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# Spark for Python Developers

A concise guide to implementing Spark big data analytics for Python developers and building a real-time and insightful trend tracker data-intensive app

**Amit Nandi**

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**Amit Nandi**



BIRMINGHAM - MUMBAI

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# Preface

*Spark for Python Developers* aims to combine the elegance and flexibility of Python with the power and versatility of Apache Spark. Spark is written in Scala and runs on the Java virtual machine. It is nevertheless polyglot and offers bindings and APIs for Java, Scala, **Python**, and R. Python is a well-designed language with an extensive set of specialized libraries. This book looks at PySpark within the PyData ecosystem. Some of the prominent PyData libraries include **Pandas**, **Blaze**, **Scikit-Learn**, **Matplotlib**, **Seaborn**, and **Bokeh**. These libraries are open source. They are developed, used, and maintained by the data scientist and Python developers community. PySpark integrates well with the PyData ecosystem, as endorsed by the Anaconda Python distribution. The book puts forward a journey to build data-intensive apps along with an architectural blueprint that covers the following steps: first, set up the base infrastructure with Spark. Second, acquire, collect, process, and store the data. Third, gain insights from the collected data. Fourth, stream live data and process it in real time. Finally, visualize the information.

Bokeh是一个专门针对Web浏览器的呈现功能的交互式可视化Python库。这是Bokeh与其它可视化库最核心的区别。

The objective of the book is to learn about PySpark and PyData libraries by building apps that analyze the Spark community's interactions on social networks. The focus is on Twitter data.

## What this book covers

*Chapter 1, Setting Up a Spark Virtual Environment*, covers how to create a segregated virtual machine as our sandbox or development environment to experiment with Spark and PyData libraries. It covers how to install Spark and the Python Anaconda distribution, which includes PyData libraries. Along the way, we explain the key Spark concepts, the Python Anaconda ecosystem, and build a Spark word count app.

*Chapter 2, Building Batch and Streaming Apps with Spark*, lays the foundation of the *Data Intensive Apps Architecture*. It describes the five layers of the apps architecture blueprint: **infrastructure**, **persistence**, **integration**, **analytics**, and **engagement**. We establish API connections with three social networks: Twitter, GitHub, and Meetup. This chapter provides the tools to connect to these three nontrivial APIs so that you can create your own data mashups at a later stage.

*Chapter 3, Juggling Data with Spark*, covers how to harvest data from Twitter and process it using Pandas, Blaze, and SparkSQL with their respective implementations of the dataframe data structure. We proceed with further investigations and techniques using Spark SQL, leveraging on the Spark dataframe data structure.

*Chapter 4, Learning from Data Using Spark*, gives an overview of the **ever** expanding library of algorithms of Spark MLlib. It covers supervised and unsupervised learning, recommender systems, optimization, and feature extraction algorithms. We put the Twitter harvested dataset through a Python Scikit-Learn and Spark MLlib K-means clustering in order to segregate the *Apache Spark* relevant tweets.

*Chapter 5, Streaming Live Data with Spark*, lays down the foundation of streaming architecture apps and describes their challenges, constraints, and benefits. We illustrate the streaming concepts with TCP sockets, followed by **live tweet** ingestion and processing directly from the Twitter firehose. We also describe Flume, a reliable, flexible, and scalable data ingestion and transport pipeline system. The combination of **Flume**, **Kafka**, and **Spark** delivers **举世无双的** **健全** **敏捷** robustness, speed, and agility in an **永远在更新着的** **不断改变的** ever-changing landscape. We end the chapter with some remarks and observations on two **streaming architectural paradigms**, the **Lambda** and **Kappa** architectures.

Flume是Cloudera提供的一个高可用的，高可靠的，分布式的海量日志采集、聚合和传输的系统，Flume支持在日志系统中定制各类数据发送方，用于收集数据，同时，Flume提供对数据进行简单处理，并写到各种数据接受方的能力。

*Chapter 6, Visualizing Insights and Trends*, focuses on a few key visualization techniques. It covers how to build word clouds and expose their intuitive power to reveal a lot of the key words, **moods**, and memes carried through thousands of tweets. We then focus on **交互式地图可视化** **Bokeh**. We build a world map from **由下到上** **覆盖** **聚全** the ground up and create a scatter plot of critical tweets. Our final visualization is to overlay an actual Google map of London, highlighting upcoming meetups and their respective topics.

Lambda立足于构建一个同时处理离线数据和实时数据分布式系统，但是因为对于一份数据，你需要同时为离线和实时编写两套不同的代码，当业务变更或者跟换系统，又需要重新编码，需要消耗巨大的人力，基于此，提出了基于Kafka的用实时完全实现数据处理的系统。

## What you need for this book

You need inquisitiveness, perseverance, and passion for data, software engineering, application architecture and scalability, and beautiful succinct visualizations. The scope is broad and wide.

You need a good understanding of Python or a similar language with object-oriented and functional programming capabilities. Preliminary experience of data wrangling with Python, R, or any similar tool is helpful.

You need to appreciate how to conceive, build, and scale data applications.

## Who this book is for

The target audience includes the following:

- Data scientists are the primary interested parties. This book will help you unleash the power of Spark and leverage your Python, R, and machine learning background.
- Software developers with a focus on Python will readily expand their skills to create data-intensive apps using Spark as a processing engine and Python visualization libraries and web frameworks.
- Data architects who can create rapid data pipelines and build the famous **Lambda architecture** that encompasses batch and streaming processing to render insights on data in real time, using the Spark and Python rich ecosystem, will also benefit from this book.

## Conventions

In this book, you will find a number of styles of text that distinguish between different kinds of information. Here are some examples of these styles, and an explanation of their meaning.

Code words in text, database table names, folder names, filenames, file extensions, pathnames, dummy URLs, user input, and Twitter handles are shown as follows "Launch PySpark with IPYNB in directory examples/AN\_Spark where the Jupyter or IPython Notebooks are stored".

A block of code is set as follows:

```
# Word count on 1st Chapter of the Book using PySpark

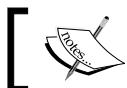
# import regex module
import re
# import add from operator module
from operator import add

# read input file
file_in = sc.textFile('/home/an/Documents/A00_Documents/Spark4Py
20150315')
```

Any command-line input or output is written as follows:

```
# install anaconda 2.x.x  
bash Anaconda-2.x.x-Linux-x86[_64].sh
```

**New terms** and **important words** are shown in bold. Words that you see on the screen, in menus or dialog boxes for example, appear in the text like this: "After installing VirtualBox, let's open the Oracle VM VirtualBox Manager and click the **New** button."



Warnings or important notes appear in a box like this.



Tips and tricks appear like this.

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# 1

## Setting Up a Spark Virtual Environment

In this chapter, we will build an isolated virtual environment for development purposes. The environment will be 由...驱动的 powered by Spark and the PyData libraries provided by the Python Anaconda distribution. These libraries include **Pandas**, **Scikit-Learn**, **Blaze**, **Matplotlib**, **Seaborn**, and **Bokeh**. We will perform the following activities:

- Setting up the development environment using the Anaconda Python distribution. This will include enabling the IPython Notebook environment powered by PySpark for our data exploration tasks.
- Installing and enabling Spark, and the PyData libraries such as Pandas, Scikit-Learn, Blaze, Matplotlib, and Bokeh.
- Building a `word count` example app to ensure that everything is working fine.

The last decade has seen the rise and dominance of data-driven behemoths such as Amazon, Google, Twitter, LinkedIn, and Facebook. These corporations, by seeding, sharing, or disclosing their 扶植；抚养；鼓励；促进；充满生机的 infrastructure concepts, software practices, and data processing frameworks, have fostered a vibrant open source software community. This has transformed the enterprise technology, systems, and software architecture.

This includes new infrastructure and **DevOps** (short for development and operations), concepts leveraging virtualization, cloud technology, and software-defined networks.

To process petabytes of data, Hadoop was developed and open sourced, taking its inspiration from the **Google File System (GFS)** and the adjoining distributed computing framework, MapReduce. Overcoming the complexities of scaling while keeping costs under control has also led to a proliferation of new data stores. Examples of recent database technology include **Cassandra**, a columnar database; **MongoDB**, a document database; and **Neo4J**, a graph database.

Hadoop, thanks to its ability to process huge datasets, has fostered a vast ecosystem to query data more iteratively and interactively with Pig, Hive, Impala, and Tez. **Hadoop is cumbersome as it operates only in batch mode using MapReduce**. Spark is creating a revolution in the analytics and data processing realm by targeting the shortcomings of disk input-output and bandwidth-intensive MapReduce jobs.

Spark is written in Scala, and therefore integrates natively with the **Java Virtual Machine (JVM)** powered ecosystem. Spark had early on provided Python API and bindings by enabling PySpark. The Spark architecture and ecosystem is inherently **polyglot**, with an obvious strong presence of Java-led systems.

This book will focus on PySpark and the PyData ecosystem. Python is one of the preferred languages in the academic and scientific community for data-intensive processing. Python has developed a rich ecosystem of libraries and tools in **data manipulation with Pandas and Blaze, in Machine Learning with Scikit-Learn, and in data visualization with Matplotlib, Seaborn, and Bokeh**. Hence, the aim of this book is to build an **end-to-end** architecture for data-intensive applications powered by Spark and Python. In order to put these concepts in to practice, we will analyze social networks such as Twitter, GitHub, and Meetup. We will focus on the activities and social interactions of Spark and the Open Source Software community by tapping into GitHub, Twitter, and Meetup.

Building data-intensive applications requires highly **scalable** infrastructure, **polyglot** storage, seamless **data integration**, **multiparadigm** analytics processing, and efficient visualization. The following paragraph describes the data-intensive app architecture **blueprint** that we will adopt throughout the book. It is the backbone of the book. We will discover Spark in the context of the broader PyData ecosystem.

#### Downloading the example code



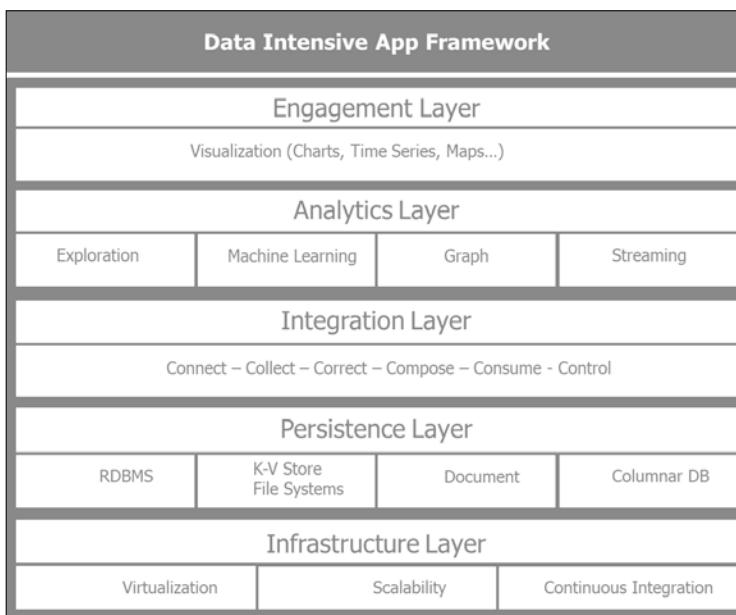
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# Understanding the architecture of data-intensive applications

In order to understand the architecture of data-intensive applications, the following conceptual framework is used. This architecture is designed on the following five layers:

- Infrastructure layer 基础架构层
- Persistence layer 数据持久层
- Integration layer 集成层
- Analytics layer 分析层
- Engagement layer 参与层

The following screenshot depicts the five layers of the **Data Intensive App Framework**:



From the bottom up, let's go through the layers and their main purpose.

