스파크 코드 분석

오현주

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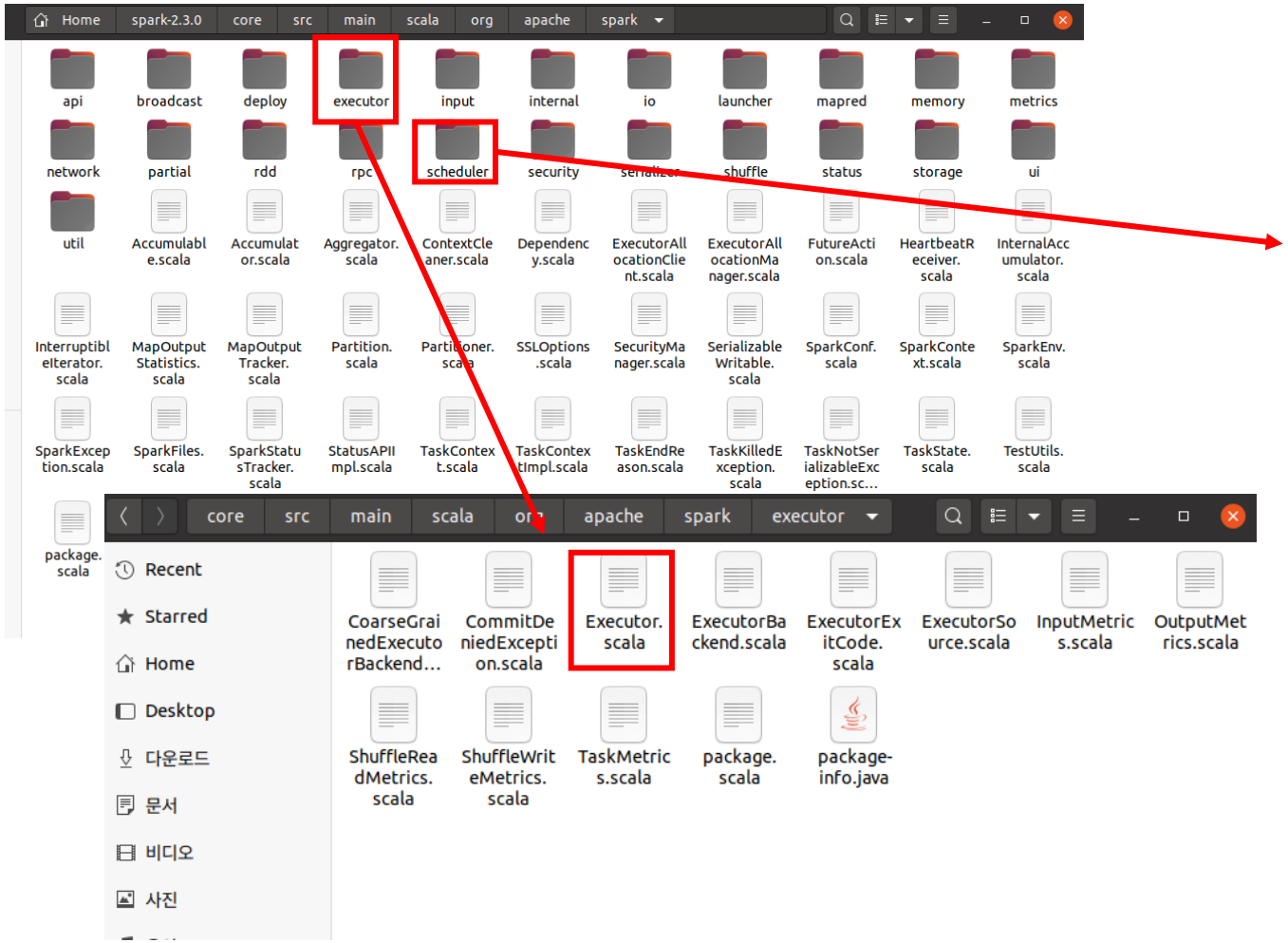
시작점 찾기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