# 1 SparkStreaming

## 1.1 前言

Spark Streaming 是基于Spark Core将流式计算分解成一系列的小批处理任务来执行。在Spark Streaming里，总体负责任务的动态调度是`JobScheduler`，而`JobScheduler`有两个很重要的成员： `JobGenerator` 和 `ReceiverTracker`。 `JobGenerator` 负责将每个 batch 生成具体的 RDD DAG，而`ReceiverTracker`负责数据的来源。

Spark Streaming里的`DStream`可以看成是Spark Core里的RDD的模板， `DStreamGraph`是RDD DAG的模板。

## 1.2 wordcount源码

```
package spark

import org.apache.spark._
import org.apache.spark.streaming._
import org.apache.spark.streaming.StreamingContext._ //
not necessary since Spark 1.3

object ncwordcount {
  def main(args: Array[String]): Unit = {

    val conf = new
SparkConf().setMaster("local[2]").setAppName("NetworkWor
dCount")
    val ssc = new StreamingContext(conf, Seconds(60))
    // Create a DStream that will connect to
hostname:port, like localhost:9999，它使用
SocketInputDStream接收tcp流
    val lines = ssc.socketTextStream("localhost", 9999)
    // Split each line into words
    val words = lines.flatMap(_.split(" "))
    // Count each word in each batch
    val pairs = words.map(word => (word, 1))
    val wordCounts = pairs.reduceByKey(_ + _)

    // Print the first ten elements of each RDD
generated in this DStream to the console
    wordCounts.print()
    ssc.start()             // Start the computation
    ssc.awaitTermination()  // Wait for the computation
to terminate
  }
}
```

## 1.3 StreamGraph

### 1.3.1 构造

参考https://cloud.tencent.com/developer/article/1198468

在构造StreamingContext时创建了DStreamGraph

```
private[streaming] val graph: DStreamGraph = {
    if (isCheckpointPresent) {
      _cp.graph.setContext(this)
      _cp.graph.restoreCheckpointData()
      _cp.graph
    } else {
      require(_batchDur != null, "Batch duration for
StreamingContext cannot be null")
      val newGraph = new DStreamGraph()
      newGraph.setBatchDuration(_batchDur)
      newGraph
    }
  }
```

若`checkpoint` 可用，会优先从 checkpoint 恢复 graph，否则新建一个。graph用来动态的创建RDD DAG，`DStreamGraph`有两个重要的成员：`inputStreams` 和`outputStreams` 。

```
private val inputStreams = new
ArrayBuffer[InputDStream[_]]()
private val outputStreams = new ArrayBuffer[DStream[_]]
()
```

Spark Streaming记录DStream DAG 的方式就是通过`DStreamGraph`实例记录所有的`outputStreams` ，因为`outputStream`会通过依赖 `dependencies` 来和parent DStream形成依赖链，通过`outputStreams` 向前追溯遍历就可以得到所有上游的DStream，另外，`DStreamGraph` 还会记录所有的`inputStreams` ，避免每次为查找 input stream 而对 output steam 进行 BFS 的消耗。

继续回到例子，这里通过ssc.socketTextStream 创建了一个`ReceiverInputDStream`，在其父类 InputDStream 中会将该`ReceiverInputDStream`添加到`inputStream`里.

接着调用了flatMap方法：

```
class FlatMappedDStream[T: ClassTag, U: ClassTag](
    parent: DStream[T],
    flatMapFunc: T => TraversableOnce[U]
  ) extends DStream[U](parent.ssc) {

  override def dependencies: List[DStream[_]] =
List(parent)

  override def slideDuration: Duration =
parent.slideDuration

  override def compute(validTime: Time): Option[RDD[U]]
= {

 parent.getOrCompute(validTime).map(_.flatMap(flatMapFun
c))
  }
}
```