Vagrant是一个基于Ruby的工具，用于创建和部署虚拟化开发环境。它 使用Oracle的开源VirtualBox虚拟化系统，使用 Chef创建自动化虚拟环境

Chef 是一个系统集成框架，为整个架构提供配置管理功能

Docker 是一个开源的应用容器引擎，让开发者可以打包他们的应用以及依赖包到一个可移植的容器中，然后发布到任何流行的 Linux 机器上，也可以实现虚拟化。容器是完全使用沙箱机制，相互之间不会有任何接口。

## Setting Up a Spark Virtual Environment

# Infrastructure layer

The infrastructure layer is primarily concerned with virtualization, scalability, and continuous integration. In practical terms, and in terms of virtualization, we will go through building our own development environment in a VirtualBox and virtual machine powered by Spark and the Anaconda distribution of Python. If we wish to scale from there, we can create a similar environment in the cloud. The practice of creating a segregated development environment and moving into test and production deployment can be automated and can be part of a continuous integration cycle powered by DevOps tools such as **Vagrant**, **Chef**, **Puppet**, and **Docker**. Docker is a very popular open source project that eases the installation and deployment of new environments. The book will be limited to building the virtual machine using VirtualBox. From a data-intensive app architecture **point of view**, we are describing the essential steps of the infrastructure layer by mentioning scalability and continuous integration beyond just virtualization.

Riak 是 Amazon 的高可用性键值存储库，用 Erlang 编写且基于 Dynamo，是一种高度可扩展的分布式数据存储。

# Persistence layer

The persistence layer manages the various repositories in accordance with data needs and shapes. It ensures the set up and management of the polyglot data stores. It includes relational database management systems such as MySQL and PostgreSQL; key-value data stores such as Hadoop, Riak, and Redis; columnar databases such as HBase and Cassandra; document databases such as MongoDB and Couchbase; and graph databases such as Neo4j. The persistence layer manages various filesystems such as Hadoop's HDFS. It interacts with various storage systems from native hard drives to Amazon S3. It manages various file storage formats such as csv, json, and parquet, which is a column-oriented format.

纵列数据库(columnar database)是纵向排列而不是横向排列存储数据的数据库管理系统(DBMS)

MongoDB 是一个基于分布式文件存储的数据库。由 C++ 语言编写。旨在为 WEB 应用提供可扩展的高性能数据存储解决方案。

MongoDB 是一个介于关系数据库和非关系数据库之间的产品，是非关系数据库当中功能最丰富，最像关系数据库的。

Neo4j是一个java开发的图数据库，它将结构化数据存储在网络(从数学角度叫做图)上而不是表中。相对于关系数据库来说，图数据库善于处理大量复杂、互连接、低结构化的数据，这些数据变化迅速，需要频繁的查询集中在关系数据库中，这些查询会导致大量的表连接，因此会产生性能上的问题。

# Integration layer

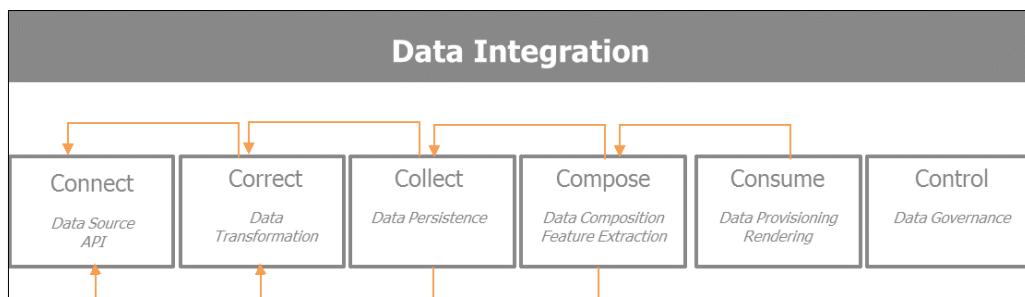
The integration layer focuses on data acquisition, transformation, quality, persistence, consumption, and governance. It is essentially driven by the following five Cs: *connect, collect, correct, compose, and consume*.

The five steps describe the lifecycle of data. They are focused on how to acquire the dataset of interest, explore it, iteratively refine and enrich the collected information, and get it ready for consumption. So, the steps perform the following operations:

- **Connect:** Targets the best way to acquire data from the various data sources, APIs offered by these sources, the input format, input schemas if they exist, the rate of data collection, and limitations from providers

- **Correct:** Focuses on transforming data for further processing and also ensures that the quality and consistency of the data received are maintained
- **Collect:** Looks at which data to store where and in what format, to ease data composition and consumption at later stages
- **Compose:** Concentrates its attention on how to mash up the various data sets collected, and enrich the information in order to build a compelling data-driven product
- **Consume:** Takes care of data provisioning and rendering and how the right data reaches the right individual at the right time
- **Control:** This sixth *additional* step will sooner or later be required as the data, the organization, and the participants grow and it is about ensuring data governance

The following diagram depicts the iterative process of data acquisition and refinement for consumption:



## Analytics layer

The analytics layer is where Spark processes data with the various models, algorithms, and machine learning pipelines in order to derive insights. For our purpose, in this book, the analytics layer is powered by Spark. We will delve deeper in subsequent chapters into the merits of Spark. In a nutshell, **what makes it so powerful is that it allows multiple paradigms of analytics processing in a single unified platform. It allows batch, streaming, and interactive analytics.** Batch processing on large datasets with longer latency periods allows us to extract patterns and insights that can feed into real-time events in streaming mode. Interactive and iterative analytics are more suited for data exploration. Spark offers bindings and APIs in Python and R. With its **SparkSQL** module and the Spark Dataframe, it offers a very familiar analytics interface.

## Engagement layer

The engagement layer interacts with the end user and provides dashboards, interactive visualizations, and alerts. We will focus here on the tools provided by the PyData ecosystem such as **Matplotlib**, **Seaborn**, and **Bokeh**.

## Understanding Spark

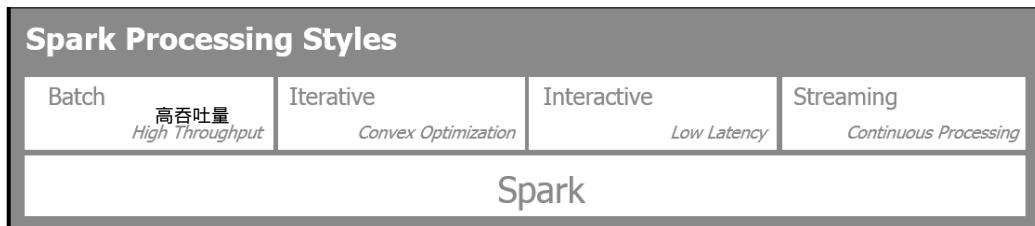
Hadoop scales horizontally as the data grows. Hadoop runs on commodity hardware, so it is cost-effective. Intensive data applications are enabled by scalable, distributed processing frameworks that allow organizations to analyze petabytes of data on large commodity clusters. Hadoop is the first open source implementation of map-reduce. Hadoop relies on a distributed framework for storage called **HDFS (Hadoop Distributed File System)**. Hadoop runs map-reduce tasks in batch jobs. Hadoop requires persisting the data to disk at each map, shuffle, and reduce process step. The overhead and the latency of such batch jobs adversely impact the performance.

Spark is a fast, distributed general analytics computing engine for large-scale data processing. The major breakthrough from Hadoop is that Spark allows data sharing between processing steps through in-memory processing of data pipelines.

Spark is unique in that it allows four different styles of data analysis and processing. Spark can be used in:

- **Batch**: This mode is used for manipulating large datasets, typically performing large map-reduce jobs
- **Streaming**: This mode is used to process incoming information in near real time
- **Iterative**: This mode is for machine learning algorithms such as a gradient descent where the data is accessed repetitively in order to reach convergence
- **Interactive**: This mode is used for data exploration as large chunks of data are in memory and due to the very quick response time of Spark

The following figure highlights the preceding four processing styles:



后两种则是未来发展的趋势，部分容错性和资源管理交由统一的资源管理系统完成：让Spark运行在一个通用的资源管理系统之上，这样可以与其他计算框架，比如MapReduce，公用一个集群资源，最大的好处是降低运维成本和提高资源利用率（资源按需分配）。

<http://dongxicheng.org/framework-on-yarn/apache-spark-comparing-three-deploying-ways/>

## Chapter 1

**独立模式**  
Spark operates in three modes: one single mode, standalone on a single machine and two distributed modes on a cluster of machines – on Yarn, the Hadoop distributed resource manager, or on Mesos, the open source cluster manager developed at Berkeley concurrently with Spark:  
独立模式无需依赖任何其他资源管理系统，Spark在standalone模式下是没有任何单点故障问题的，这是借助zookeeper实现的，思想类似于Hbase master单点故障解决方案。



Spark offers a polyglot interface in Scala, Java, Python, and R.

## Spark libraries

Spark comes with batteries included, with some powerful libraries:

- **SparkSQL:** This provides the SQL-like ability to interrogate structured data and interactively explore large datasets 查询
- **SparkMLLIB:** This provides major algorithms and a pipeline framework for machine learning
- **Spark Streaming:** This is for near real-time analysis of data using micro batches and sliding windows on incoming streams of data
- **Spark GraphX:** This is for graph processing and computation on complex connected entities and relationships 实体和关系

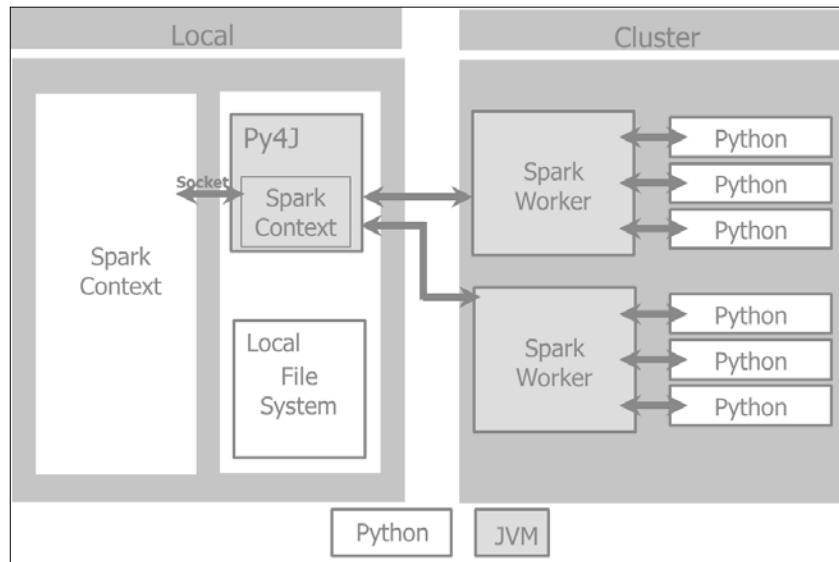
## PySpark in action

Spark is written in Scala. The whole Spark ecosystem naturally leverages the JVM environment and capitalizes on HDFS natively. Hadoop HDFS is one of the many data stores supported by Spark. Spark is agnostic and from the beginning interacted with multiple data sources, types, and formats.

