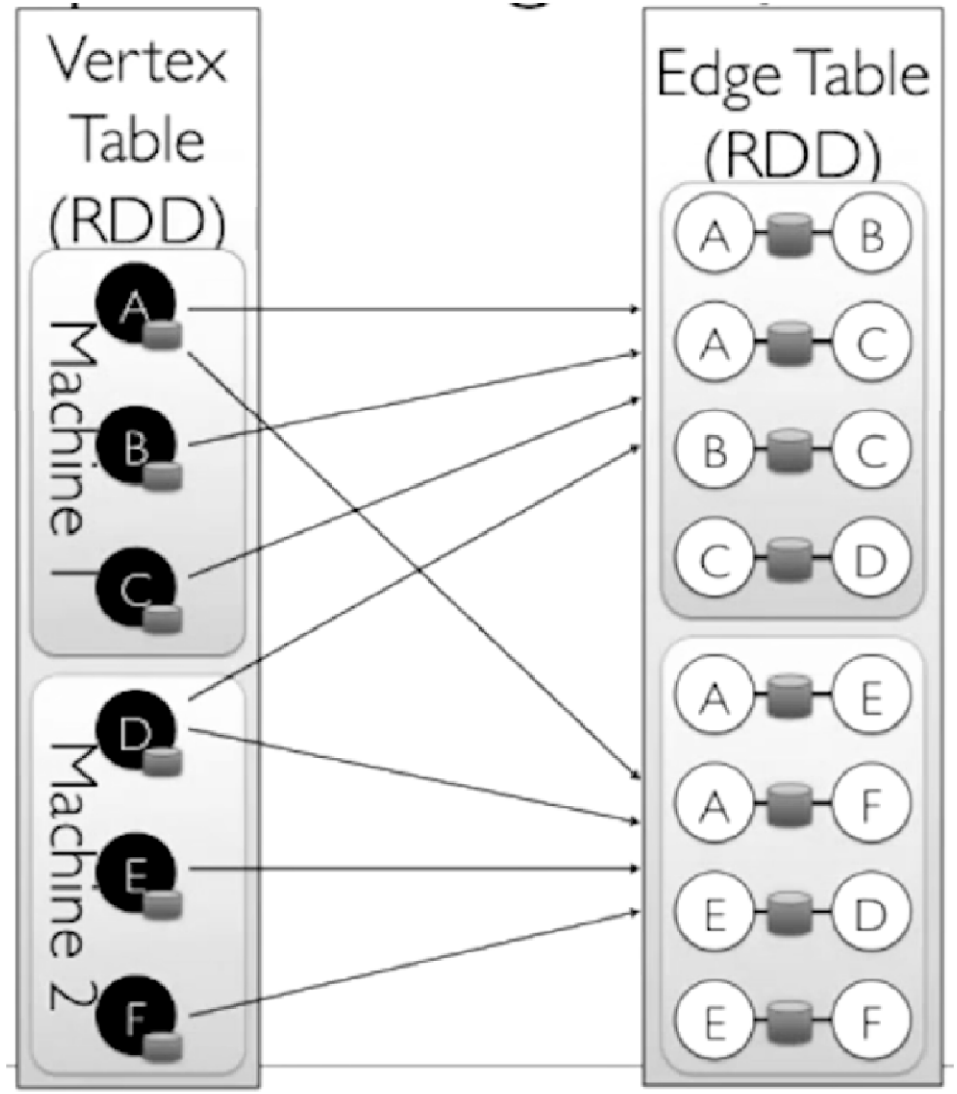
A Graph as-a Table



Triplets Under