Experience and Lessons Learned for Large-Scale Graph Analysis using GraphX

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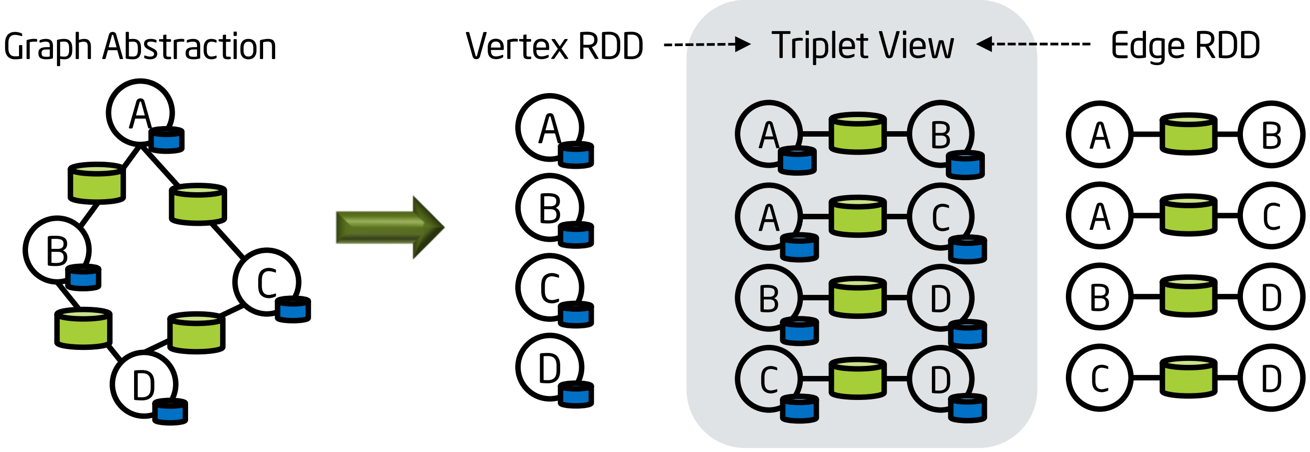
Spark Summit East 2015

GraphX Framework

GraphX framework

- Graph parallel computations on Spark data-parallel engine
- Recast graph systems optimizations as distributed dataflow operations
  - Join, view maintenance, etc.



GraphX Applications

GraphX applications

- PageRank

```
while (iteration < numIter) {
  rankGraph.cache()
  val updates = rankGraph.aggregateMessages(…)
  rankGraph = rankGraph.joinVertices(updates, …)
  …
  iteration += 1
}
```

- Large-scale, iterative Spark applications
  - Billions of edges, 1000s of iterations

Experience applicable to general large-scale iterative Spark applications (read: *machine learning*)

The Dreaded Stack Overflow

Stack overflow error

- First sign of a web-scale problem ☺

```
...
15/03/05 04:14:08 INFO scheduler.DAGScheduler: Job 458 failed: foreachPartition at PageRank.scala:110, took 138.912943 s
Exception in thread "main" org.apache.spark.SparkException: Job aborted due to stage failure: Task 268 in stage 213428.0
failed 4 times, most recent failure: Lost task 268.3 in stage 213428.0 (TID 689532, sr431):
java.lang.StackOverflowError
                at java.io.ObjectInputStream.defaultReadFields(ObjectInputStream.java:1982)
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                ...
15/03/05 04:14:08 INFO scheduler.TaskSetManager: Lost task 32.2 in stage 213428.0 (TID 689524) on executor sr431:
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...
```

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- Root cause
  - Serialization of RDD objects with extremely long lineage (due to large iteration# in the program)
- Work-arounds
  - Allocate large JVM stack frame size (i.e., -Xss), but suffer from large serialization overheads
  - Checkpoint RDD periodically