创建了一个 FlatMappedDStream ，而该类的compute方法是在父DStream（ReceiverInputDStream） 在对应batch时间的RDD上调用了flatMap方法，也就是构造了 rdd.flatMap(func)这样的代码，后面的操作类似，随后形成的是rdd.flatMap(func1).map(func2).reduceByKey(func3).take()，这不就是我们spark core里的东西吗。另外其dependencies是直接指向了其构造参数parent，也就是刚才的ReceiverInputDStream，每个新建的DStream的dependencies都是指向了其父DStream，这样就构成了一个依赖链，也就是形成了DStream DAG。

## 1.3.2 job触发

print方法源码

```
  def print(num: Int): Unit = ssc.withScope {
    def foreachFunc: (RDD[T], Time) => Unit = {
      (rdd: RDD[T], time: Time) => {
        val firstNum = rdd.take(num + 1)
        // scalastyle:off println
        println("---------------------------------------
----")
        println(s"Time: $time")
        println("---------------------------------------
----")
        firstNum.take(num).foreach(println)
        if (firstNum.length > num) println("...")
        println()
        // scalastyle:on println
      }
    }
    foreachRDD(context.sparkContext.clean(foreachFunc),
displayInnerRDDOps = false)
  }

//对DStream中的所有RDD应用操作
  private def foreachRDD(
      foreachFunc: (RDD[T], Time) => Unit,
      displayInnerRDDOps: Boolean): Unit = {
    new ForEachDStream(this,
      context.sparkContext.clean(foreachFunc, false),
displayInnerRDDOps).register()
  }
//生成Job
#ForEachDStream.scala
  override def generateJob(time: Time): Option[Job] = {
    parent.getOrCompute(time) match {
      case Some(rdd) =>
        val jobFunc = () =>
createRDDWithLocalProperties(time, displayInnerRDDOps) {
          foreachFunc(rdd, time)
        }
      //Job的run方法会执行jobFunc方法
        Some(new Job(time, jobFunc))
      case None => None
    }
  }

//DAG添加outputstream
  private[streaming] def register(): DStream[T] = {
    ssc.graph.addOutputStream(this)
    this
  }
```

## 1.4 启动源码

```
def start(): Unit = synchronized {
    state match {
      case INITIALIZED =>
        startSite.set(DStream.getCreationSite())
        StreamingContext.ACTIVATION_LOCK.synchronized {

 StreamingContext.assertNoOtherContextIsActive()
          try {
            //验证工作, duration非空, outputStream非空
            validate()
//启动Jobscheduler线程
            ThreadUtils.runInNewThread("streaming-
start") {
              sparkContext.setCallSite(startSite.get)
              sparkContext.clearJobGroup()

 sparkContext.setLocalProperty(SparkContext.SPARK_JOB_IN
TERRUPT_ON_CANCEL, "false")

 savedProperties.set(SerializationUtils.clone(sparkConte
xt.localProperties.get()))
              scheduler.start()
            }
            state = StreamingContextState.ACTIVE
          } catch {
            case NonFatal(e) =>
              logError("Error starting the context,
marking it as stopped", e)
              scheduler.stop(false)
              state = StreamingContextState.STOPPED
              throw e
          }
          StreamingContext.setActiveContext(this)
        }
        shutdownHookRef =
ShutdownHookManager.addShutdownHook(
          StreamingContext.SHUTDOWN_HOOK_PRIORITY)
(stopOnShutdown)
        // Registering Streaming Metrics at the start of
the StreamingContext
        assert(env.metricsSystem != null)

 env.metricsSystem.registerSource(streamingSource)
        uiTab.foreach(_.attach())
        logInfo("StreamingContext started")
      case ACTIVE =>
        logWarning("StreamingContext has already been
started")
```

```
      case STOPPED =>
        throw new
IllegalStateException("StreamingContext has already been
stopped")
    }
  }
```