PySpark is not a transcribed version of Spark on a Java-enabled dialect of Python such as Jython. PySpark provides integrated API bindings around Spark and enables full usage of the Python ecosystem within all the nodes of the cluster with the pickle Python serialization and, more importantly, supplies access to the rich ecosystem of Python's machine learning libraries such as Scikit-Learn or data processing such as Pandas.

When we initialize a Spark program, the first thing a Spark program must do is to create a `SparkContext` object. It tells Spark how to access the cluster. The Python program creates a `PySparkContext`. Py4J is the gateway that binds the Python program to the Spark JVM `SparkContext`. The JVM `SparkContext` serializes the application codes and the closures and sends them to the cluster for execution. The cluster manager allocates resources and schedules, and ships the closures to the Spark workers in the cluster who activate Python virtual machines as required. In each machine, the Spark Worker is managed by an executor that controls computation, storage, and cache.

Here's an example of how the Spark driver manages both the PySpark context and the Spark context with its local filesystems and its interactions with the Spark worker through the cluster manager:



## The Resilient Distributed Dataset

Spark applications consist of a driver program that runs the user's main function, creates distributed datasets on the cluster, and executes various parallel operations (transformations and actions) on those datasets.

Spark applications are run as an independent set of processes, coordinated by a `SparkContext` in a driver program.

The `SparkContext` will be allocated system resources (machines, memory, CPU) from the **Cluster manager**.

The SparkContext manages executors who manage workers in the cluster.

The driver program has Spark **jobs** that need to run. The jobs are split into **tasks** submitted to the executor for completion. The executor takes care of computation, storage, and caching in each machine.

The key building block in Spark is the **RDD (Resilient Distributed Dataset)**. A dataset is a collection of elements. Distributed means the dataset can be on any node in the cluster. Resilient means that the dataset could get lost or partially lost without major harm to the computation in progress as Spark will re-compute from the data lineage in memory, also known as the **DAG** (short for **Directed Acyclic Graph**) of operations. Basically, Spark will snapshot in memory a state of the RDD in the cache. If one of the computing machines crashes during operation, Spark rebuilds the RDDs from the cached RDD and the DAG of operations. RDDs recover from node failure.

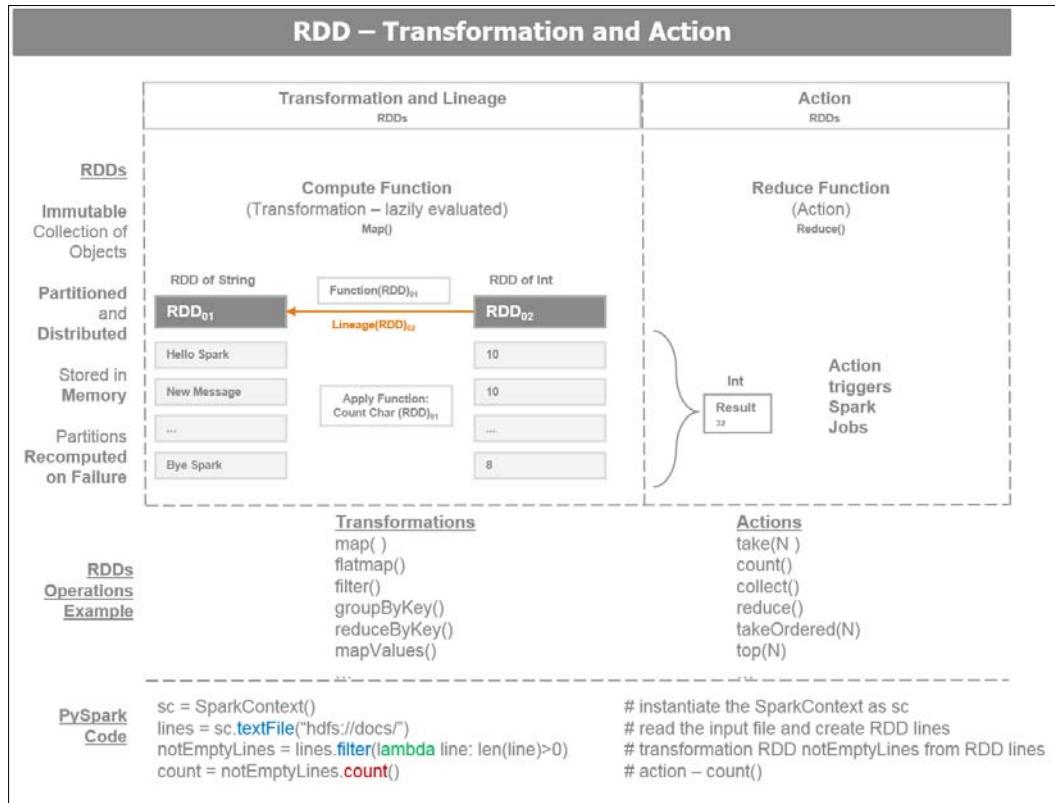
There are two types of operation on RDDs:

- **Transformations:** A transformation takes an existing RDD and leads to a pointer of a new transformed RDD. An RDD is immutable. Once created, it cannot be changed. Each transformation creates a new RDD. Transformations are lazily evaluated. Transformations are executed only when an action occurs. In the case of failure, the data lineage of transformations rebuilds the RDD.
- **Actions:** An action on an RDD triggers a **Spark job** and yields a value. An action operation causes Spark to execute the (lazy) transformation operations that are required to compute the RDD returned by the action. The action results in a DAG of operations. The DAG is compiled into stages where each stage is executed as a series of tasks. A task is a fundamental unit of work.

Here's some useful information on RDDs:

- RDDs are created from a data source such as an HDFS file or a DB query. There are three ways to create an RDD:
  - Reading from a datastore
  - Transforming an existing RDD
  - Using an in-memory collection
- RDDs are transformed with functions such as `map` or `filter`, which yield new RDDs.
- An action such as `first`, `take`, `collect`, or `count` on an RDD will deliver the results into the Spark driver. The Spark driver is the client through which the user interacts with the Spark cluster.

The following diagram illustrates the RDD transformation and action:



## Understanding Anaconda

Anaconda is a widely used free Python distribution maintained by **Continuum** (<https://www.continuum.io/>). We will use the prevailing software stack provided by Anaconda to generate our apps. In this book, we will use PySpark and the PyData ecosystem. The PyData ecosystem is promoted, supported, and maintained by **Continuum** and powered by the **Anaconda** Python distribution. The Anaconda Python distribution essentially saves time and aggravation in the installation of the Python environment; we will use it in conjunction with Spark. Anaconda has its own package management that supplements the traditional `pip install` and `easy-install`. Anaconda comes with batteries included, 即：也就是 some of the most important packages such as Pandas, Scikit-Learn, Blaze, Matplotlib, and Bokeh. An upgrade to any of the installed library is a simple command at the console:

```
$ conda update
```

A list of installed libraries in our environment can be obtained with command:

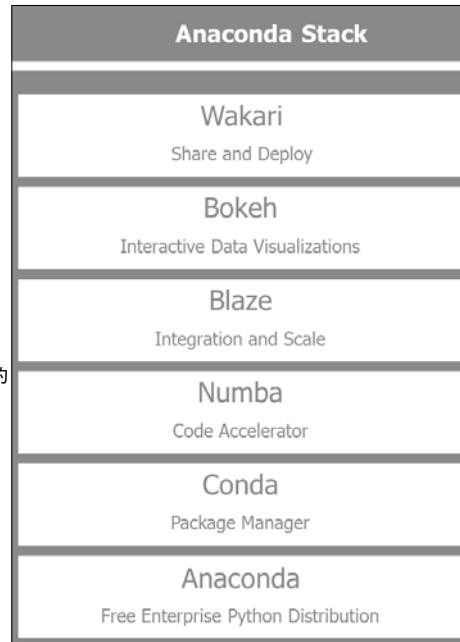
```
$ conda list
```

程序的执行方法有两种，解释执行和编译执行

The key components of the stack are as follows:

- **Anaconda**: This is a free Python distribution with almost 200 Python packages for science, math, engineering, and data analysis.
- **Conda**: This is a package manager that takes care of all the dependencies of installing a complex software stack. This is not restricted to Python and manages the install process for R and other languages.
- **Numba**: This provides the power to speed up code in Python with high-performance functions and just-in-time compilation.  
即时编译器：既想占跨平台的好处，又想提供编译执行的效率  
Blaze是新一代NumPy, Python实现的科学计算包，专门为大数据打造，用于处理分布式的各种不同数据源的计算。  
即时编译器是在运行时按需将字节码编译为机器码，它并不会一下子把所有的字节码都编译为机器码，而是可以以文件、函数、代码块为代码进行按需编译，并会把编译结果缓存以便后续重用。
- **Blaze**: This enables large scale data analytics by offering a uniform and adaptable interface to access a variety of data providers, which include streaming Python, Pandas, SQLAlchemy, and Spark.
- **Bokeh**: This provides interactive data visualizations for large and streaming datasets.
- **Wakari**: This allows us to share and deploy IPython Notebooks and other apps on a hosted environment.

The following figure shows the components of the Anaconda stack:



Blaze将同时扩展现有的数学计算库NumPy和科学计算库SciPy，使其更适应大数据技术。Blaze将聚焦在内核外处理超过系统内存容量的大型数据集，并同时支持分布式数据和流数据。而Bokeh则是一个用于大数据可视化的Python库，Continuum称之为“可扩展、交互式以及易于使用的可视化系统”。Bokeh将整合许多可视化技术，将包含Stencil可视化模型和Grammar of Graphics。

Numba项目能够将处理NumPy数组的Python函数JIT编译为机器码执行，从而上百倍的提高程序的运算速度。而基于浏览器的Python开发环境Wakari能省去配置Python开发环境的麻烦。

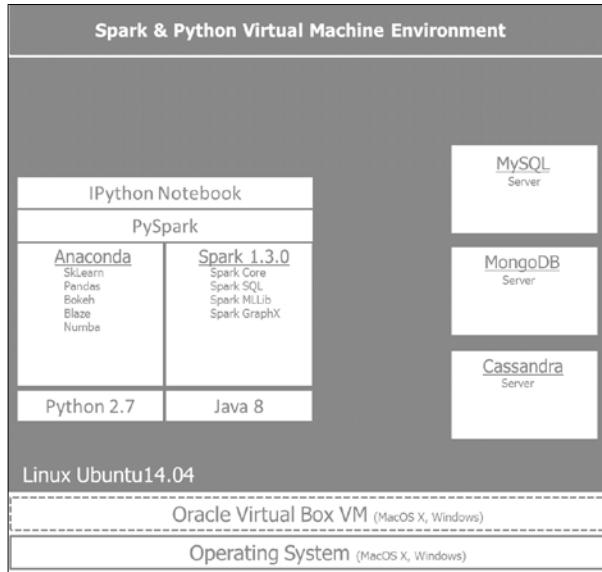
# Setting up the Spark powered environment

In this section, we will learn to set up Spark:

- Create a segregated development environment in a virtual machine running on Ubuntu 14.04, so it does not interfere with any existing system.
- Install Spark 1.3.0 with its dependencies, namely.
- Install the Anaconda Python 2.7 environment with all the required libraries such as Pandas, Scikit-Learn, Blaze, and Bokeh, and enable PySpark, so it can be accessed through IPython Notebooks.
- Set up the backend or data stores of our environment. We will use MySQL as the relational database, MongoDB as the document store, and Cassandra as the columnar database.