the Hood



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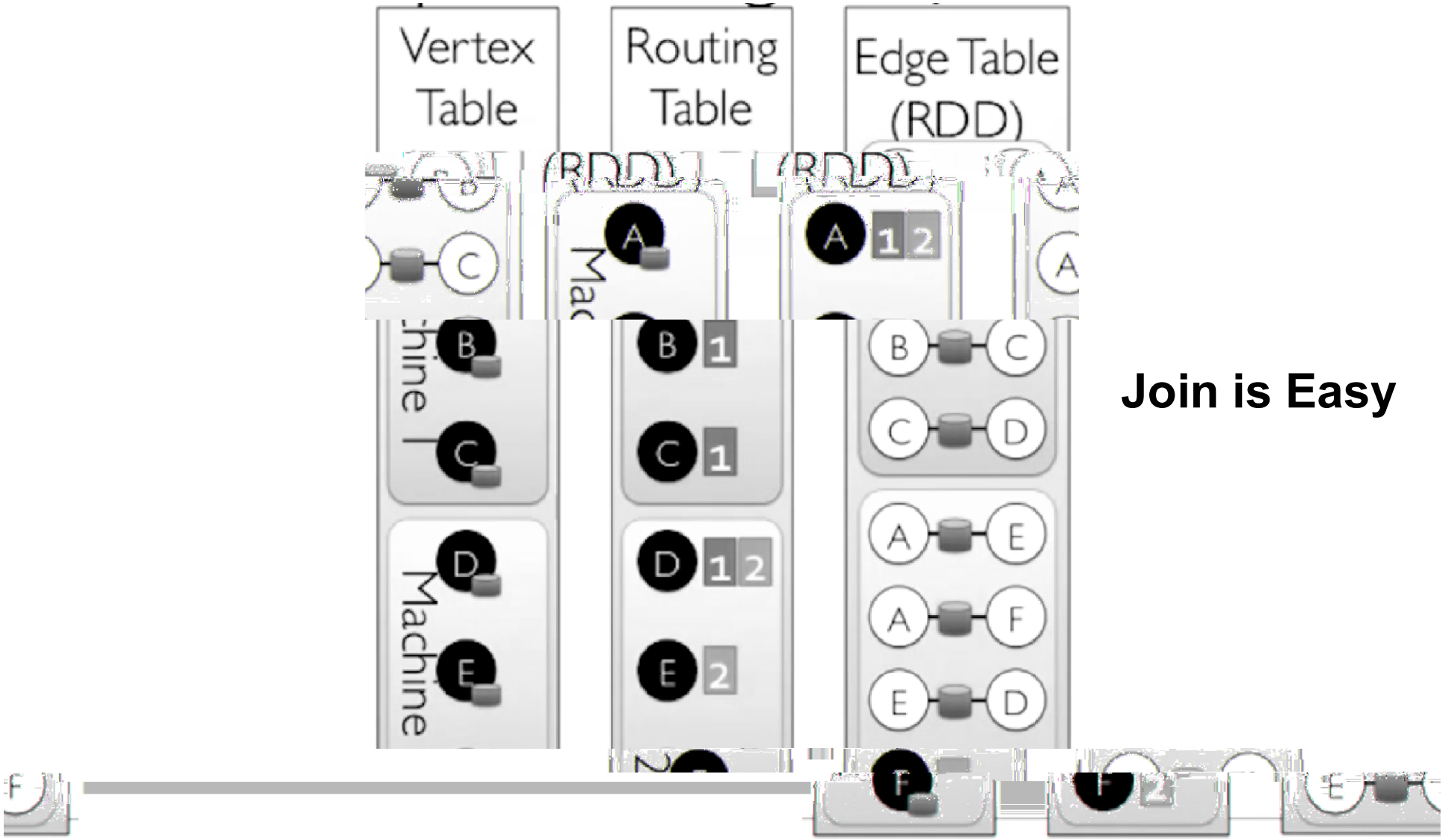
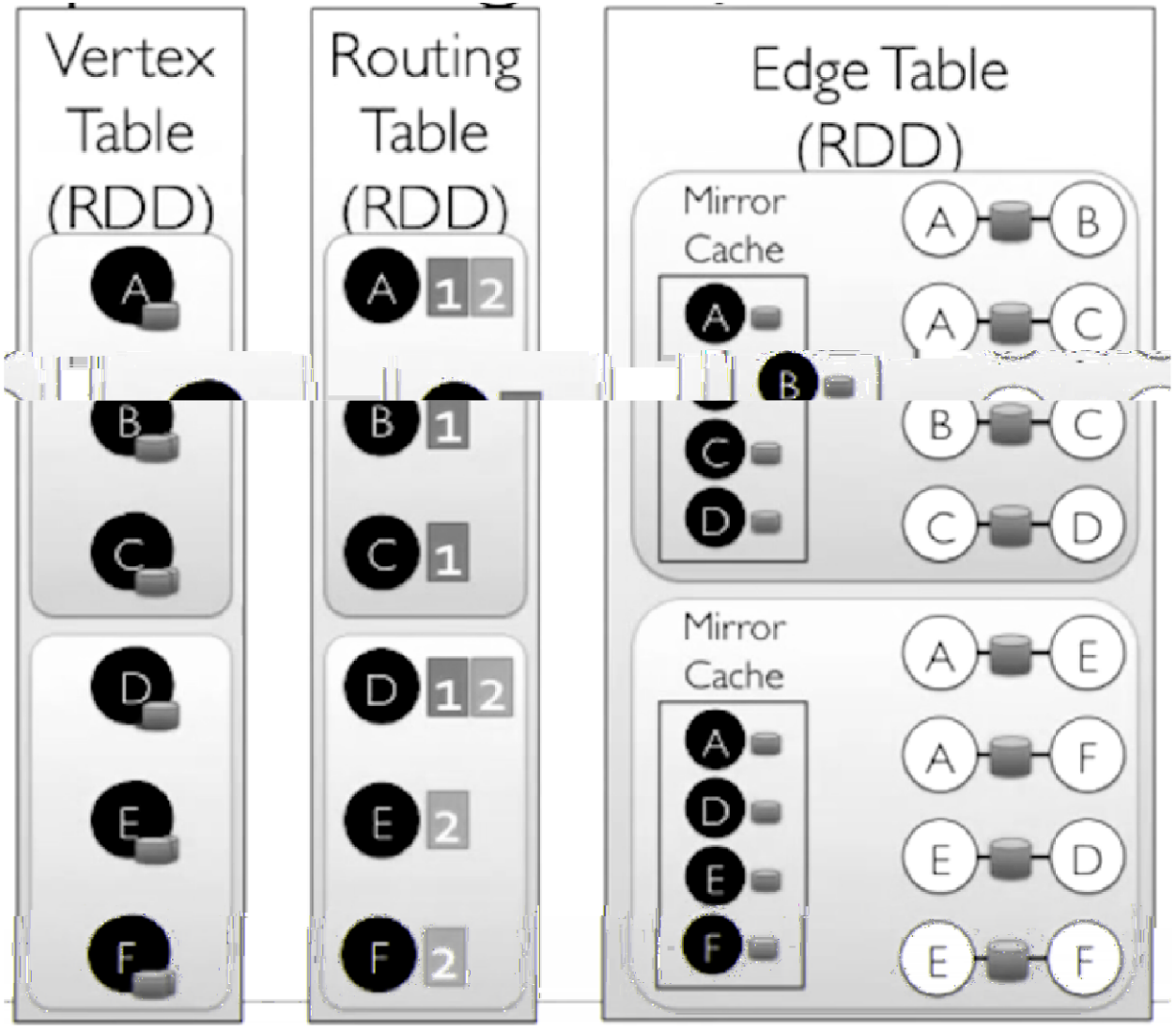