## 1.5 JobScheduler线程启动

调度Spark上的job，使用JobScheduler生成Job且使用线程池执行他们

```
  private val jobExecutor =

 ThreadUtils.newDaemonFixedThreadPool(numConcurrentJobs,
"streaming-job-executor")
```

```

  def start(): Unit = synchronized {
    if (eventLoop != null) return // scheduler has
already been started

    logDebug("Starting JobScheduler")
    //启动eventLoop线程
    eventLoop = new EventLoop[JobSchedulerEvent]
("JobScheduler") {
      override protected def onReceive(event:
JobSchedulerEvent): Unit = processEvent(event)

      override protected def onError(e: Throwable): Unit
= reportError("Error in job scheduler", e)
    }
    eventLoop.start()

    // attach rate controllers of input streams to
receive batch completion updates
    for {
      inputDStream <- ssc.graph.getInputStreams
      rateController <- inputDStream.rateController
    } ssc.addStreamingListener(rateController)
//启动事件总线new
StreamingListenerBus(ssc.sparkContext.listenerBus)
    listenerBus.start()
    receiverTracker = new ReceiverTracker(ssc)
    inputInfoTracker = new InputInfoTracker(ssc)
    //Executor动态分配线程
    executorAllocationManager =
ExecutorAllocationManager.createIfEnabled(
      ssc.sparkContext,
      receiverTracker,
      ssc.conf,
      ssc.graph.batchDuration.milliseconds,
      clock)

 executorAllocationManager.foreach(ssc.addStreamingListe
ner)
    receiverTracker.start()
    jobGenerator.start()
    executorAllocationManager.foreach(_.start())
    logInfo("Started JobScheduler")
  }
```

### 1.5.1 事件处理

eventLoop线程的事件处理方法处理三类事件：

```
        case JobStarted(job, startTime) =>
handleJobStart(job, startTime)
        case JobCompleted(job, completedTime) =>
handleJobCompletion(job, completedTime)
        case ErrorReported(m, e) => handleError(m, e)
```

这三类事件都继承自JobSchedulerEvent

#### 1.5.1.1 JobStarted事件

```
  private def handleJobStart(job: Job, startTime: Long)
{
    //new ConcurrentHashMap[Time, JobSet]
    val jobSet = jobSets.get(job.time)
    val isFirstJobOfJobSet = !jobSet.hasStarted
    jobSet.handleJobStart(job)
    //把批处理启动事件放入事件队列
    if (isFirstJobOfJobSet) {
listenerBus.post(StreamingListenerBatchStarted(jobSet.to
BatchInfo))
    }
    job.setStartTime(startTime)
/**把输出操作启动事件异步放入事件队列
将会被Spark listener bus中所有的StreamingListeners处理
```

```
  */
 listenerBus.post(StreamingListenerOutputOperationStarte
d(job.toOutputOperationInfo))
    logInfo("Starting job " + job.id + " from job set of
time " + jobSet.time)
  }
```

### 1.5.1.2 JobComplete事件

```
  private def handleJobCompletion(job: Job,
completedTime: Long) {
    val jobSet = jobSets.get(job.time)
    jobSet.handleJobCompletion(job)
    job.setEndTime(completedTime)

 listenerBus.post(StreamingListenerOutputOperationComple
ted(job.toOutputOperationInfo))
    logInfo("Finished job " + job.id + " from job set of
time " + jobSet.time)
    if (jobSet.hasCompleted) {
      jobSets.remove(jobSet.time)
      jobGenerator.onBatchCompletion(jobSet.time)
      logInfo("Total delay: %.3f s for time %s
(execution: %.3f s)".format(
        jobSet.totalDelay / 1000.0,
jobSet.time.toString,
        jobSet.processingDelay / 1000.0
      ))

 listenerBus.post(StreamingListenerBatchCompleted(jobSet
.toBatchInfo))
    }
    job.result match {
      case Failure(e) =>
        reportError("Error running job " + job, e)
      case _ =>
    }
  }
```