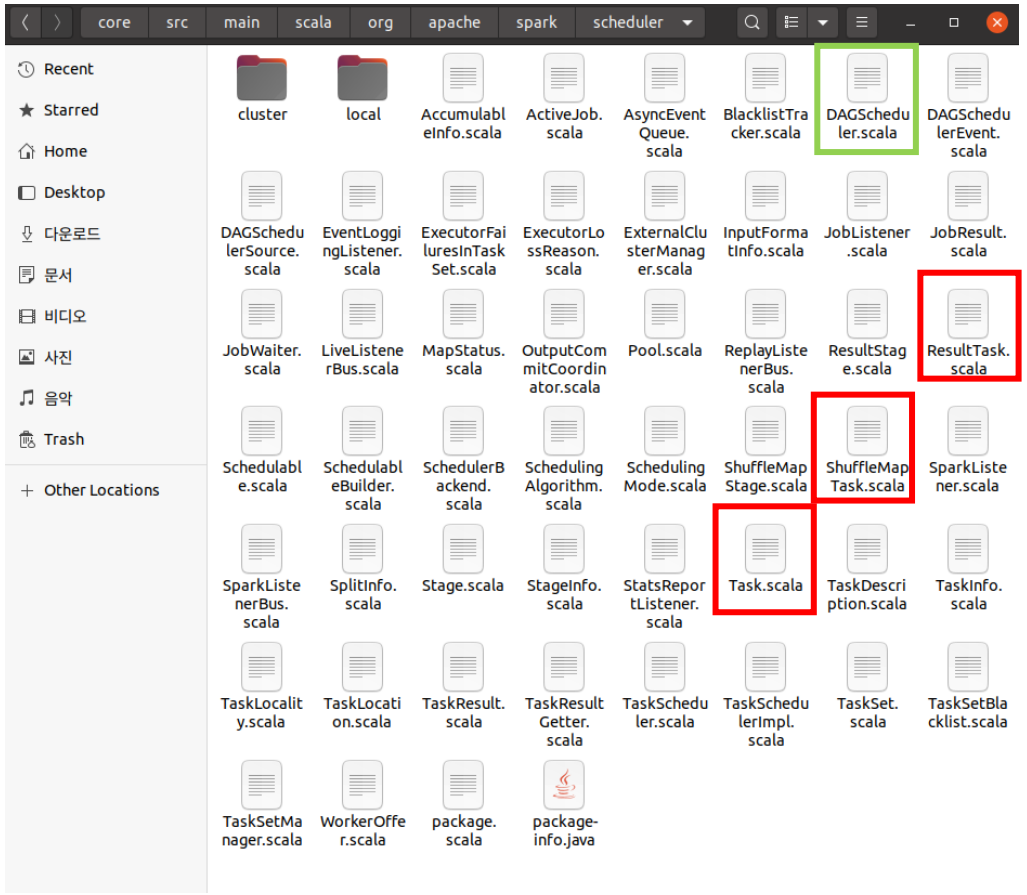
core
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package-info.java