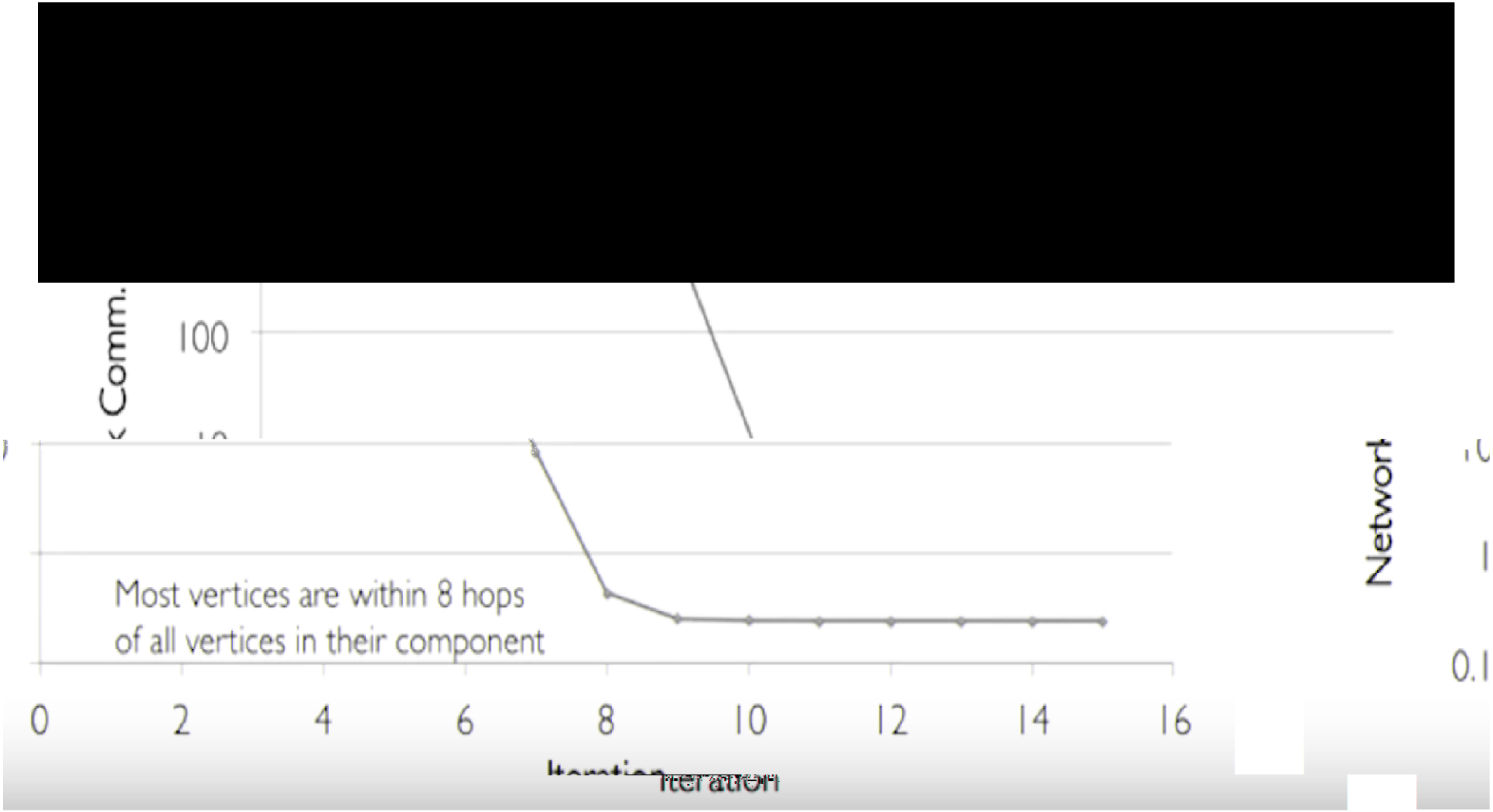
Join is Easy

Triplets Under the Hood



Send only vertex properties that changed

Reduction in Communication Due to Caching



Graph Partitioning

Graph Partitioning

- **Goal:** create a balanced graph partition

- **Challenges:**
  - Problem is NPH
  - Heuristics exist but they are complex and there is a chicken & egg problem here