## 1.5.2 启动ReceiverTracker

用于管理ReceiverInputDStreams的receivers的执行,两个属性:

receiverTrackingInfos 记录所有receiver的信息

receiverPreferredLocations存储receiver偏好的位置，用于调度receivers

### 1.5.2.1 启动Receivers

```
//把receiver分发到worker节点，并执行
private def launchReceivers(): Unit = {
    val receivers = receiverInputStreams.map { nis =>
      val rcvr = nis.getReceiver()
      rcvr.setReceiverId(nis.id)
      rcvr
    }
//执行一个测试job:确保所有的slave都注册了，避免所有的receiver调
度到同一个节点。
    runDummySparkJob()
/**向ReceiverTrackerEndpoint发送了StartAllReceivers消息
*/
    logInfo("Starting " + receivers.length + "
receivers")
    endpoint.send(StartAllReceivers(receivers))
  }


  private def runDummySparkJob(): Unit = {
    if (!ssc.sparkContext.isLocal) {
      ssc.sparkContext.makeRDD(1 to 50, 50).map(x => (x,
1)).reduceByKey(_ + _, 20).collect()
    }
    assert(getExecutors.nonEmpty)
  }
```

### 1.5.2.2 receiver执行

SparkStreaming有很多Receiver，我们看SocketReceiver如何执行

```
// SocketInputDStream.scala
def onStart() {
      socket = new Socket(host, port)
    new Thread("Socket Receiver") {
      setDaemon(true)
      override def run() { receive() }
    }.start()
  }

  def receive() {
    try {
      val iterator =
bytesToObjects(socket.getInputStream())
      while(!isStopped && iterator.hasNext) {
        store(iterator.next())
      }
    } finally {
      onStop()
    }
  }


/**存储单条数据到spark内存，聚合成数据块后才push到内存*/
  def store(dataItem: T) {
    supervisor.pushSingle(dataItem)
  }
// ReceiverSupervisorImpl.scala
  def pushSingle(data: Any) {
    defaultBlockGenerator.addData(data)
  }
```

这里提到了ReceiverSupervisor，这个类就是监控worker上的Receiver并处理Receiver接收到的数据。最主要的是它提供了BlockGenerator把接收到的数据流切分为数据块。

### 1.5.3 启动Jobgenerator

```
    eventLoop = new EventLoop[JobGeneratorEvent]
("JobGenerator") {
      override protected def onReceive(event:
JobGeneratorEvent): Unit = processEvent(event)

      override protected def onError(e: Throwable): Unit
= {
        jobScheduler.reportError("Error in job
generator", e)
      }
    }
    eventLoop.start()
```

一共有四种JobGeneratorEvent:

```
      case GenerateJobs(time) => generateJobs(time)
      case ClearMetadata(time) => clearMetadata(time)
      case DoCheckpoint(time, clearCheckpointDataLater)
=>
        doCheckpoint(time, clearCheckpointDataLater)
      case ClearCheckpointData(time) =>
clearCheckpointData(time)
```