시작점 찾기

※ REPL(Read, Evaluate, Print, Loop) 에서 변수 선언이 이루어지면 인터프리터에서 해당 변수의 type과 value를 리턴해줌

SparkContext.scala | WordCountScalaHDFSScript.scala | MapOutputTracker.scala | TaskContext.scala

```
1 import java.util.ArrayList
2 import java.util.Random
3 val start = System.currentTimeMillis()
4
5 val text = sc.textFile("hdfs://localhost:9000/user/ubuntu/wordcount/input/500mb.csv")
6 val counts = text.flatMap(line => line.split(" ")).map(word => (word, 1)).reduceByKey(_+_)
7 counts.saveAsTextFile("hdfs://localhost:9000/user/ubuntu/wordcount/output")
8 System.out.println("Spark Wordcount Complete")
9
10 val end = System.currentTimeMillis()
11 System.out.println("time:"+(end-start)/1000.0+"sec")
```

※ action 시작

```
user@user-MS-7B23:~/spark-2.3.0$ ./bin/spark-shell -i /home/user/WordCountScalaHDFSScript.scala
21/03/29 01:01:02 WARN Utils: Your hostname, user-MS-7B23 resolves to a loopback address: 127.0.1.1; using 203.153.147.216 instead (on interface eno1)
21/03/29 01:01:02 WARN Utils: Set SPARK_LOCAL_IP if you need to bind to another address
21/03/29 01:01:03 WARN NativeCodeLoader: Unable to load native-hadoop library for your platform... using builtin-java classes where applicable
Using Spark's default log4j profile: org/apache/spark/log4j-defaults.properties
Setting default log level to "WARN".
To adjust logging level use sc.setLogLevel(newLevel). For SparkR, use setLogLevel(newLevel).
Spark context Web UI available at http://203.153.147.216:4040
Spark context available as 'sc' (master = local[*], app id = local-1616947266183).
Spark session available as 'spark'.
Loading /home/user/WordCountScalaHDFSScript.scala...
import java.util.ArrayList
import java.util.Random
start: Long = 1616947267445
text: org.apache.spark.rdd.RDD[String] = hdfs://localhost:9000/user/ubuntu/wordcount/input/500mb.csv MapPartitionsRDD[1] at textFile at <console>:26
counts: org.apache.spark.rdd.RDD[(String, Int)] = ShuffledRDD[4] at reduceByKey at <console>:27
DAGScheduler.scala-runJob start
DAGScheduler.scala-submitJob() start
DAGScheduler.scala-submitJob() finish 0
```

DAG scheduler

Action의 결과를 얻어내기 위해 해야하는 일

- Job을 위한 execution DAG(Directed Acyclic Graph) 만듦
  - 즉, 각 Job을 위한 DAG stage들을 만듦
  - RDD Lineage를 stage DAG로 변환
    - Stage는 shuffle dependency들에 의해 나뉘어짐
    - 하나의 Stage 처리를 위해 하나 이상의 Task 필요

      → DAG scheduler는 생성된 stage들을 TaskSet들로 만들어서 TaskScheduler에게 submit함
- 고려해야할 부분 5가지
  - **Jobs, Stages, Tasks**, Cache tracking, Preferred locations, Cleanup