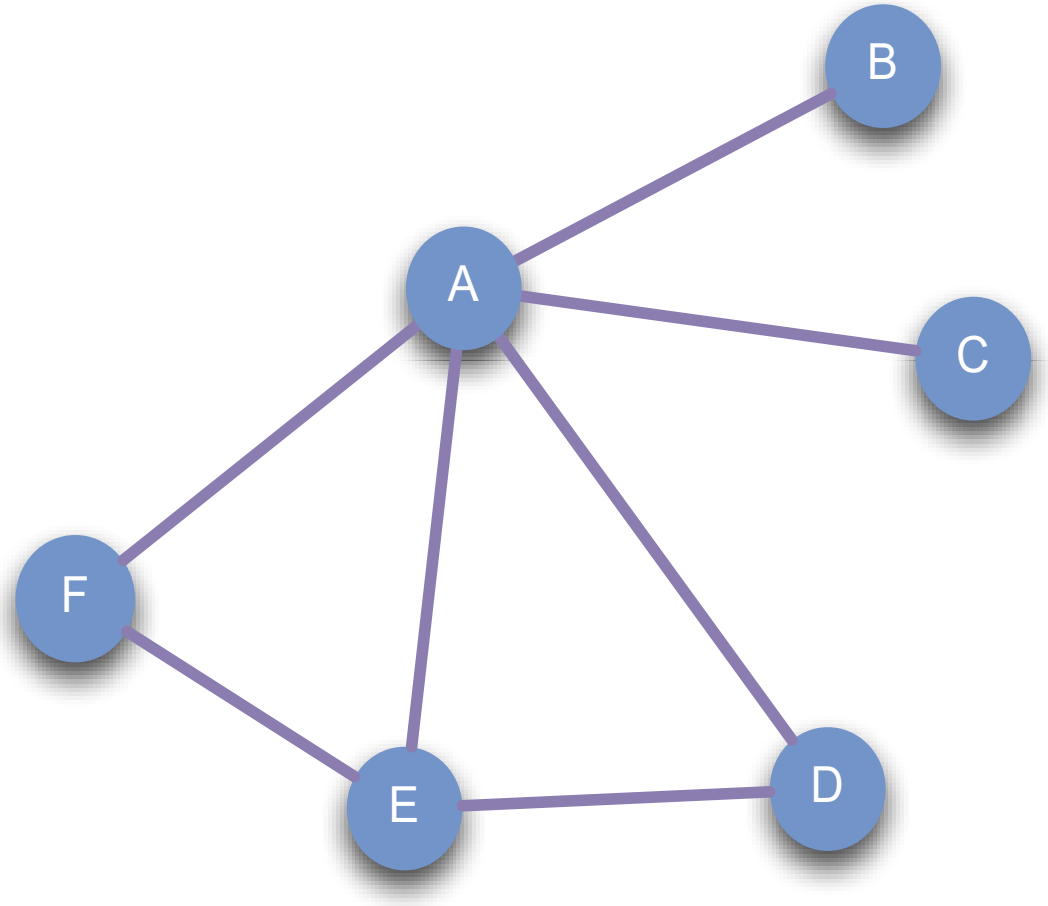
GraphX Partitioning

- Controls edge partitioning
- Four built in partitioning strategies
- Can also write custom partitioning