下面看看job的生成

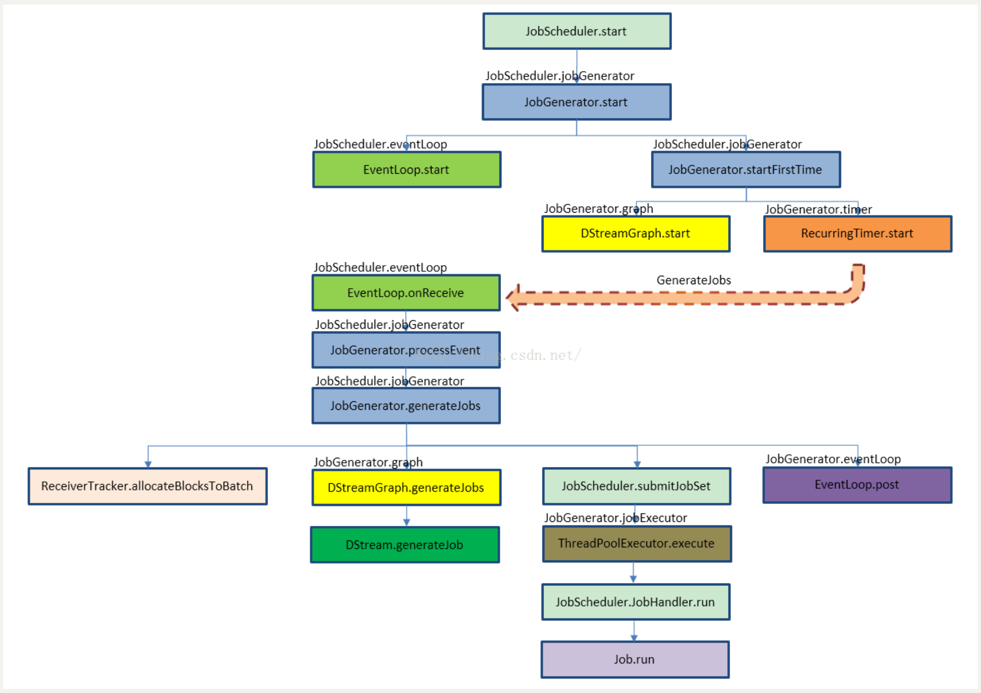
### 1.5.3.1 生成Job

```
  /** Generate jobs and perform checkpointing for the
given `time`.  */
  private def generateJobs(time: Time) {
    // Checkpoint all RDDs marked for checkpointing to
ensure their lineages are
    // truncated periodically. Otherwise, we may run
into stack overflows (SPARK-6847).

 ssc.sparkContext.setLocalProperty(RDD.CHECKPOINT_ALL_MA
RKED_ANCESTORS, "true")
    Try {
 /**获取根据interval time划分的block块数据*/
jobScheduler.receiverTracker.allocateBlocksToBatch(time)
      /**通过DStreamGraph 生成Job*/
      graph.generateJobs(time) // generate jobs using
allocated block
    } match {
      case Success(jobs) =>
        val streamIdToInputInfos =
jobScheduler.inputInfoTracker.getInfo(time)
      /**最终把JobSet提交给jobScheduler*/
        jobScheduler.submitJobSet(JobSet(time, jobs,
streamIdToInputInfos))
      case Failure(e) =>
        jobScheduler.reportError("Error generating jobs
for time " + time, e)

 PythonDStream.stopStreamingContextIfPythonProcessIsDead
(e)
    }
    eventLoop.post(DoCheckpoint(time,
clearCheckpointDataLater = false))
  }
```

整体逻辑


JobScheduler.start
JobScheduler.jobGenerator
JobGenerator.start
JobScheduler.eventLoop
EventLoop.start
JobScheduler.jobGenerator
JobGenerator.startFirstTime
JobGenerator.graph
DStreamGraph.start
JobGenerator.timer
RecurringTimer.start
JobScheduler.eventLoop
EventLoop.onReceive
GenerateJobs
JobScheduler.jobGenerator
JobGenerator.processEvent
JobScheduler.jobGenerator
JobGenerator.generateJobs
ReceiverTracker.allocateBlocksToBatch
JobGenerator.graph
DStreamGraph.generateJobs
DStream.generateJob
JobScheduler.submitJobSet
JobGenerator.jobExecutor
ThreadPoolExecutor.execute
JobScheduler.JobHandler.run
Job.run
JobGenerator.eventLoop
EventLoop.post

Timer定时器，定期向产生Job生成事件，

```
  private val timer = new RecurringTimer(clock,
ssc.graph.batchDuration.milliseconds,
    longTime => eventLoop.post(GenerateJobs(new
Time(longTime))), "JobGenerator")
```