DAG scheduler

```scala
def runJob[T, U](
    rdd: RDD[T],
    func: (TaskContext, Iterator[T]) => U,
    partitions: Seq[Int],
    callSite: CallSite,
    resultHandler: (Int, U) => Unit,
    properties: Properties): Unit = {
  var startRunJob = System.currentTimeMillis() //kahu
  println("DAGScheduler.scala-runJob start")  //kahu
  val start = System.nanoTime

  println("DAGScheduler.scala-submitJob() start")  //kahu
  var startSubmitJob = System.currentTimeMillis() //kahu
  val waiter = submitJob(rdd, func, partitions, callSite, resultHandler, properties)
  var finishSubmitJob = System.currentTimeMillis() //kahu
  println("DAGScheduler.scala-submitJob() finish "+(finishSubmitJob-startSubmitJob)/1000)  //kahu

  ThreadUtils.awaitReady(waiter.completionFuture, Duration.Inf)
  waiter.completionFuture.value.get match {
    case scala.util.Success(_) =>
      logInfo("Job %d finished: %s, took %f s".format
        (waiter.jobId, callSite.shortForm, (System.nanoTime - start) / 1e9))
    case scala.util.Failure(exception) =>
      logInfo("Job %d failed: %s, took %f s".format
        (waiter.jobId, callSite.shortForm, (System.nanoTime - start) / 1e9))
      // SPARK-8644: Include user stack trace in exceptions coming from DAGScheduler.
      val callerStackTrace = Thread.currentThread().getStackTrace.tail
      exception.setStackTrace(exception.getStackTrace ++ callerStackTrace)
      throw exception
  }

  var finishRunJob = System.currentTimeMillis() //kahu
  println("DAGScheduler.scala-runJob finish "+(finishRunJob-startRunJob)/1000)  //kahu
}
```

```scala
/**
 * Submit an action job to the scheduler.
 *
 * @param rdd target RDD to run tasks on
 * @param func a function to run on each partition of the RDD
 * @param partitions set of partitions to run on; some jobs may not want to compute on all
 *   partitions of the target RDD, e.g. for operations like first()
 * @param callSite where in the user program this job was called
 * @param resultHandler callback to pass each result to
 * @param properties scheduler properties to attach to this job, e.g. fair scheduler pool name
 *
 * @return a JobWaiter object that can be used to block until the job finishes executing
 *         or can be used to cancel the job.
 *
 * @throws IllegalArgumentException when partitions ids are illegal
 */
def submitJob[T, U](
    rdd: RDD[T],
    func: (TaskContext, Iterator[T]) => U,
    partitions: Seq[Int],
    callSite: CallSite,
    resultHandler: (Int, U) => Unit,
    properties: Properties): JobWaiter[U] = {

  // Check to make sure we are not launching a task on a partition that does not exist.
  val maxPartitions = rdd.partitions.length
  partitions.find(p => p >= maxPartitions || p < 0).foreach { p =>
    throw new IllegalArgumentException(
      "Attempting to access a non-existent partition: " + p + ". " +
        "Total number of partitions: " + maxPartitions)
  }

  val jobId = nextJobId.getAndIncrement()
  if (partitions.size == 0) {
    // Return immediately if the job is running 0 tasks
    return new JobWaiter[U](this, jobId, 0, resultHandler)
  }

  assert(partitions.size > 0)
  val func2 = func.asInstanceOf[(TaskContext, Iterator[_]) => _]
  val waiter = new JobWaiter(this, jobId, partitions.size, resultHandler)
  eventProcessLoop.post(JobSubmitted(
    jobId, rdd, func2, partitions.toArray, callSite, waiter,
    SerializationUtils.clone(properties)))
  waiter
}
```

Executor.scala

- Spark executor, backed by a threadpool to run tasks
- Can be used with Mesos, YARN, and the standalone scheduler
- Executor.scala 내부의 TaskRunner 클래스

```scala
class TaskRunner(
    execBackend: ExecutorBackend,
    private val taskDescription: TaskDescription)
  extends Runnable {

  val taskId = taskDescription.taskId
  val threadName = s"Executor task launch worker for task $taskId"
  private val taskName = taskDescription.name

  /** If specified, this task has been killed and this option contains the reason. */
  @volatile private var reasonIfKilled: Option[String] = None

  @volatile private var threadId: Long = -1

  def getThreadId: Long = threadId

  /** Whether this task has been finished. */
  @GuardedBy("TaskRunner.this")
  private var finished = false

  def isFinished: Boolean = synchronized { finished }

  /** How much the JVM process has spent in GC when the task starts to run. */
  @volatile var startGCTime: Long = _

  /**
   * The task to run. This will be set in run() by deserializing the task binary coming
   * from the driver. Once it is set, it will never be changed.
   */
  @volatile var task: Task[Any] = _
```