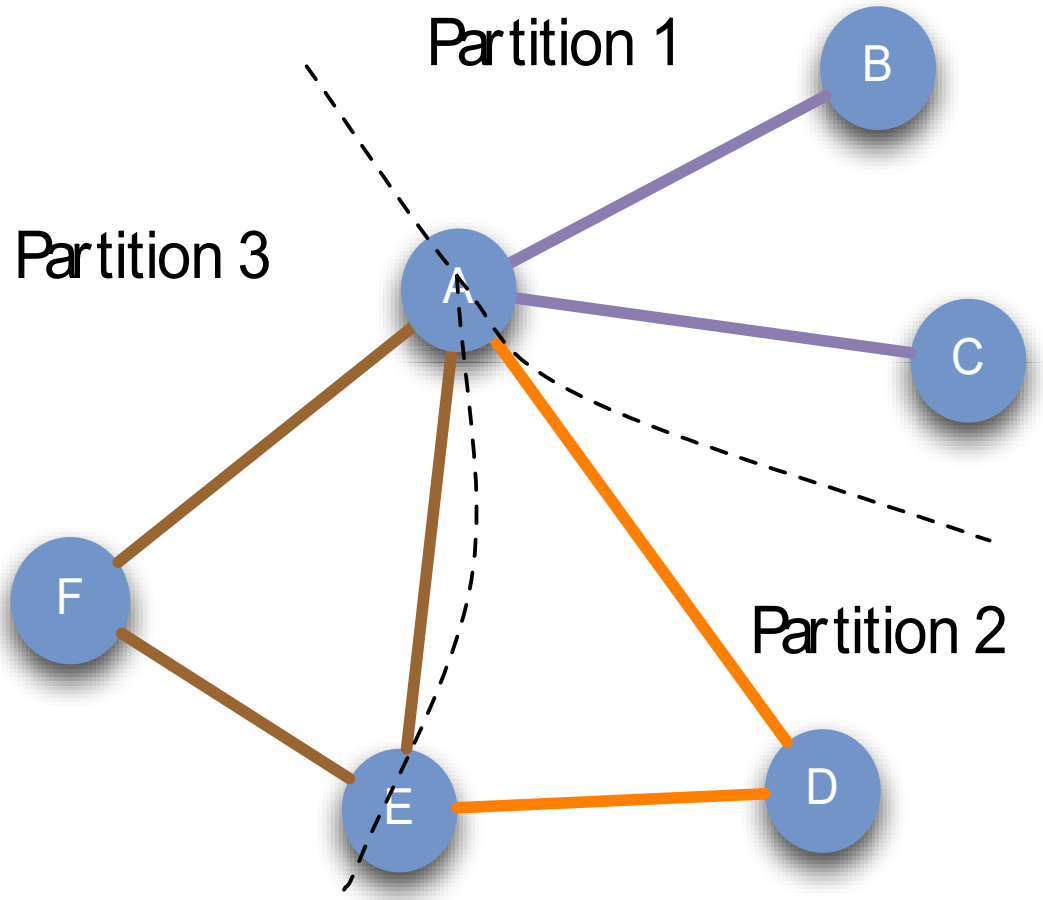
- Partitioning can be based on vertex/edge