Each storage backend serves a specific purpose depending on the nature of the data to be handled. The MySQL RDBMs is used for standard tabular processed information that can be easily queried using SQL. As we will be processing a lot of JSON-type data from various APIs, the easiest way to store them is in a document. For real-time and time-series-related information, Cassandra is best suited as a columnar database.

The following diagram gives a view of the environment we will build and use throughout the book:



## Setting up an Oracle VirtualBox with Ubuntu

Setting up a clean new VirtualBox environment on Ubuntu 14.04 is the safest way to create a development environment that does not conflict with existing libraries and can be later replicated in the cloud using a similar list of commands.

In order to set up an environment with Anaconda and Spark, we will create a VirtualBox virtual machine running Ubuntu 14.04.

Let's go through the steps of using VirtualBox with Ubuntu:

1. Oracle VirtualBox VM is free and can be downloaded from <https://www.virtualbox.org/wiki/Downloads>. The installation is pretty straightforward.
2. After installing VirtualBox, let's open the Oracle VM VirtualBox Manager and click the **New** button.
3. We'll give the new VM a name, and select Type **Linux** and Version **Ubuntu (64 bit)**.
4. You need to download the ISO from the Ubuntu website and allocate sufficient **RAM (4 GB recommended)** and **disk space (20 GB recommended)**. We will use the Ubuntu 14.04.1 LTS release, which is found here: <http://www.ubuntu.com/download/desktop>.
5. Once the installation completed, it is advisable to install the VirtualBox Guest Additions by going to (from the VirtualBox menu, with the new VM running) **Devices | Insert Guest Additions CD image**. Failing to provide the guest additions in a Windows host gives a very limited user interface with reduced window sizes.
6. Once the additional installation completes, reboot the VM, and it will be ready to use. It is helpful to enable the shared clipboard by selecting the VM and clicking **Settings**, then go to **General | Advanced | Shared Clipboard** and click on **Bidirectional**.

## Installing Anaconda with Python 2.7

PySpark currently runs only on Python 2.7. (There are requests from the community to upgrade to Python 3.3.) To install Anaconda, follow these steps:

1. Download the Anaconda Installer for Linux 64-bit Python 2.7 from <http://continuum.io/downloads#all>.

2. After downloading the Anaconda installer, open a terminal and navigate to the directory or folder where the installer has been saved. From here, run the following command, replacing the 2.x.x in the command with the version number of the downloaded installer file:

```
# install anaconda 2.x.x  
bash Anaconda-2.x.x-Linux-x86[_64].sh
```

3. After accepting the license terms, you will be asked to specify the install location (which defaults to ~/anaconda).
4. After the self-extraction is finished, you should add the anaconda binary directory to your PATH environment variable:

```
# add anaconda to PATH  
bash Anaconda-2.x.x-Linux-x86[_64].sh
```

## Installing Java 8

Spark runs on the JVM and requires the Java **SDK** (short for **Software Development Kit**) and **not** the **JRE** (short for **Java Runtime Environment**), as we will build apps with Spark. The recommended version is Java Version 7 or higher. Java 8 is the most suitable, as it includes many of the functional programming techniques available with Scala and Python.

To install Java 8, follow these steps:

1. Install Oracle Java 8 using the following commands:

```
# install oracle java 8  
$ sudo apt-get install software-properties-common  
$ sudo add-apt-repository ppa:webupd8team/java  
$ sudo apt-get update  
$ sudo apt-get install oracle-java8-installer
```

2. Set the JAVA\_HOME environment variable and ensure that the Java program is on your PATH.
3. Check that JAVA\_HOME is properly installed:

```
#  
$ echo JAVA_HOME
```

## Installing Spark

Head over to the Spark download page at <http://spark.apache.org/downloads.html>.

The Spark download page offers the possibility to download earlier versions of Spark and different package and download types. We will select the latest release, pre-built for Hadoop 2.6 and later. The easiest way to install Spark is to use a Spark package prebuilt for Hadoop 2.6 and later, rather than build it from source. Move the file to the directory `~/spark` under the root directory.

Download the latest release of Spark—Spark 1.5.2, released on November 9, 2015:

1. Select Spark release **1.5.2 (Nov 09 2015)**,
2. Choose the package type **Prebuilt for Hadoop 2.6 and later**,
3. Choose the download type **Direct Download**,
4. Download Spark: **spark-1.5.2-bin-hadoop2.6.tgz**,
5. Verify this release using the 1.3.0 signatures and checksums,

This can also be accomplished by running:

```
# download spark
$ wget http://d3kbcqa49mib13.cloudfront.net/spark-1.5.2-bin-hadoop2.6.tgz
```

Next, we'll extract the files and clean up:

```
# extract, clean up, move the unzipped files under the spark directory
$ tar -xf spark-1.5.2-bin-hadoop2.6.tgz
$ rm spark-1.5.2-bin-hadoop2.6.tgz
$ sudo mv spark-* spark
```

Now, we can run the Spark Python interpreter with:

```
# run spark
$ cd ~/spark
./bin/pyspark
```

You should see something like this:

## Welcome to

```
 _ _ _ / _ _ _ _ _ _ / _ _ _  
 _ \ _ \ _ \ _ \ _ ^ / _ / _ ' _ /  
 / _ / . _ / \ _ , _ / _ / _ / \ _ \   version 1.5.2  
 / _ /  
  
Using Python version 2.7.6 (default, Mar 22 2014 22:59:56)  
SparkContext available as sc.  
  
>>> 友好的
```

The interpreter will have already provided us with a Spark context object, `sc`, which we can see by running:

```
>>> print(sc)


< pyspark.context.SparkContext object at 0x7f34b61c4e50>


```

# Enabling IPython Notebook

We will work with IPython Notebook for a friendlier user experience than the console.

You can launch IPython Notebook by using the following command:

```
$ IPYTHON_OPTS="notebook --pylab inline" ./bin/pyspark
```

Launch PySpark with `IPYNB` in the directory `examples/AN_Spark` where Jupyter or IPython Notebooks are stored:

```
# cd to /home/an/spark/spark-1.5.0-bin-hadoop2.6/examples/AN_Spark
# launch command using python 2.7 and the spark-csv package:
$ IPYTHON_OPTS='notebook' /home/an/spark/spark-1.5.0-bin-hadoop2.6/bin/
pyspark --packages com.databricks:spark-csv_2.11:1.2.0

# launch command using python 3.4 and the spark-csv package:
$ IPYTHON_OPTS='notebook' PYSPARK_PYTHON=python3
/home/an/spark/spark-1.5.0-bin-hadoop2.6/bin/pyspark --packages com.
databricks:spark-csv 2.11:1.2.0
```

## Building our first app with PySpark

We are ready to check now that everything is working fine. The obligatory word count will be put to the test in processing a word count on the first chapter of this book.

The code we will be running is listed here:

```
# Word count on 1st Chapter of the Book using PySpark

# import regex module
import re
# import add from operator module
from operator import add

# read input file
file_in = sc.textFile('/home/an/Documents/A00_Documents/Spark4Py
20150315')

# count lines
print('number of lines in file: %s' % file_in.count())

# add up lengths of each line
chars = file_in.map(lambda s: len(s)).reduce(add)
print('number of characters in file: %s' % chars)

# Get words from the input file
words = file_in.flatMap(lambda line: re.split('\W+', line.lower() .
strip()))
# words of more than 3 characters
words = words.filter(lambda x: len(x) > 3)
# set count 1 per word
words = words.map(lambda w: (w,1))
# reduce phase - sum count all the words
words = words.reduceByKey(add)
```

In this program, we are first reading the file from the directory /home/an/ Documents/A00\_Documents/Spark4Py 20150315 into file\_in.

We are then introspecting the file by counting the number of lines and the number of characters per line.

1. local :这种方式是在本地启动一个线程来运行作业；
2. local[N] :也是本地模式,但是启动了N个线程；
3. local[\*] :还是本地模式,但是用了系统中所有的核；
4. local[N,M] :这里有两个参数,第一个代表的是用到的核个数;第二个参数代表的是容许该作业失败M次.上面的几种模式没有指定M参数,其默认值都是1;
5. local-cluster[N,cores,memory] :本地伪集群模式,参数的含义我就不说了,看名字就知道;
6. spark:// :这是用到了Spark的Standalone模式
7. (mesos|zks):// :这是Mesos模式；
- 8.yarn-standalone\yarn-cluster\yarn-client :这是YARN模式.前面两种代表的是集群模式;后面代表的是客户端模式;
- 9.smr:// :这种你就不知道了吧?smr其实是Spark In MapReduce的缩写.我们知道MapReduce 1中是没有YARN的,如果你在MapReduce 1中使用Spark,那么就用这种模式吧。

## Setting Up a Spark Virtual Environment

We are splitting the input file in to words and getting them in lower case. For our word count purpose, we are choosing words longer than three characters in order to avoid shorter and much more frequent words such as *the, and, for* to skew the count in their favor. Generally, they are considered stop words and should be filtered out in any language processing task.

At this stage, we are getting ready for the MapReduce steps. To each word, we map a value of 1 and reduce it by summing all the unique words.

Here are illustrations of the code in the IPython Notebook. The first 10 cells are preprocessing the word count on the dataset, which is retrieved from the local file directory.

```
In [ ]: # Pyspark context sc is up and running
sc

In [1]: # sc master - running locally
sc.master

Out[1]: u'local[*]'

## Word count on manuscript using PySpark

In [3]: # import regex module
import re
# import add from operator module
from operator import add

In [4]: # read input file
file_in = sc.textFile('/home/an/Documents/A00_Documents/Spark4Py 20150315')

In [5]: # count Lines
print('number of lines in file: %s' % file_in.count())
#
# add up Lengths of each Line
chars = file_in.map(lambda s: len(s)).reduce(add)
print('number of characters in file: %s' % chars)

number of lines in file: 176
number of characters in file: 11019

In [6]: # Get words from the input file
words = file_in.flatMap(lambda line: re.split('\W+', line.lower().strip()))

In [7]: # words of more than 3 characters
words = words.filter(lambda x: len(x) > 3)

In [8]: # set count 1 per word
words = words.map(lambda w: (w,1))

In [9]: # reduce phase - sum count all the words
words = words.reduceByKey(add)

In [10]: # create tuple (count, word) and sort in descending
words = words.map(lambda x: (x[1], x[0])).sortByKey(False)
```

Swap the word count tuples in the format (count, word) in order to sort by count, which is now the primary key of the tuple:

```
# create tuple (count, word) and sort in descending
words = words.map(lambda x: (x[1], x[0])).sortByKey(False)

# take top 20 words by frequency
words.take(20)
```

In order to display our result, we are creating the tuple (count, word) and displaying the top 20 most frequently used words in descending order:

In [9]:	<i># reduce phase - sum count all the words</i> words = words.reduceByKey(add)
In [10]:	<i># create tuple (count, word) and sort in descending</i> words = words.map(lambda x: (x[1], x[0])).sortByKey(False)
In [11]:	<i># take top 20 words by frequency</i> words.take(20)
Out[11]:	<pre>[(45, u'spark'),  (26, u'data'),  (20, u'with'),  (18, u'anaconda'),  (16, u'layer'),  (15, u'python'),  (13, u'hadoop'),  (12, u'such'),  (11, u'from'),  (11, u'install'),  (10, u'distributed'),  (10, u'will'),  (9, u'processing'),  (8, u'download'),  (8, u'pyspark'),  (8, u'cluster'),  (7, u'environment'),  (7, u'that'),  (7, u'which'),  (7, u'analytics')]</pre>
In [12]:	<i># create function for histogram of most frequent words</i> #  %matplotlib inline import matplotlib.pyplot as plt  def histogram(words): count = map(lambda x: x[1], words) word = map(lambda x: x[0], words) plt.barh(range(len(count)), count, color = 'grey') plt.yticks(range(len(count)), word)
In [13]:	<i># Change order of tuple (word, count) from (count, word)</i> words = words.map(lambda x:(x[1], x[0])) words.take(25)

Let's create a histogram function:

```
# create function for histogram of most frequent words

%matplotlib inline
import matplotlib.pyplot as plt
#


def histogram(words):
    count = map(lambda x: x[1], words)
    word = map(lambda x: x[0], words)
    plt.barh(range(len(count)), count, color = 'grey')
    plt.yticks(range(len(count)), word)

# Change order of tuple (word, count) from (count, word)
words = words.map(lambda x:(x[1], x[0]))
words.take(25)

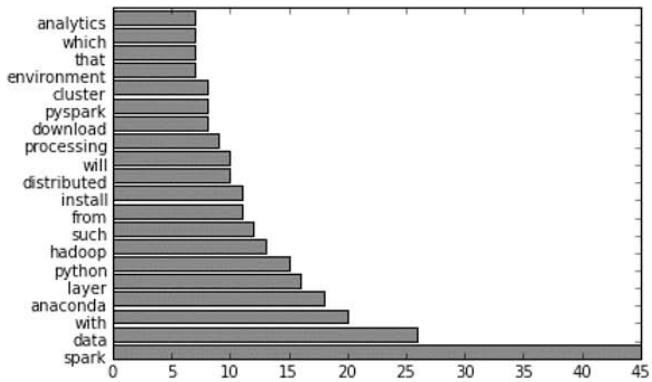
# display histogram
histogram(words.take(25))
```

Here, we visualize the most frequent words by plotting them in a bar chart. We have to first swap the tuple from the original (count, word) to (word, count):

```
In [13]: # Change order of tuple (word, count) from (count, word)
words = words.map(lambda x:(x[1], x[0]))
words.take(25)

Out[13]: [(u'spark', 45),
(u'data', 26),
(u'with', 20),
(u'anaconda', 18),
(u'layer', 16),
(u'python', 15),
(u'hadoop', 13),
(u'such', 12),
(u'from', 11),
(u'install', 11),
(u'distributed', 10),
(u'will', 10),
(u'processing', 9),
(u'download', 8),
(u'pyspark', 8),
(u'cluster', 8),
(u'environment', 7),
(u'that', 7),
(u'which', 7),
(u'analytics', 7),
(u'oracle', 7),
(u'manager', 6),
(u'large', 6),
(u'following', 6),
(u'machine', 6)]
```

```
In [14]: # display histogram
histogram(words.take(20))
```



So here you have it: the most frequent words used in the first chapter are **Spark**, followed by **Data** and **Anaconda**.

## **Virtualizing the environment with Vagrant**

In order to create a portable Python and Spark environment that can be easily shared and cloned, the development environment can be built with a `vagrantfile`.

We will point to the **Massive Open Online Courses (MOOCs)** delivered by *Berkeley University and Databricks*:

- *Introduction to Big Data with Apache Spark*, Professor Anthony D. Joseph can be found at <https://www.edx.org/course/introduction-big-data-apache-spark-uc-berkeleyx-cs100-1x>
- *Scalable Machine Learning*, Professor Ameet Talwalkar can be found at <https://www.edx.org/course/scalable-machine-learning-uc-berkeleyx-cs190-1x>

The course labs were executed on IPython Notebooks powered by PySpark. They can be found in the following GitHub repository: <https://github.com/spark-mooc/mooc-setup/>.

Once you have set up Vagrant on your machine, follow these instructions to get started: <https://docs.vagrantup.com/v2/getting-started/index.html>.

Clone the `spark-mooc/mooc-setup/` github repository in your work directory and launch the command `$ vagrant up`, within the cloned directory:

Be aware that the version of Spark may be outdated as the `vagrantfile` may not be up-to-date.

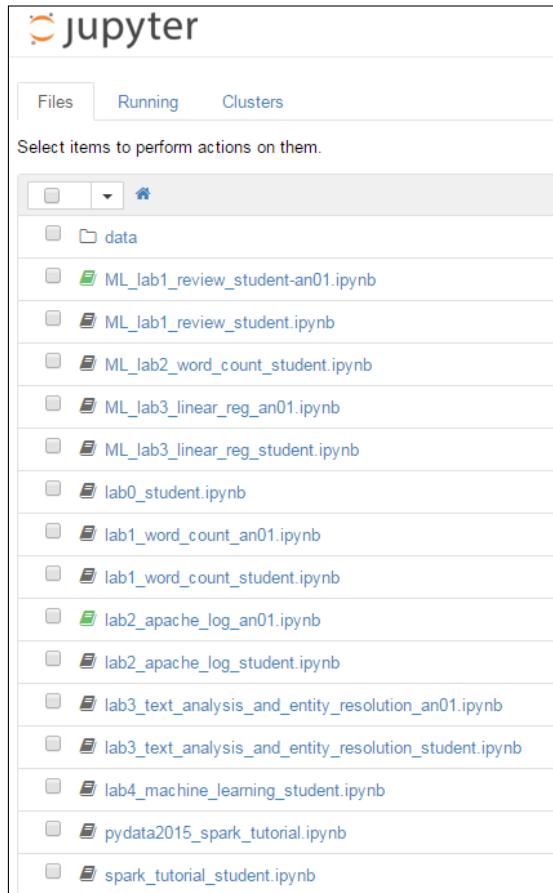
You will see an output similar to this:

```
C:\Programs\spark\edx1001\mooc-setup-master>vagrant up
Bringing machine 'sparkvm' up with 'virtualbox' provider...
==> sparkvm: Checking if box 'sparkmooc/base' is up to date...
==> sparkvm: Clearing any previously set forwarded ports...
==> sparkvm: Clearing any previously set network interfaces...
==> sparkvm: Preparing network interfaces based on configuration...
      sparkvm: Adapter 1: nat
==> sparkvm: Forwarding ports...
      sparkvm: 8001 => 8001 (adapter 1)
      sparkvm: 4040 => 4040 (adapter 1)
      sparkvm: 22 => 2222 (adapter 1)
==> sparkvm: Booting VM...
==> sparkvm: Waiting for machine to boot. This may take a few minutes...
      sparkvm: SSH address: 127.0.0.1:2222
      sparkvm: SSH username: vagrant
      sparkvm: SSH auth method: private key
```

```
sparkvm: Warning: Connection timeout. Retrying...
sparkvm: Warning: Remote connection disconnect. Retrying...
==> sparkvm: Machine booted and ready!
==> sparkvm: Checking for guest additions in VM...
==> sparkvm: Setting hostname...
==> sparkvm: Mounting shared folders...
sparkvm: /vagrant => C:/Programs/spark/edx1001/mooc-setup-master
==> sparkvm: Machine already provisioned. Run `vagrant provision` or use
the `--provision`
==> sparkvm: to force provisioning. Provisioners marked to run always
will still run.

C:\Programs\spark\edx1001\mooc-setup-master>
```

This will launch the IPython Notebooks powered by PySpark on localhost:8001:



## Moving to the cloud

As we are dealing with distributed systems, an environment on a virtual machine running on a single laptop is limited for exploration and learning. We can move to the cloud in order to experience the power and scalability of the Spark distributed framework.

## Deploying apps in Amazon Web Services

Once we are ready to scale our apps, we can migrate our development environment to **Amazon Web Services (AWS)**.

How to run Spark on EC2 is clearly described in the following page:  
<https://spark.apache.org/docs/latest/ec2-scripts.html>.

We emphasize five key steps in setting up the AWS Spark environment:

1. Create an AWS EC2 key pair via the AWS console <http://aws.amazon.com/console/>.

2. Export your key pair to your environment:

```
export AWS_ACCESS_KEY_ID=accesskeyid  
export AWS_SECRET_ACCESS_KEY=secretaccesskey
```

3. Launch your cluster:

```
~$ cd $SPARK_HOME/ec2  
ec2$ ./spark-ec2 -k <keypair> -i <key-file> -s <num-slaves> launch  
<cluster-name>
```

4. SSH into a cluster to run Spark jobs:

```
ec2$ ./spark-ec2 -k <keypair> -i <key-file> login <cluster-name>
```

5. Destroy your cluster after usage:

```
ec2$ ./spark-ec2 destroy <cluster-name>
```

## Virtualizing the environment with Docker

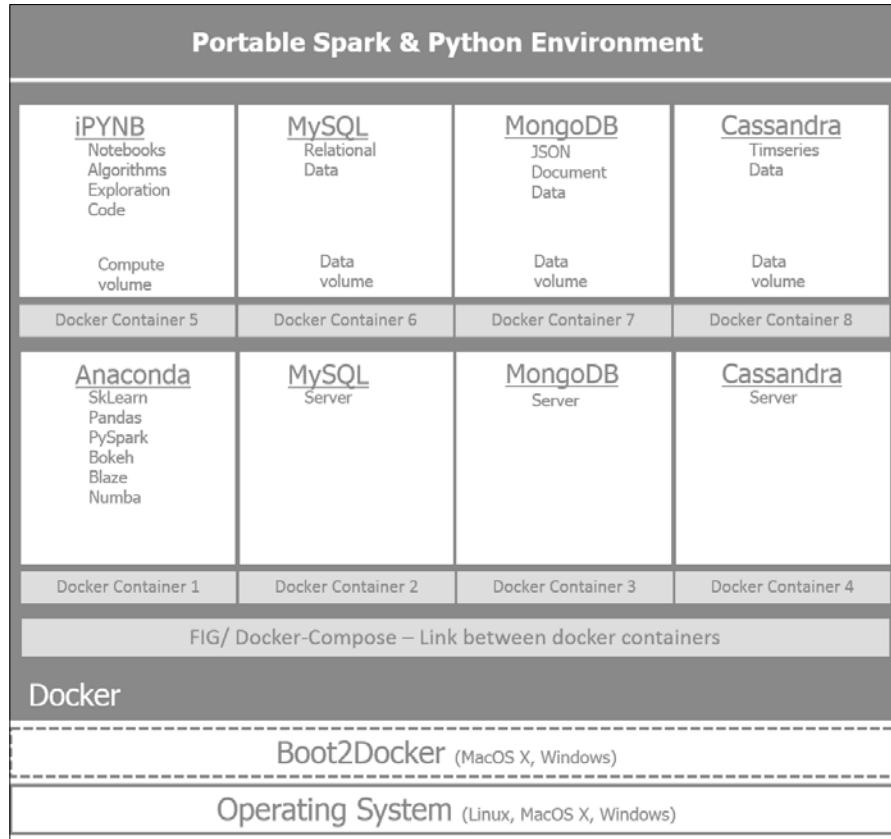
In order to create a portable Python and Spark environment that can be easily shared and cloned, the development environment can be built in Docker containers.