Executor.scala

- TaskRunner 클래스 내의 run 함수
  - run 함수 내의 실제 task 실행 부분

```
override def run(): Unit = {
  var runJobStart = System.currentTimeMillis() //kahu
  println(executorId+" Executor.scala-Taskrunner.class-run()-start") //kahu

  threadId = Thread.currentThread.getId
  Thread.currentThread.setName(threadName)
  val threadMXBean = ManagementFactory.getThreadMXBean
  val taskMemoryManager = new TaskMemoryManager(env.memoryManager, taskId)
  val deserializeStartTime = System.currentTimeMillis()
  val deserializeStartCpuTime = if (threadMXBean.isCurrentThreadCpuTimeSupported) {
    threadMXBean.getCurrentThreadCpuTime
  } else 0L
  Thread.currentThread.setContextClassLoader(replClassLoader)
  val ser = env.closureSerializer.newInstance()
  logInfo(s"Running $taskName (TID $taskId)")
  execBackend.statusUpdate(taskId, TaskState.RUNNING, EMPTY_BYTE_BUFFER)
  var taskStart: Long = 0
  var taskStartCpu: Long = 0
  startGCTime = computeTotalGcTime()
```

```
// Run the actual task and measure its runtime.
println("real task start")  //kahu
taskStart = System.currentTimeMillis()
taskStartCpu = if (threadMXBean.isCurrentThreadCpuTimeSupported) {
  threadMXBean.getCurrentThreadCpuTime
} else 0L
var threwException = true
val value = try {
  val res = task.run(
    taskAttemptId = taskId,
    attemptNumber = taskDescription.attemptNumber,
    metricsSystem = env.metricsSystem)
  threwException = false
  res
} finally {
  val releasedLocks = env.blockManager.releaseAllLocksForTask(taskId)
  val freedMemory = taskMemoryManager.cleanUpAllAllocatedMemory()

  if (freedMemory > 0 && !threwException) {
    val errMsg = s"Managed memory leak detected; size = $freedMemory bytes, TID = $taskId"
    if (conf.getBoolean("spark.unsafe.exceptionOnMemoryLeak", false)) {
      throw new SparkException(errMsg)
    } else {
      logWarning(errMsg)
    }
  }

  if (releasedLocks.nonEmpty && !threwException) {
    val errMsg =
      s"${releasedLocks.size} block locks were not released by TID = $taskId:\n" +
        releasedLocks.mkString("[", ", ", "]")
    if (conf.getBoolean("spark.storage.exceptionOnPinLeak", false)) {
      throw new SparkException(errMsg)
    } else {
      logInfo(errMsg)
    }
  }
}
task.context.fetchFailed.foreach { fetchFailure =>
  // uh-oh.  it appears the user code has caught the fetch-failure without throwing any
  // other exceptions.  Its *possible* this is what the user meant to do (though highly
  // unlikely).  So we will log an error and keep going.
  logError(s"TID ${taskId} completed successfully though internally it encountered " +
    s"unrecoverable fetch failures!  Most likely this means user code is incorrectly " +
    s"swallowing Spark's internal ${classOf[FetchFailedException]}", fetchFailure)
}
val taskFinish = System.currentTimeMillis()
val taskFinishCpu = if (threadMXBean.isCurrentThreadCpuTimeSupported) {
  threadMXBean.getCurrentThreadCpuTime
} else 0L

println(executorId+": real task time "+(taskFinish-taskStart)/1000);  //kahu
```

Task.scala

- A unit of execution
- Two kinds of Task's in Spark
  - ShuffleMapTask.scala
    - 마지막 stage 이전의 stage들은 ShuffleMapTask들을 가지고 있음
    - A ShuffleMapTask executes the task and divides the task output to multiple buckets(based on the task's partitioner)
  - ResultTask.scala
    - Job에서 가장 마지막 stage는 여러 개의 ResultTask들을 가지고 있음
    - A ResultTask executes the task and sends the task output back to the driver application

ShuffleMapTask.scala

- Divides the elements of an RDD into multiple buckets
- ShuffleMapTask.scala에서 runTask 함수

```scala
override def runTask(context: TaskContext): MapStatus = {

  println("ShuffleMapTask.scala-runTask() start")  //kahu
  // Deserialize the RDD using the broadcast variable.
  val threadMXBean = ManagementFactory.getThreadMXBean
  val deserializeStartTime = System.currentTimeMillis()
  val deserializeStartCpuTime = if (threadMXBean.isCurrentThreadCpuTimeSupported) {
    threadMXBean.getCurrentThreadCpuTime
  } else 0L
  val ser = SparkEnv.get.closureSerializer.newInstance()
  val (rdd, dep) = ser.deserialize[(RDD[_], ShuffleDependency[_, _, _])](
    ByteBuffer.wrap(taskBinary.value), Thread.currentThread.getContextClassLoader)
  _executorDeserializeTime = System.currentTimeMillis() - deserializeStartTime
  _executorDeserializeCpuTime = if (threadMXBean.isCurrentThreadCpuTimeSupported) {
    threadMXBean.getCurrentThreadCpuTime - deserializeStartCpuTime
  } else 0L

  var writer: ShuffleWriter[Any, Any] = null
  try {
    val manager = SparkEnv.get.shuffleManager
    writer = manager.getWriter[Any, Any](dep.shuffleHandle, partitionId, context)
    writer.write(rdd.iterator(partition, context).asInstanceOf[Iterator[_ <: Product2[Any, Any]]])
    writer.stop(success = true).get
  } catch {
    case e: Exception =>
      try {
        if (writer != null) {
          writer.stop(success = false)
        }
      } catch {
        case e: Exception =>
          log.debug("Could not stop writer", e)
      }
      throw e
  }
}
```