### 1.5.3.2 数据分配

```
def allocateBlocksToBatch(batchTime: Time): Unit =
synchronized {
    if (lastAllocatedBatchTime == null || batchTime >
lastAllocatedBatchTime) {
      val streamIdToBlocks = streamIds.map { streamId =>
          (streamId,
getReceivedBlockQueue(streamId).dequeueAll(x => true))
      }.toMap
      val allocatedBlocks =
AllocatedBlocks(streamIdToBlocks)
      if (writeToLog(BatchAllocationEvent(batchTime,
allocatedBlocks))) {
        timeToAllocatedBlocks.put(batchTime,
allocatedBlocks)
        lastAllocatedBatchTime = batchTime
      } else {
        logInfo(s"Possibly processed batch $batchTime
needs to be processed again in WAL recovery")
      }
    }
```

### 1.5.4 事件总线listenerBus

LiveListenerBus对象，该对象是内部维护了两个队列queues和queuedEvents

参考https://www.jianshu.com/p/0a3bc1d21181

### 1.5.5 Executor动态分配机制

参考https://www.jianshu.com/p/e1d9456a4880

### 1.5.6 blockGenerator

几个比较重要的属性

```
  // blockInterval是有一个默认值的，默认是200ms，将数据封装成
block的时间间隔
  private val blockIntervalMs =
conf.getTimeAsMs("spark.streaming.blockInterval",
"200ms")
  require(blockIntervalMs > 0,
s"'spark.streaming.blockInterval' should be a positive
value")
```

```
  // 这个相当于每隔200ms，就去执行一个函数updateCurrentBuffer
  private val blockIntervalTimer =
    new RecurringTimer(clock, blockIntervalMs,
updateCurrentBuffer, "BlockGenerator")
  // blocksForPushing队列的长度是可以调节的，默认是长度是10
  private val blockQueueSize =
conf.getInt("spark.streaming.blockQueueSize", 10)
  // blocksForPushing队列
  private val blocksForPushing = new
ArrayBlockingQueue[Block](blockQueueSize)
  // blockPushingThread后台线程，启动之后，就会调用
keepPushingBlocks()方法
  // 这个方法中就会每隔一段时间，去blocksForPushing队列中取
block
  private val blockPushingThread = new Thread() {
override def run() { keepPushingBlocks() } }

  // 创建currentBuffer，用于存放原始数据
  @volatile private var currentBuffer = new
ArrayBuffer[Any]
```

### 1.5.6.1 启动block生成定时器和推送线程

```
  /** Start block generating and pushing threads. */
  def start(): Unit = synchronized {
    if (state == Initialized) {
      state = Active
      /**每隔200ms，将currentBuffer中的数据取出，并生成一个
Block*/
      blockIntervalTimer.start()
      blockPushingThread.start()
    }
  }
```

### 1.5.6.2 blockIntervalTimer执行逻辑

当启动定时器的时候，它就会每隔200ms，将currentBuffer中的数据取出，并生成一个Block

```
 private def updateCurrentBuffer(time: Long): Unit = {
    try {
      var newBlock: Block = null
      synchronized { //防止并发写
```

```
        if (currentBuffer.nonEmpty) {
          //清空currentBuffer
          val newBlockBuffer = currentBuffer
          currentBuffer = new ArrayBuffer[Any]
          val blockId = StreamBlockId(receiverId, time -
blockIntervalMs)
          listener.onGenerateBlock(blockId)
          //构造新的Block
          newBlock = new Block(blockId, newBlockBuffer)
        }
      }

      if (newBlock != null) {
        blocksForPushing.put(newBlock)  //入队， put is
blocking when queue is full
      }
    }
  }
```