把...首字母大写  
We wish capitalize on Docker's two main functions:

- Creating isolated containers that can be easily deployed on different operating systems or in the cloud.

- Allowing easy sharing of the development environment image with all its dependencies using The DockerHub. The DockerHub is similar to GitHub. It allows easy cloning and version control. The 简介；简要说明 snapshot image of the configured environment can be the baseline for further enhancements.

The following diagram illustrates a Docker-enabled environment with Spark, Anaconda, and the database server and their respective data volumes.



Docker offers the ability to clone and deploy an environment from the Dockerfile.

You can find an example Dockerfile with a PySpark and Anaconda setup at the following address: <https://hub.docker.com/r>thisgokeboysef/pyspark-docker/~/dockerfile/>.

Install Docker as per the instructions provided at the following links:

- <http://docs.docker.com/mac/started/> if you are on Mac OS X
- <http://docs.docker.com/linux/started/> if you are on Linux
- <http://docs.docker.com/windows/started/> if you are on Windows

Install the docker container with the Dockerfile provided earlier with the following command:

```
$ docker pull thisgokeboysef/pyspark-docker
```

Other great sources of information on how to *dockerize* your environment can be seen at Lab41. The GitHub repository contains the necessary code:

<https://github.com/Lab41/ipython-spark-docker>

The supporting blog post is rich in information on thought processes involved in building the docker environment: <http://lab41.github.io/blog/2015/04/13/ipython-on-spark-on-docker/>.

## Summary

We set the context of building data-intensive apps by describing the overall architecture structured around the **infrastructure**, **persistence**, **integration**, **analytics**, and **engagement layers**. We also discussed Spark and Anaconda with their respective building blocks. We set up an environment in a VirtualBox with Anaconda and Spark and demonstrated a word count app using the text content of the first chapter as input.

In the next chapter, we will delve more deeply into the architecture blueprint for data-intensive apps and tap into the Twitter, GitHub, and Meetup APIs to get a feel 感受到 of the data we will be mining with Spark.

# 2

## Building Batch and Streaming Apps with Spark

The objective of the book is to teach you about PySpark and the PyData libraries by building an app that analyzes the Spark community's interactions on social networks. We will gather information on Apache Spark from GitHub, check the relevant tweets on Twitter, and get a feel for the buzz around Spark in the broader open source software communities using **Meetup**.

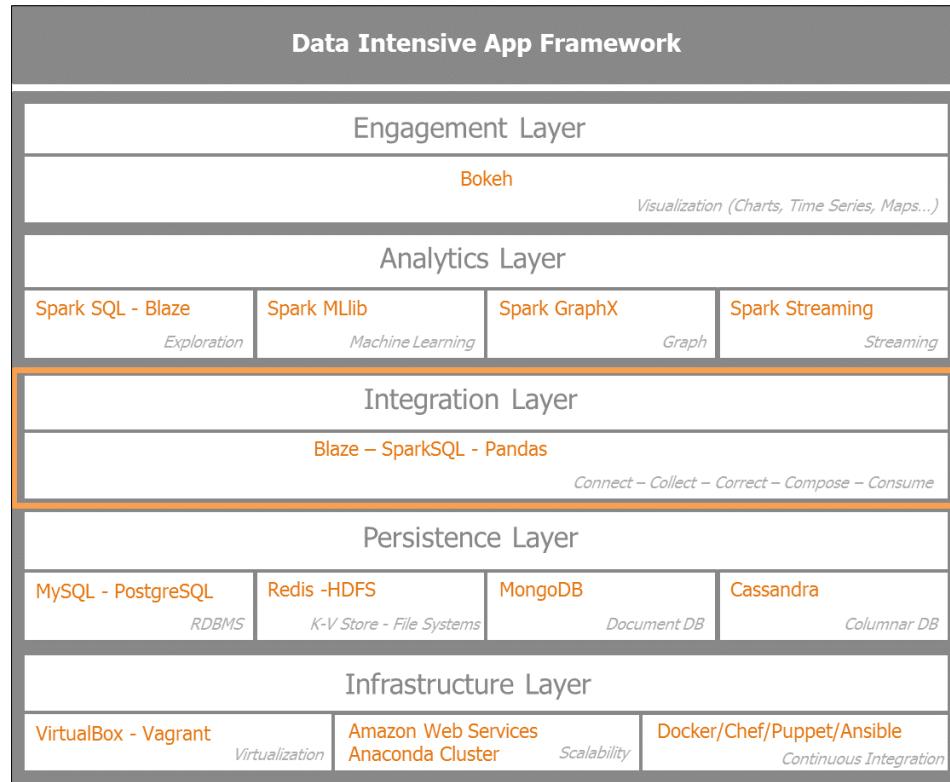
In this chapter, we will outline the various sources of data and information. We will get an understanding of their structure. We will outline the data processing pipeline, from collection to batch and streaming processing.

In this section, we will cover the following points:

- Outline data processing pipelines from collection to batch and stream processing, effectively depicting the architecture of the app we are planning to build.
- Check out the various data sources (GitHub, Twitter, and Meetup), their data structure (JSON, structured information, unstructured text, geo-location, time series data, and so on), and their complexities. We also discuss the tools to connect to three different APIs, so you can build your own data mashups. The book will focus on Twitter in the following chapters.

## Architecting data-intensive apps

We defined the data-intensive app framework architecture blueprint in the previous chapter. Let's put back in context the various software components we are going to use throughout the book in our original framework. Here's an illustration of the various components of software mapped in the data-intensive architecture framework:



Spark is an extremely efficient, distributed computing framework. In order to exploit its full power, we need to architect our solution accordingly. For performance reasons, the overall solution needs to also be aware of its usage in terms of CPU, storage, and network.

These imperatives drive the architecture of our solution:

- **Latency:** This architecture combines slow and fast processing. Slow processing is done on historical data in batch mode. This is also called data at rest. This phase builds precomputed models and data patterns that will be used by the fast processing arm once live continuous data is fed into the system. Fast processing of data or real-time analysis of streaming data refers to data in motion. Data at rest is essentially processing data in batch mode with a longer latency. Data in motion refers to the streaming computation of data ingested in real time.
- **Scalability:** Spark is natively linearly scalable through its distributed in-memory computing framework. Databases and data stores interacting with Spark need to be also able to scale linearly as data volume grows.
- **Fault tolerance:** When a failure occurs due to hardware, software, or network reasons, the architecture should be resilient enough and provide availability at all times.
- **Flexibility:** The data pipelines put in place in this architecture can be adapted and retrofitted very quickly depending on the use case.

Spark is unique as it allows batch processing and streaming analytics on the same unified platform.

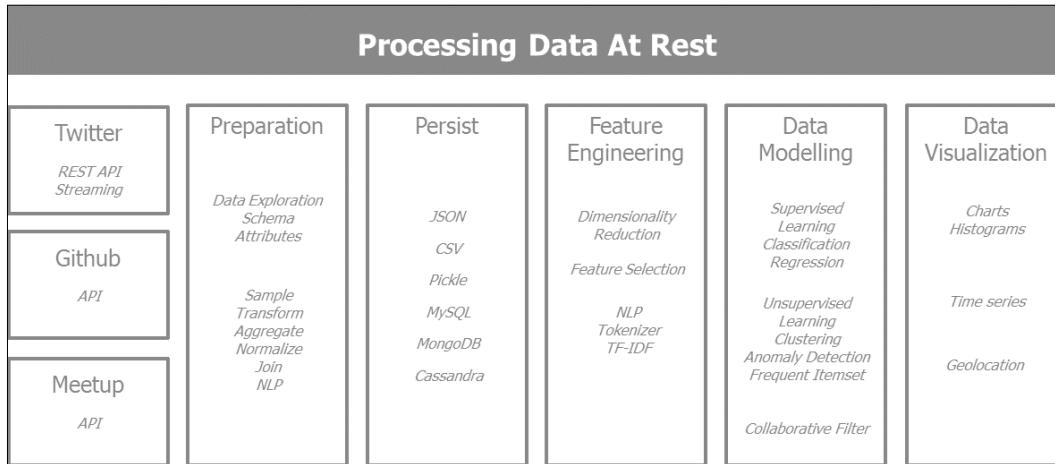
We will consider two data processing pipelines:

- The first one handles data at rest and is focused on putting together the pipeline for batch analysis of the data
- The second one, data in motion, targets real-time data ingestion and delivering insights based on precomputed models and data patterns

## Processing data at rest

Let's get an understanding of the data at rest or batch processing pipeline. The objective in this pipeline is to ingest the various datasets from Twitter, GitHub, and Meetup; prepare the data for Spark MLlib, the machine learning engine; and derive the base models that will be applied for insight generation in batch mode or in real time.

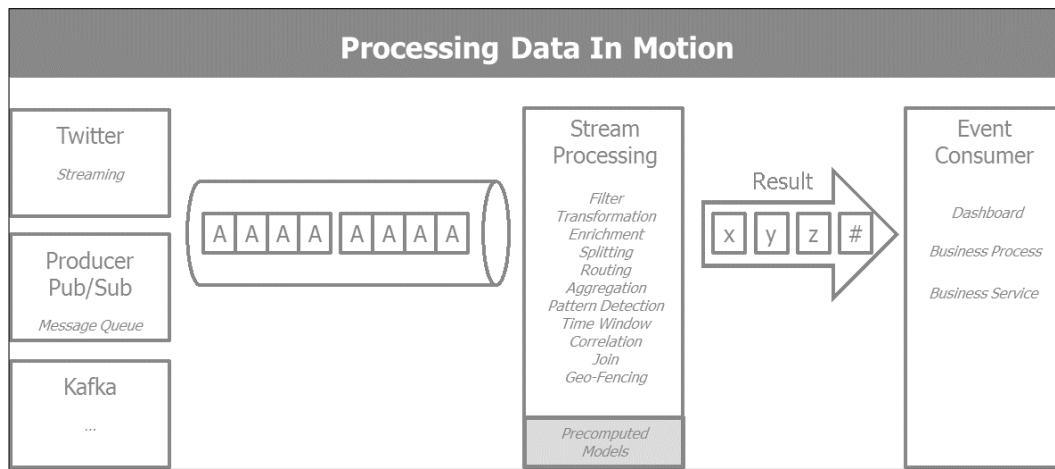
The following diagram illustrates the data pipeline in order to enable processing data at rest:



## Processing data in motion

Processing data in motion introduces a new level of complexity, as we are introducing a new possibility of failure. If we want to scale, we need to consider bringing in distributed message queue systems such as Kafka. We will dedicate a subsequent chapter to understanding streaming analytics.

The following diagram depicts a data pipeline for processing data in motion:



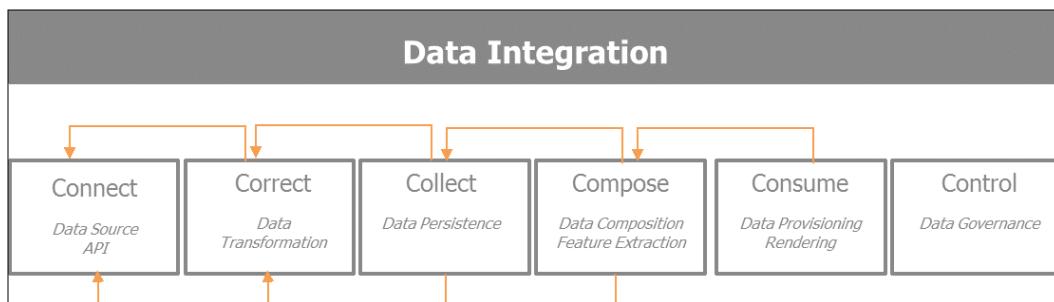
## Exploring data interactively

Building a data-intensive app is not as straightforward as exposing a database to a web interface. During the setup of both the data at rest and data in motion processing, we will capitalize on Spark's ability to analyse data interactively and refine the data richness and quality required for the machine learning and streaming activities. Here, we will go through an iterative cycle of data collection, refinement, and investigation in order to get to the dataset of interest for our apps.