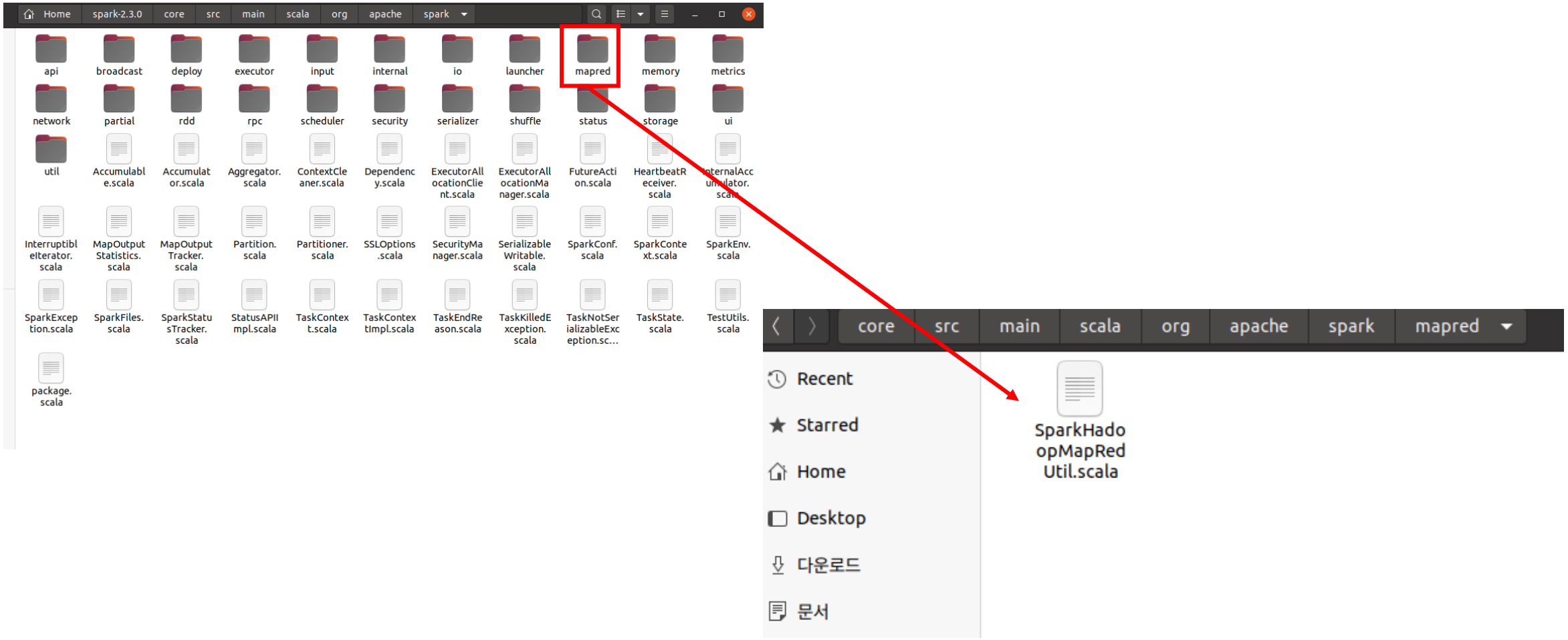
ResultTask.scala

- A task that sends back the output to the driver application
- ResultTask.scala의 runTask 메소드

```scala
override def runTask(context: TaskContext): U = {
  println("ResultTask.scala start")  //kahu
  // Deserialize the RDD and the func using the broadcast variables.
  val threadMXBean = ManagementFactory.getThreadMXBean
  val deserializeStartTime = System.currentTimeMillis()
  val deserializeStartCpuTime = if (threadMXBean.isCurrentThreadCpuTimeSupported) {
    threadMXBean.getCurrentThreadCpuTime
  } else 0L
  val ser = SparkEnv.get.closureSerializer.newInstance()
  val (rdd, func) = ser.deserialize[(RDD[T], (TaskContext, Iterator[T]) => U)](
    ByteBuffer.wrap(taskBinary.value), Thread.currentThread.getContextClassLoader)
  _executorDeserializeTime = System.currentTimeMillis() - deserializeStartTime
  _executorDeserializeCpuTime = if (threadMXBean.isCurrentThreadCpuTimeSupported) {
    threadMXBean.getCurrentThreadCpuTime - deserializeStartCpuTime
  } else 0L

  func(context, rdd.iterator(partition, context))
}
```