Pitfall of RDD Checkpoint

Lazy execution of checkpoint

- Fruitless if marking the RDD for checkpointing after it is materialized

```
//PageRank:
while (i <- 0 to numIter) {
  if ((i % 10) == 9)
    rankGraph.checkpoint()
  rankGraph.cache()
  val updates = rankGraph.aggregateMessages(…)
  rankGraph = rankGraph.joinVertices(updates, …)
  …
}
```

```
RDD.checkpoint() {
  ...
  checkpointData.get.
    markForCheckpoint()
}
```

```
SparkContext.runJob() {
  ...
  dagScheduler.runJob(...)
  rdd.doCheckpoint()
}
```

```
RDD.doCheckpoint() {
  if (!doCheckpointCalled) {
    doCheckpointCalled = true
    checkpointData.get.
      doCheckpoint()
    ...
  }
}
```

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```

Design pattern for managing graph persistence

- *mllib.impl.PeriodicGraphCheckpointer* (call *updateGraph* before the graph is materialized)

```
for (i <- 0 to numIter) {
  graph = ...
  graphCheckpointer.updateGraph(graph)
  ...
}
```

Pitfall of RDD Checkpoint

“Leakage” of RDD lineage

- Checkpointing breaks long lineage of RDD “dependence”
    - Lineage can still “leak” through reference in RDD member variables/methods

```
class ZippedRDD (var rdd1, var rdd2, ...)
extends RDD {
  override def compute(part, sc) = {
    ...
    rdd1.iterator(parts(0), sc) zip
      rdd2.iterator(parts(1), sc)
  }

  def clearDependencies() {
    super.clearDependencies()
    rdd1 = null
    rdd2 = null
}
```

Pitfall of RDD Checkpoint

"Leakage" of RDD lineage

- Checkpointing breaks long lineage of RDD "dependence"
  - Lineage can still "leak" through reference in RDD member variables/methods

Design pattern

- RDD reference through dependences whenever possible
- Transient member variable whenever possible
- Clear extra RDD references after checkpointing whenever possible

General fix needed?

- Only RDD.compute required at worker (see SPARK-4672)

```
class ZippedRDD (var rdd1, var rdd2, ...)
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  def clearDependencies() {
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    rdd1 = null
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```