g.partitionBy(PartitionStrategy.**EdgePartition2D, numPartitions)**

Vertex Cut Partitioning



Vertex Cut Partitioning



Support Partitioning Strategies

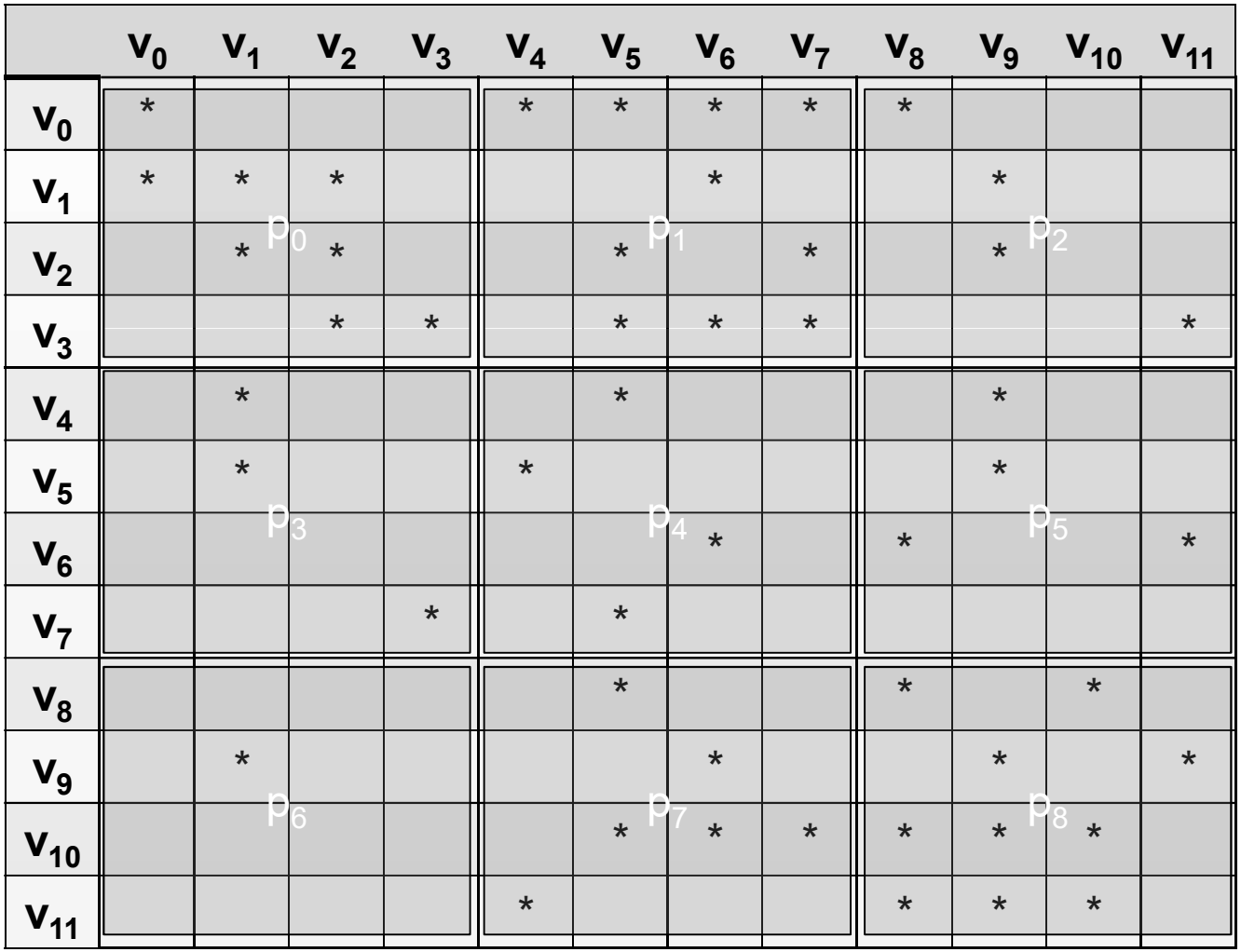
```
trait PartitionStrategy {
  def getPartition(src: VertexId, dst: VertexId, numParts: PartitionID): PartitionID
}
```

- **RandomVertexCut** – select edge partition based on **(src, dst)** hash
- **CanonicalRandomVertexCut –** same as above only canonical
- **EdgePartition1D** – partitioning based only on source vertex id (bad for hypernodes)

Partition As Sparse Matrix EdgePartition2D

	v_0	v_1	v_2	v_3	v_4	v_5	v_6	v_7	v_8	v_9	v_{10}	v_{11}
v_0	*				*	*	*	*	*			
v_1	*	*	*				*			*		
v_2		*	*			*		*		*		
v_3			*	*		*	*	*				*
v_4		*				*				*		
v_5		*			*					*		
v_6							*		*			*
v_7				*		*						
v_8						*			*		*	
v_9		*					*			*		*
v_{10}						*	*	*	*	*	*	
v_{11}					*				*	*	*	

Partition As Sparse Matrix EdgePartition2D



Summary

1. Graph-parallel processing on Spark
2. Unify tables/graphs processing
3. Work being done to improve performance brining it closer to specialized engines such as GraphLab

References

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