SparkHadoopMapRedUtil.scala



SparkHadoopMapRedUtil.scala

- Commits a task output
  - Coordinates with the driver in order to determine whether this attempt can commit
    - Some other task attempt might be racing to commit the same output partition
  - SparkHadoopMapRedUtil.scala 내의 commitTask 함수

```scala
def commitTask(
    committer: MapReduceOutputCommitter,
    mrTaskContext: MapReduceTaskAttemptContext,
    jobId: Int,
    splitId: Int): Unit = {

  println("SparkHadoopMapRedUtil.scala-commitTask() start")  //kahu

  val mrTaskAttemptID = mrTaskContext.getTaskAttemptID

  // Called after we have decided to commit
  def performCommit(): Unit = {
    try {
      committer.commitTask(mrTaskContext)
      logInfo(s"$mrTaskAttemptID: Committed")
    } catch {
      case cause: IOException =>
        logError(s"Error committing the output of task: $mrTaskAttemptID", cause)
        committer.abortTask(mrTaskContext)
        throw cause
    }
  }

  // First, check whether the task's output has already been committed by some other attempt
  if (committer.needsTaskCommit(mrTaskContext)) {
    val shouldCoordinateWithDriver: Boolean = {
      val sparkConf = SparkEnv.get.conf
      // We only need to coordinate with the driver if there are concurrent task attempts.
      // Note that this could happen even when speculation is not enabled (e.g. see SPARK-8029).
      // This (undocumented) setting is an escape-hatch in case the commit code introduces bugs.
      sparkConf.getBoolean("spark.hadoop.outputCommitCoordination.enabled", defaultValue = true)
    }

    if (shouldCoordinateWithDriver) {
      val outputCommitCoordinator = SparkEnv.get.outputCommitCoordinator
      val taskAttemptNumber = TaskContext.get().attemptNumber()
      val stageId = TaskContext.get().stageId()
      val canCommit = outputCommitCoordinator.canCommit(stageId, splitId, taskAttemptNumber)

      if (canCommit) {
        performCommit()
      } else {
        val message =
          s"$mrTaskAttemptID: Not committed because the driver did not authorize commit"
        logInfo(message)
        // We need to abort the task so that the driver can reschedule new attempts, if necessary
        committer.abortTask(mrTaskContext)
        throw new CommitDeniedException(message, stageId, splitId, taskAttemptNumber)
      }
    } else {
      // Speculation is disabled or a user has chosen to manually bypass the commit coordination
      performCommit()
    }
  } else {
    // Some other attempt committed the output, so we do nothing and signal success
    logInfo(s"No need to commit output of task because needsTaskCommit=false: $mrTaskAttemptID")
  }

  println("SparkHadoopMapRedUtil.scala-commitTask()-Finish")  //kahu
}
```

```
DAGScheduler.scala-runJob start
DAGScheduler.scala-submitJob() start
DAGScheduler.scala-submitJob() finish 0
driver Executor.scala-Taskrunner.class-run()-start
driver Executor.scala-Taskrunner.class-run()-start
driver Executor.scala-Taskrunner.class-run()-start
driver Executor.scala-Taskrunner.class-run()-start