## Connecting to social networks

Let's delve into the first steps of the data-intensive app architecture's integration layer. We are going to focus on harvesting the data, ensuring its integrity and preparing for batch and streaming data processing by Spark at the next stage. This phase is described in the five process steps: *connect*, *correct*, *collect*, *compose*, and *consume*. These are iterative steps of data exploration that will get us acquainted with the data and help us refine the data structure for further processing.

The following diagram depicts the iterative process of data acquisition and refinement for consumption:



We connect to the social networks of interest: Twitter, GitHub, and Meetup. We will discuss the mode of access to the **APIs** (short for **Application Programming Interface**) and how to create a RESTful connection with those services while respecting the rate limitation imposed by the social networks. **REST** (short for **Representation State Transfer**) is the most widely adopted architectural style on the Internet in order to enable scalable web services. It relies on exchanging messages predominantly in **JSON** (short for **JavaScript Object Notation**). RESTful APIs and web services implement the four most prevalent verbs **GET**, **PUT**, **POST**, and **DELETE**. **GET** is used to retrieve an element or a collection from a given **URI**. **PUT** updates a collection with a new one. **POST** allows the creation of a new entry, while **DELETE** eliminates a collection.

## Getting Twitter data

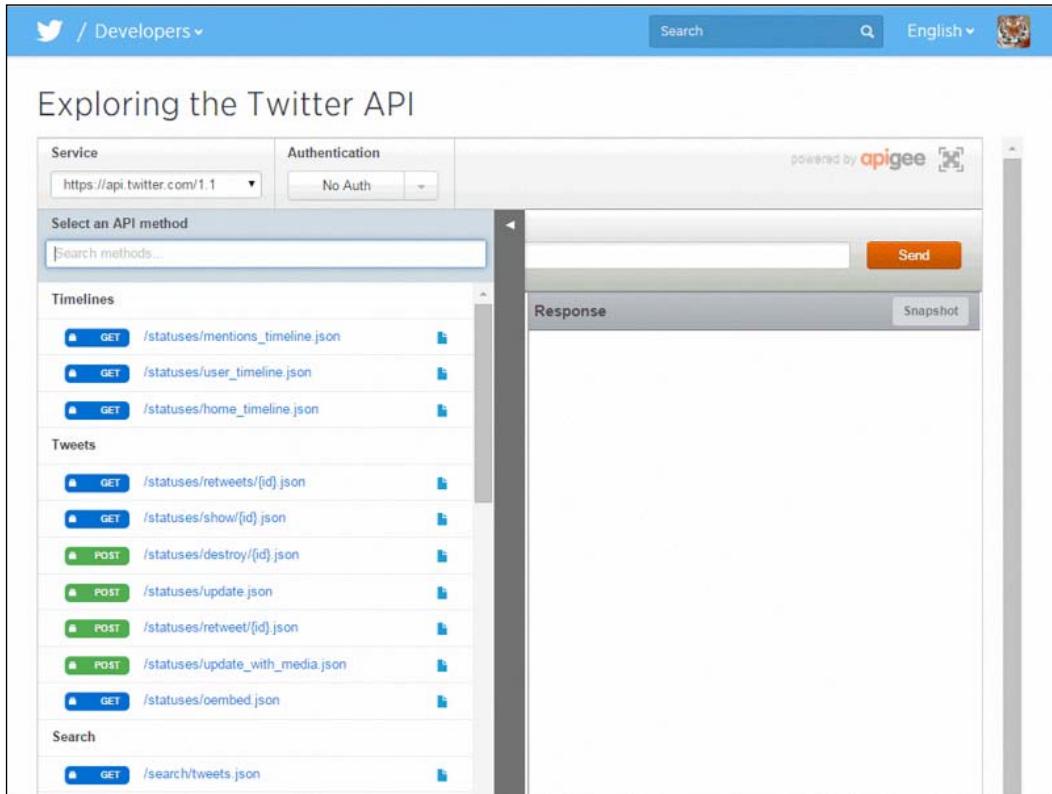
Twitter allows access to registered users to its search and streaming tweet services under an authorization protocol called OAuth that allows API applications to securely act on a user's behalf. In order to create the connection, the first step is to create an application with Twitter at <https://apps.twitter.com/app/new>.

The screenshot shows the 'Create an application' page on the Twitter Application Management interface. At the top, there is a cookie consent message: 'To bring you Twitter, we and our partners use cookies on our and other websites. Cookies help personalize Twitter content, tailor Twitter Ads, measure their performance, and provide you with a better, faster, safer Twitter experience. By using our services, you agree to our Cookie Use.' Below this, the main title 'Create an application' is displayed. The form is divided into sections: 'Application Details', 'Name \*' (Sparky), 'Description \*' (Apache Spark Twitterati), 'Website \*' (Sparky.org), and 'Callback URL'. A note below the callback URL field states: 'Where should we return after successfully authenticating? OAuth 1.0a applications should explicitly specify their oauth\_callback URL on the request token step, regardless of the value given here. To restrict your application from using callbacks, leave this field blank.'

Once the application has been created, Twitter will issue the four codes that will allow it to tap into the Twitter hose:

```
CONSUMER_KEY = 'GetYourKey@Twitter'  
CONSUMER_SECRET = ' GetYourKey@Twitter'  
OAUTH_TOKEN = ' GetYourToken@Twitter'  
OAUTH_TOKEN_SECRET = ' GetYourToken@Twitter'
```

If you wish to get a feel for the various RESTful queries offered, you can explore the Twitter API on the dev console at <https://dev.twitter.com/rest/tools/console>:



The screenshot shows the Twitter API Dev Console interface. At the top, there's a navigation bar with the Twitter logo, 'Developers', a search bar, and language selection ('English'). Below the header, the title 'Exploring the Twitter API' is displayed. A sidebar on the left lists various API methods categorized under 'Timelines', 'Tweets', and 'Search'. Each method entry includes a small icon indicating the HTTP verb (e.g., GET, POST), the endpoint path, and a refresh button. To the right of the sidebar is a large 'Response' area with a 'Send' button and a 'Snapshot' button.

Category	Method	Endpoint
Timelines	GET	/statuses/mentions_timeline.json
	GET	/statuses/user_timeline.json
	GET	/statuses/home_timeline.json
Tweets	GET	/statuses/retweets/[id].json
	GET	/statuses/show/[id].json
	POST	/statuses/destroy/[id].json
	POST	/statuses/update.json
	POST	/statuses/retweet/[id].json
	POST	/statuses/update_with_media.json
	GET	/statuses/oembed.json
Search	GET	/search/tweets.json

We will make a programmatic connection on Twitter using the following code, which will activate our OAuth access and allows us to tap into the Twitter API under the rate limitation. In the streaming mode, the limitation is for a GET request.

## Getting GitHub data

GitHub uses a similar authentication process to Twitter. Head to the developer site and retrieve your credentials after duly registering with GitHub at <https://developer.github.com/v3/>:

The screenshot shows the GitHub Developer API v3 Overview page. At the top, there's a navigation bar with links for API, Developers, Blog, Support, and Search. Below the navigation, there are tabs for API, Reference, Webhooks, Guides, and Libraries. The main content area has a heading 'Overview' with a sub-section 'Current Version'. To the right is a sidebar with a tree view of API resources:

- Overview
  - Media Types
  - OAuth
  - OAuth Authorizations API
  - Other Authentication Methods
  - Troubleshooting
  - Versions
- Activity
  - Events
  - Event Types & Payloads
  - Feeds
  - Notifications
  - Starring
  - Watching
- Gists
- Git Data
  - Blobs
  - Commits
  - References
  - Tags
  - Trees

## Getting Meetup data

Meetup can be accessed using the token issued in the developer resources to members of Meetup.com. The necessary token or OAuth credential for Meetup API access can be obtained on their developer's website at [https://secure.meetup.com/meetup\\_api](https://secure.meetup.com/meetup_api):

The screenshot shows the Meetup API homepage. At the top, there are navigation links for 'Meetup', 'Find a Meetup Group', 'Start a Meetup Group', and user profile icons. Below the header is a navigation bar with 'Meetup API' (selected), 'Documentation', 'Console', 'API Key', 'OAuth Consumers', 'Widget Foundry', 'Applications', and 'Client Libraries'. The main content area features a large blue banner with the text 'Extend your community' and a stylized 'Meetup API' logo. To the right of the banner is a sidebar titled 'API methods' containing a search bar and a list of categories: 'abuse', 'batch', 'boards', 'categories', 'cities', and 'dashboard', each with a list of corresponding API endpoints.

## Analyzing the data

Let's get a first feel for the data extracted from each of the social networks and get an understanding of the data structure from each these sources.

## Discovering the anatomy of tweets

In this section, we are going to establish connection with the Twitter API. Twitter offers two connection modes: the REST API, which allows us to search historical tweets for a given search term or hashtag, and the streaming API, which delivers real-time tweets under the rate limit in place.

In order to get a better understanding of how to operate with the Twitter API, we will go through the following steps:

1. Install the Twitter Python library.
2. Establish a connection programmatically via OAuth, the authentication required for Twitter.
3. Search for recent tweets for the query *Apache Spark* and explore the results obtained.
4. Decide on the key attributes of interest and retrieve the information from the JSON output.