### 1.5.6.3 blockPushingThread执行逻辑

```
/** Keep pushing blocks to the BlockManager. */
  private def keepPushingBlocks() {
    logInfo("Started block pushing thread")

    def areBlocksBeingGenerated: Boolean = synchronized
{
      state != StoppedGeneratingBlocks
    }

    try {
      // 只要block持续在产生，那么就会一直去blocksForPushing队
列中取block
      while (areBlocksBeingGenerated) {
        Option(blocksForPushing.poll(10,
TimeUnit.MILLISECONDS)) match {
          //如果拿到block,调用pushBlock
          case Some(block) => pushBlock(block)
          case None =>
        }
      }
    }
  //ReceiverSupervisorImpl.scala
  private def pushBlock(block: Block) {
    listener.onPushBlock(block.id, block.buffer)
    logInfo("Pushed block " + block.id)
  }
```

从上面代码中可以看出，只要BlockGenerator一直在运行没有停止，它就会持续不断的产生Block，那么这里就会从blocksForPushing队列中持续不断的去取Block进行推送。这里的blocksForPushing是一个阻塞队列，默认阻塞时间是10ms

推送是通过BlockGeneratorListener的onPushBlock进行推送的

```
def pushAndReportBlock(
      receivedBlock: ReceivedBlock,
      metadataOption: Option[Any],
      blockIdOption: Option[StreamBlockId]
    ) {
    // 取出BlockId
    val blockId = blockIdOption.getOrElse(nextBlockId)
    // 获取当前系统时间
    val time = System.currentTimeMillis
    // 这里使用receivedBlockHandler，调用storeBlock方法，将
block存储到BlockManager中
    // 从这里的源码里可以看到预写日志机制
    val blockStoreResult =
receivedBlockHandler.storeBlock(blockId, receivedBlock)
    logDebug(s"Pushed block $blockId in
${(System.currentTimeMillis - time)} ms")
    // 拿到block数据长度
    val numRecords = blockStoreResult.numRecords
    // 封装一个ReceivedBlockInfo对象，里面包含streamId 和
block store结果
    val blockInfo = ReceivedBlockInfo(streamId,
numRecords, metadataOption, blockStoreResult)
    // 调用ReceiverTrackerEndPoint，向ReceiverTracker发送
AddBlock消息
    trackerEndpoint.askWithRetry[Boolean]
(AddBlock(blockInfo))
    logDebug(s"Reported block $blockId")
  }
```

这个方法主要包含了两个功能，一个是调用receivedBlockHandler的storeBlock将Block保存到BlockManager（或写入预写日志）；另一个就是将保存的Block信息封装为ReceivedBlockInfo，发送给ReceiverTracker。下面我们先分析第一个：　　存储block的组件receivedBlockHandler会依据是否开启预写日志功能，而创建不同的receivedBlockHandler，如下所示：

```
private val receivedBlockHandler: ReceivedBlockHandler =
{
    // 如果开启了预写日志机制，默认是false（这里参数是
spark.streaming.receiver.writeAheadLog.enable）
    // 如果为true，那么ReceivedBlockHandler就是
WriteAheadLogBasedBlockHandler，
    // 如果没有开启预写日志机制，那么就创建为
BlockManagerBasedBlockHandler
    if (WriteAheadLogUtils.enableReceiverLog(env.conf))
{
      if (checkpointDirOption.isEmpty) {
        throw new SparkException(
          "Cannot enable receiver write-ahead log
without checkpoint directory set. " +
            "Please use streamingContext.checkpoint() to
set the checkpoint directory. " +
            "See documentation for more details.")
      }
      new
WriteAheadLogBasedBlockHandler(env.blockManager,
receiver.streamId,
        receiver.storageLevel, env.conf, hadoopConf,
checkpointDirOption.get)
    } else {
      new
BlockManagerBasedBlockHandler(env.blockManager,
receiver.storageLevel)
    }
  }
```