driver Executor.scala-Taskrunner.class-run()-start
Executor.scala-Taskrunner.class-run()-actualTaskrun-start
Executor.scala-Taskrunner.class-run()-actualTaskrun-start
Executor.scala-Taskrunner.class-run()-actualTaskrun-start
Executor.scala-Taskrunner.class-run()-actualTaskrun-start
Executor.scala-Taskrunner.class-run()-actualTaskrun-start
ShuffleMapTask.scala-runTask() start
ShuffleMapTask.scala-runTask() start
ShuffleMapTask.scala-runTask() start
ShuffleMapTask.scala-runTask() start
ShuffleMapTask.scala-runTask() start
[Stage 0:>                                                          (0 + 5) / 5]driver Executor.scala-Taskrunner.class-run()-actualTaskrun-finish 2
driver Executor.scala-run()-finish 2
[Stage 0:===========>                                               (1 + 4) / 5]driver Executor.scala-Taskrunner.class-run()-actualTaskrun-finish 3
driver Executor.scala-run()-finish 3
driver Executor.scala-Taskrunner.class-run()-actualTaskrun-finish 3
driver Executor.scala-run()-finish 3
driver Executor.scala-Taskrunner.class-run()-actualTaskrun-finish 3
driver Executor.scala-run()-finish 3
driver Executor.scala-Taskrunner.class-run()-actualTaskrun-finish 3
driver Executor.scala-run()-finish 3
driver Executor.scala-Taskrunner.class-run()-start
driver Executor.scala-Taskrunner.class-run()-start
driver Executor.scala-Taskrunner.class-run()-start
driver Executor.scala-Taskrunner.class-run()-start
driver Executor.scala-Taskrunner.class-run()-start
Executor.scala-Taskrunner.class-run()-actualTaskrun-start
Executor.scala-Taskrunner.class-run()-actualTaskrun-start
Executor.scala-Taskrunner.class-run()-actualTaskrun-start
Executor.scala-Taskrunner.class-run()-actualTaskrun-start
Executor.scala-Taskrunner.class-run()-actualTaskrun-start
ResultTask.scala start
ResultTask.scala start
ResultTask.scala start
ResultTask.scala start
ResultTask.scala start
[Stage 1:>                                                          (0 + 5) / 5]SparkHadoopMapRedUtil.scala-commitTask() start
SparkHadoopMapRedUtil.scala-commitTask() start
SparkHadoopMapRedUtil.scala-commitTask() start
SparkHadoopMapRedUtil.scala-commitTask() start
SparkHadoopMapRedUtil.scala-commitTask() start
SparkHadoopMapRedUtil.scala-commitTask()-Finish
SparkHadoopMapRedUtil.scala-commitTask()-Finish
SparkHadoopMapRedUtil.scala-commitTask()-Finish
SparkHadoopMapRedUtil.scala-commitTask()-Finish
SparkHadoopMapRedUtil.scala-commitTask()-Finish
driver Executor.scala-Taskrunner.class-run()-actualTaskrun-finish 0
driver Executor.scala-Taskrunner.class-run()-actualTaskrun-finish 0
driver Executor.scala-Taskrunner.class-run()-actualTaskrun-finish 0
driver Executor.scala-Taskrunner.class-run()-actualTaskrun-finish 0
driver Executor.scala-run()-finish 0
driver Executor.scala-run()-finish 0
driver Executor.scala-Taskrunner.class-run()-actualTaskrun-finish 0
driver Executor.scala-run()-finish 0
driver Executor.scala-run()-finish 0
driver Executor.scala-run()-finish 0
DAGScheduler.scala-runJob finish 5
Spark WordCount Complete
end: Long = 1616997291629
time:6.838sec
```