```
class ZippedRDD (@transient val rdd1,
  @transient val rdd2,    ...) extends RDD {
  override def compute(part, sc) = {
    ...
    dependences(0).rdd.iterator(parts(0), sc) zip
      dependences(1).rdd.iterator(parts(1), sc)
    }
}
```

Costs of RDD Checkpoint

PageRank for Twitter graph

- One iteration: ~100s
- Checkpointing vertex RDD: ~20s
- Checkpointing edge RDD: ~140s

For more complete information about performance and benchmark results, visit www.intel.com/benchmarks.

A Closer Look at RDD Lineage for GraphX

PageRank

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while (iteration < numIter) {
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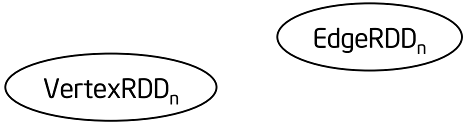

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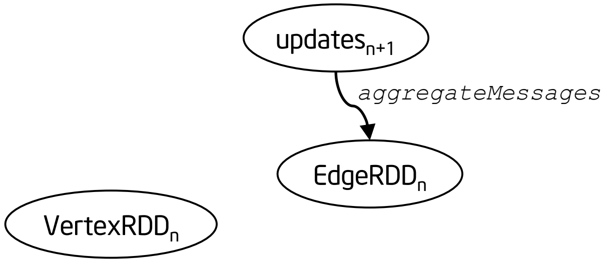

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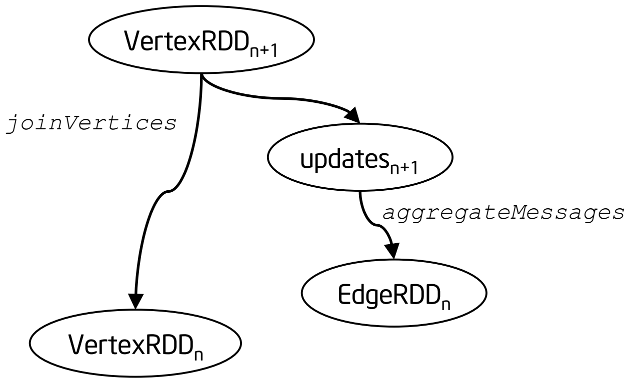

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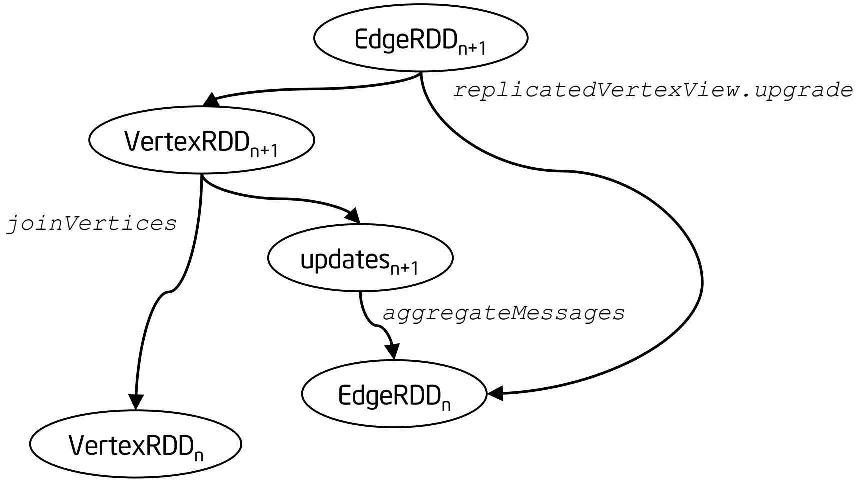

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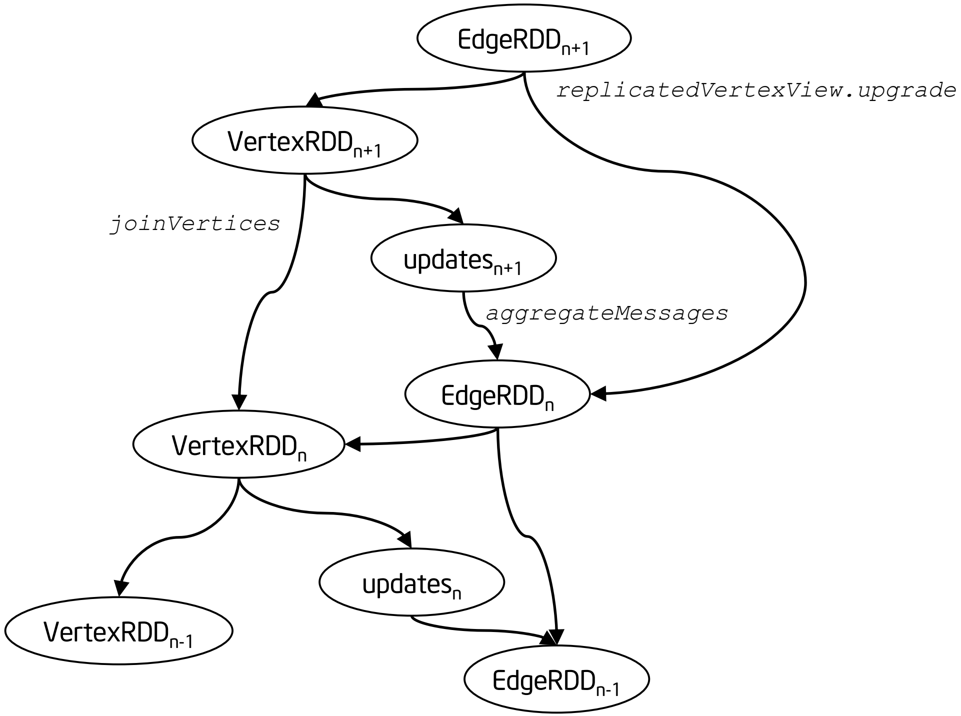

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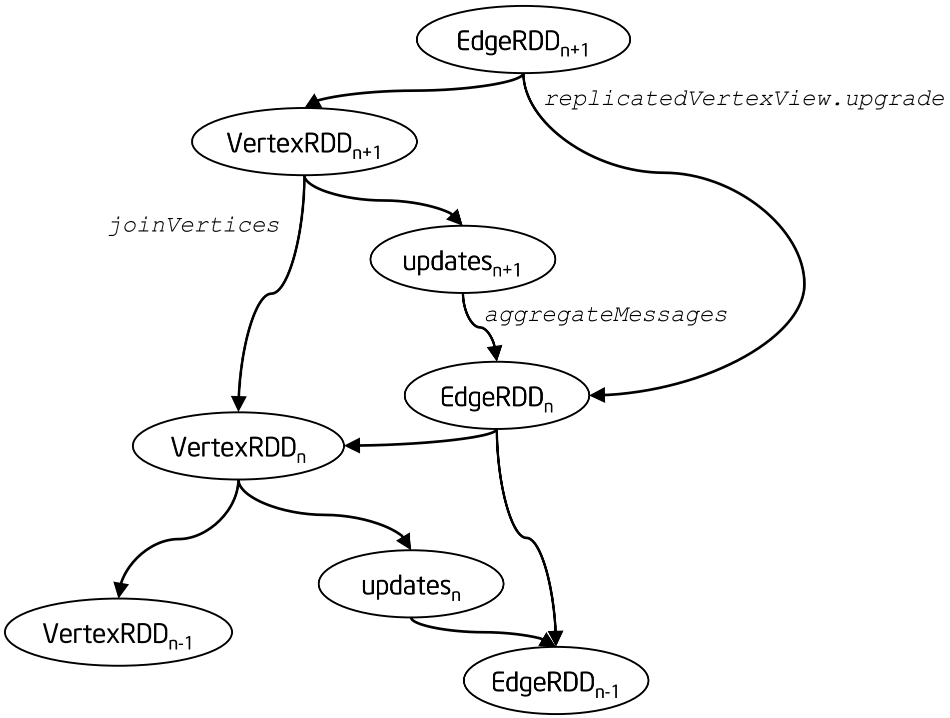

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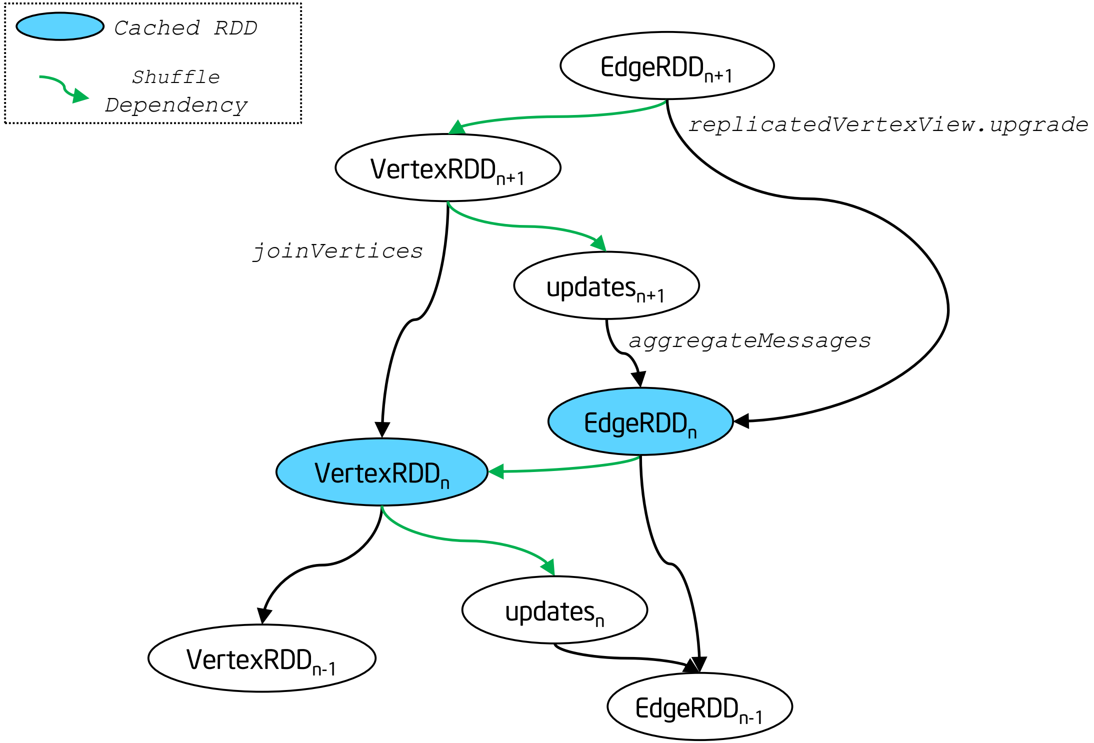

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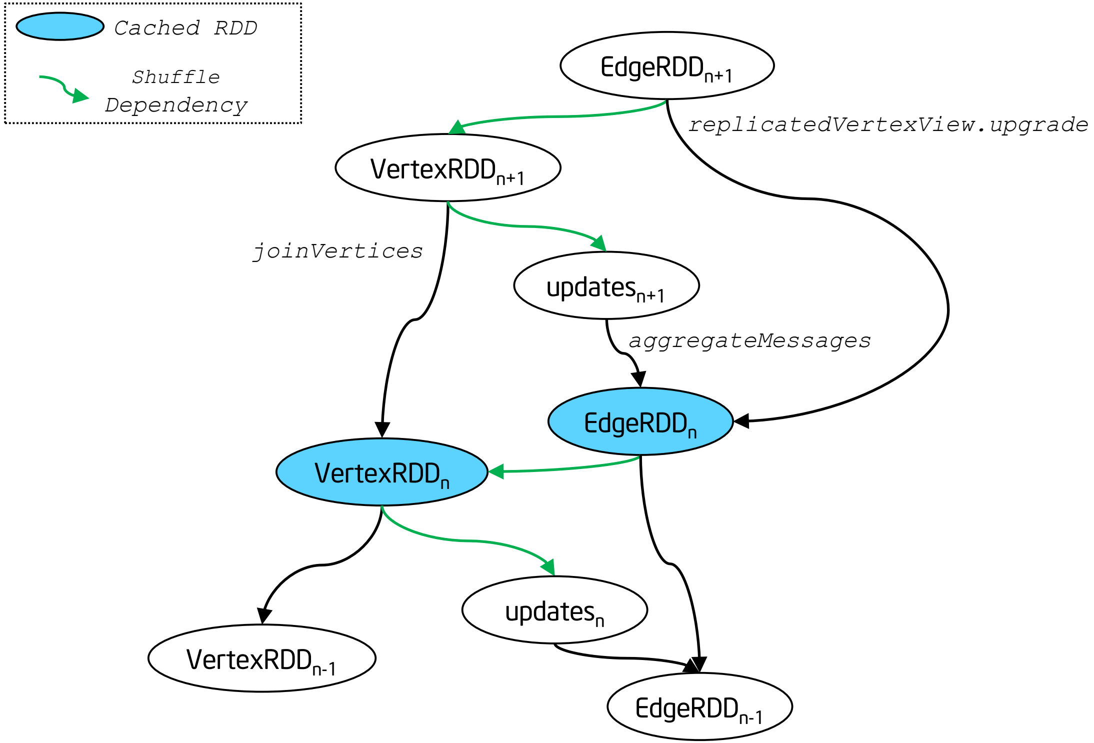

Extremely long RDD lineage

- Vertex and edge chains
  - $VertexRDD_0 \rightarrow VertexRDD_1 \rightarrow VertexRDD_2 \rightarrow \ldots$
  - $EdgeRDD_0 \rightarrow EdgeRDD_1 \rightarrow EdgeRDD_2 \rightarrow \ldots$
- Result of “graph optimizations”
  - In-place update of vertices and edges
- Possible improvements
  - Leverage the cached RDDs in the chain?
  - Reconstruct replicated vertexes?

Summary

GraphX

- Graph parallel computations on Spark data-parallel engine
  - Recast graph systems optimizations as distributed dataflow operations
- Effective support of web-scale graph applications through careful scaling
  - Billions of edges, 1000s of iterations
  - Applicable to general, large-scale, iterative Spark (e.g., ML) applications

Notices and Disclaimers

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