它会判断是否开启了预写日志，通过读取spark.streaming.receiver.writeAheadLog.enable这个参数是否被设置为true。如果开启了那么就创建WriteAheadLogBasedBlockHandler，否则的话就创建BlockManagerBasedBlockHandler。　下面我们就WriteAheadLogBasedBlockHandler来进行分析它的storeBlock方法：

```
def storeBlock(blockId: StreamBlockId, block:
ReceivedBlock): ReceivedBlockStoreResult = {
    var numRecords = None: Option[Long]
    // 先将Block的数据序列化
    val serializedBlock = block match {
      case ArrayBufferBlock(arrayBuffer) =>
        numRecords = Some(arrayBuffer.size.toLong)
        blockManager.dataSerialize(blockId,
arrayBuffer.iterator)
```

```
      case IteratorBlock(iterator) =>
        val countIterator = new
CountingIterator(iterator)
        val serializedBlock =
blockManager.dataSerialize(blockId, countIterator)
        numRecords = countIterator.count
        serializedBlock
      case ByteBufferBlock(byteBuffer) =>
        byteBuffer
      case _ =>
        throw new Exception(s"Could not push $blockId to
block manager, unexpected block type")
    }

    // 将数据保存到BlockManager中去，以及复制一份副本到其他
executor的BlockManager上，以供容错
    val storeInBlockManagerFuture = Future {
      val putResult =
        blockManager.putBytes(blockId, serializedBlock,
effectiveStorageLevel, tellMaster = true)
      if (!putResult.map { _._1 }.contains(blockId)) {
        throw new SparkException(
          s"Could not store $blockId to block manager
with storage level $storageLevel")
      }
    }

    // 将Block存入预写日志，使用Future来获取写入结果
    val storeInWriteAheadLogFuture = Future {
      writeAheadLog.write(serializedBlock,
clock.getTimeMillis())
    }

    // 等待两个写入完成，并合并写入结果信息，并返回写入结果信息
    val combinedFuture =
storeInBlockManagerFuture.zip(storeInWriteAheadLogFuture
).map(_._2)
    val walRecordHandle = Await.result(combinedFuture,
blockStoreTimeout)
    WriteAheadLogBasedStoreResult(blockId, numRecords,
walRecordHandle)
  }
```

从上面代码中看出，主要分为两步：首先将Block的数据进行序列化，然后将其放入BlockManager中进行存储，它会序列化并复制一份到其他Executor的BlockManager上。这里就可以看出开启预写日志的容错措施首先会将数据复制一份到其他的Worker节点的executor的BlockManager上；接着将Block的数据写入预写日志中（一般是HDFS文件）。　　从上面可以看出预写日志的容错措施主要有两个：一是将数据备份到其他的Worker节点的executor上（默认持久化级别是_SER 和 _2）；再者将数据写入到预写日志中。相当于提供了双重保障，因此能够提供较强的容错性（当然这会牺牲一定的性能）。　　接着我们分析第二个，发送ReceivedBlockInfo信息给ReceiverTracker。这个就简单说一下，ReceiverTracker在收到AddBlock的消息之后，会进行判断是否开启预写日志，假如开启预写日志那么需要将Block的信息写入一份到预写日志中，否则的话，就保存在缓存中。　　总结一下：上面的数据接收和存储功能，依据BlockGenerator组件来对接收到的数据进行缓存、封装和推送，最终将数据推送到BlockManager（以及预写日志中）。其中，主要是依靠一个定时器blockIntervalTimer，每隔200ms，从currentBuffer中取出全部数据，封装为一个block，放入blocksForPushing队列中；接着blockPushingThread，不断的从blocksForPushing队列中取出block进行推送，这是一个阻塞队列,阻塞时间默认是10ms。然后通过BlockGeneratorListener的onPushBlock()（最终调用的是pushArrayBuffer），将数据进行推送到BlockManager（加入开启了预写日志，那么也会写入一份到预写日志中），以及发送AddBlock消息给ReceiverTracker进行Block的注册。