Let's go through it step-by-step:

1. Install the Python Twitter library. In order to install it, you need to write `pip install twitter` from the command line:

```
$ pip install twitter
```

2. Create the Python Twitter API class and its base methods for authentication, searching, and parsing the results. `self.auth` gets the credentials from Twitter. It then creates a registered API as `self.api`. We have implemented two methods: the first one to search Twitter with a given query and the second one to parse the output to retrieve relevant information such as the tweet ID, the tweet text, and the tweet author. The code is as follows:

```
import twitter
import urlparse
from pprint import pprint as pp

class TwitterAPI(object):
    """
    TwitterAPI class allows the Connection to Twitter via OAuth
    once you have registered with Twitter and receive the
    necessary credentiaials
    """

    # initialize and get the twitter credentials
    def __init__(self):
        consumer_key = 'Provide your credentials'
        consumer_secret = 'Provide your credentials'
        access_token = 'Provide your credentials'
        access_secret = 'Provide your credentials'

        self.consumer_key = consumer_key
        self.consumer_secret = consumer_secret
```

```

        self.access_token = access_token
        self.access_secret = access_secret

#
# authenticate credentials with Twitter using OAuth
        self.auth = twitter.oauth.OAuth(access_token, access_
secret, consumer_key, consumer_secret)
        # creates registered Twitter API
        self.api = twitter.Twitter(auth=self.auth)
#
# search Twitter with query q (i.e. "ApacheSpark") and max. result
    def searchTwitter(self, q, max_res=10, **kwargs):
        search_results = self.api.search.tweets(q=q, count=10,
**kwargs)
        statuses = search_results['statuses']
        max_results = min(1000, max_res)

        for _ in range(10):
            try:
                next_results = search_results['search_metadata']
                ['next_results']
            except KeyError as e:
                break

            next_results = urlparse.parse_qsl(next_results[1:])
            kwargs = dict(next_results)
            search_results = self.api.search.tweets(**kwargs)
            statuses += search_results['statuses']

            if len(statuses) > max_results:
                break
        return statuses
#
# parse tweets as it is collected to extract id, creation
# date, user id, tweet text
    def parseTweets(self, statuses):
        return [ (status['id'],
                  status['created_at'],
                  status['user']['id'],
                  status['user']['name'],
                  status['text'], url['expanded_url'])
                 for status in statuses
                 for url in status['entities']['urls']
        ]

```

3. Instantiate the class with the required authentication:

```
t= TwitterAPI()
```

4. Run a search on the query term *Apache Spark*:

```
q="ApacheSpark"
tsearch = t.searchTwitter(q)
```

5. Analyze the JSON output:

```
pp(tsearch[1])

{u'contributors': None,
 u'coordinates': None,
 u'created_at': u'Sat Apr 25 14:50:57 +0000 2015',
 u'entities': {u'hashtags': [{u'indices': [74, 86], u'text': u'sparksummit'}],
               u'media': [{u'display_url': u'pic.twitter.com/WKUMRXxIWZ',
                           u'expanded_url': u'http://twitter.com/bigdata/status/591976255831969792/photo/1',
                           u'id': 591976255156715520,
                           u'id_str': u'591976255156715520',
                           u'indices': [143, 144],
                           u'media_url':
... (snip) ...
               u'text': u'RT @bigdata: Enjoyed catching up with @ApacheSpark users & leaders at #sparksummit NYC: video clips are out http://t.co/qrqpP6cG9s http://t\u2026',
               u'truncated': False,
               u'user': {u'contributors_enabled': False,
                         u'created_at': u'Sat Apr 04 14:44:31 +0000 2015',
                         u'default_profile': True,
                         u'default_profile_image': True,
                         u'description': u '',
                         u'entities': {u'description': {u'urls': []}},
                         u'favourites_count': 0,
                         u'follow_request_sent': False,
                         u'followers_count': 586,
                         u'following': False,
                         u'friends_count': 2,
                         u'geo_enabled': False,
                         u'id': 3139047660,
                         u'id_str': u'3139047660',
                         u'is_translation_enabled': False,
                         u'is_translator': False,
```

```
        u'lang': u'zh-cn',
        u'listed_count': 749,
        u'location': u'',
        u'name': u'Mega Data Mama',
        u'notifications': False,
        u'profile_background_color': u'C0DEED',
        u'profile_background_image_url': u'http://abs.twimg.com/images/themes/theme1/bg.png',
        u'profile_background_image_url_https': u'https://abs.twimg.com/images/themes/theme1/bg.png',
        ... (snip) ...
        u'screen_name': u'MegaDataMama',
        u'statuses_count': 26673,
        u'time_zone': None,
        u'url': None,
        u'utc_offset': None,
        u'verified': False} }
```

6. Parse the Twitter output to retrieve key information of interest:

```
tparsed = t.parseTweets(tsearch)
pp(tparsed)

[(591980327784046592,
  u'Sat Apr 25 15:01:23 +0000 2015',
  63407360,
  u'Jos\xe9 Carlos Baquero',
  u'Big Data systems are making a difference in the fight against
cancer. #BigData #ApacheSpark http://t.co/pnOLmsKdL9',
  u'http://tumblr.co/ZqTggs1jHytN0'),
 (591977704464875520,
  u'Sat Apr 25 14:50:57 +0000 2015',
  3139047660,
  u'Mega Data Mama',
  u'RT @bigdata: Enjoyed catching up with @ApacheSpark users & leaders at #sparksummit NYC: video clips are out http://t.co/qrqpP6cG9s http://t\u2026',
  u'http://goo.gl/eF5xwK'),
 (591977172589539328,
  u'Sat Apr 25 14:48:51 +0000 2015',
  2997608763,
  u'Emma Clark',
  u'RT @bigdata: Enjoyed catching up with @ApacheSpark users & leaders at #sparksummit NYC: video clips are out http://t.co/qrqpP6cG9s http://t\u2026',
  u'http://goo.gl/eF5xwK'),
```

```
... (snip)...
(591879098349268992,
u'Sat Apr 25 08:19:08 +0000 2015',
331263208,
u'Mario Molina',
u'#ApacheSpark speeds up big data decision-making http://t.
co/8hdEXreNfN',
u'http://www.computerweekly.com/feature/Apache-Spark-speeds-up-
big-data-decision-making'])
```

## Exploring the GitHub world

In order to get a better understanding on how to operate with the GitHub API, we will go through the following steps:

1. Install the GitHub Python library.
2. Access the API by using the token provided when we registered in the developer website.
3. Retrieve some key facts on the Apache foundation that is hosting the spark repository.

Let's go through the process step-by-step:

1. Install the Python PyGithub library. In order to install it, you need to `pip install PyGithub` from the command line:

```
pip install PyGithub
```

2. Programmatically create a client to instantiate the GitHub API:

```
from github import Github
```

```
# Get your own access token
```

```
ACCESS_TOKEN = 'Get_Your_Own_Access_Token'
```

```
# We are focusing our attention to User = apache and Repo = spark
```

```
USER = 'apache'
REPO = 'spark'
```

```
g = Github(ACCESS_TOKEN, per_page=100)
user = g.get_user(USER)
repo = user.get_repo(REPO)
```

3. Retrieve key facts from the Apache User. There are 640 active Apache repositories in GitHub:

```
repos_apache = [repo.name for repo in g.get_user('apache').get_repos()]
len(repos_apache)
640
```

4. Retrieve key facts from the Spark repository, The programming languages used in the Spark repo are given here under:

```
pp(repo.get_languages())
```

```
{u'C': 1493,
 u'CSS': 4472,
 u'Groff': 5379,
 u'Java': 1054894,
 u'JavaScript': 21569,
 u'Makefile': 7771,
 u'Python': 1091048,
 u'R': 339201,
 u'Scala': 10249122,
 u'Shell': 172244}
```

5. Retrieve a few key participants of the wide Spark GitHub repository network. There are 3,738 stargazers in the Apache Spark repository at the time of writing. The network is immense. The first stargazer is *Matei Zaharia*, the cofounder of the Spark project when he was doing his PhD in Berkeley.

```
stargazers = [ s for s in repo.get_stargazers() ]
print "Number of stargazers", len(stargazers)
Number of stargazers 3738

[stargazers[i].login for i in range (0,20)]
[u'mateiz',
 u'beyang',
 u'abo',
 u'CodingCat',
 u'andy327',
 u'CrazyJvm',
 u'jyotiska',
 u'BaiGang',
 u'sundstei',
 u'dianacarroll',
 u'ybotco',
 u'xelax',
```

```
u'prabeesh',
u'invkrh',
u'bedla',
u'nadesai',
u'pcpratts',
u'narkisr',
u'Honghe',
u'Jacke']
```

## Understanding the community through Meetup

In order to get a better understanding of how to operate with the Meetup API, we will go through the following steps:

1. Create a Python program to call the Meetup API using an authentication token.
2. Retrieve information of past events for meetup groups such as *London Data Science*.
3. Retrieve the profile of the meetup members in order to analyze their participation in similar meetup groups.

Let's go through the process step-by-step:

1. As there is no reliable Meetup API Python library, we will programmatically create a client to instantiate the Meetup API:

```
import json
import mimetools
import requests
import urllib
from pprint import pprint as pp

MEETUP_API_HOST = 'https://api.meetup.com'
EVENTS_URL = MEETUP_API_HOST + '/2/events.json'
MEMBERS_URL = MEETUP_API_HOST + '/2/members.json'
GROUPS_URL = MEETUP_API_HOST + '/2/groups.json'
RSVP_URL = MEETUP_API_HOST + '/2/rsvps.json'
PHOTOS_URL = MEETUP_API_HOST + '/2/photos.json'
GROUP_URLNAME = 'London-Machine-Learning-Meetup'
# GROUP_URLNAME = 'London-Machine-Learning-Meetup' # 'Data-Science-London'
```

```
class MeetupAPI(object):
    """
    Retrieves information about meetup.com
    """
    def __init__(self, api_key, num_past_events=10, http_timeout=1,
                 http_retries=2):
        """
        Create a new instance of MeetupAPI
        """
        self._api_key = api_key
        self._http_timeout = http_timeout
        self._http_retries = http_retries
        self._num_past_events = num_past_events

    def get_past_events(self):
        """
        Get past meetup events for a given meetup group
        """
        params = {'key': self._api_key,
                  'group_urlname': GROUP_URLNAME,
                  'status': 'past',
                  'desc': 'true'}
        if self._num_past_events:
            params['page'] = str(self._num_past_events)

        query = urllib.urlencode(params)
        url = '{0}?{1}'.format(EVENTS_URL, query)
        response = requests.get(url, timeout=self._http_timeout)
        data = response.json()['results']
        return data

    def get_members(self):
        """
        Get meetup members for a given meetup group
        """
        params = {'key': self._api_key,
                  'group_urlname': GROUP_URLNAME,
                  'offset': '0',
                  'format': 'json',
                  'page': '100',
                  'order': 'name'}
        query = urllib.urlencode(params)
```

```
url = '{0}?{1}'.format(MEMBERS_URL, query)
response = requests.get(url, timeout=self._http_timeout)
data = response.json()['results']
return data

def get_groups_by_member(self, member_id='38680722'):
    """
    Get meetup groups for a given meetup member
    """
    params = {'key': self._api_key,
              'member_id': member_id,
              'offset': '0',
              'format': 'json',
              'page': '100',
              'order': 'id'}
    query = urllib.urlencode(params)
    url = '{0}?{1}'.format(GROUPS_URL, query)
    response = requests.get(url, timeout=self._http_timeout)
    data = response.json()['results']
    return data
```

2. Then, we will retrieve past events from a given Meetup group:

```
m = MeetupAPI(api_key='Get_Your_Own_Key')
last_meetups = m.get_past_events()
pp(last_meetups[5])

{u'created': 1401809093000,
 u'description': u"<p>We are hosting a joint meetup between Spark London and Machine Learning London. Given the excitement in the machine learning community around Spark at the moment a joint meetup is in order!</p> <p>Michael Armbrust from the Apache Spark core team will be flying over from the States to give us a talk in person.\xa0Thanks to our sponsors, Cloudera, MapR and Databricks for helping make this happen.</p> <p>The first part of the talk will be about MLlib, the machine learning library for Spark,\xa0and the second part, on\x0aSpark SQL.</p> <p>Don't sign up if you have already signed up on the Spark London page though!</p> <p>\n\nAbstract for part one:</p> <p>In this talk, we\u2019ll introduce Spark and show how to use it to build fast, end-to-end machine learning workflows. Using Spark\u2019s high-level API, we can process raw data with familiar libraries in Java, Scala or Python (e.g. NumPy) to extract the features for machine learning. Then, using MLlib, its built-in machine learning library, we can run scalable versions of popular algorithms. We\u2019ll also cover upcoming development work including new built-in algorithms and R bindings.</p> <p>\n\nAbstract for part two:\xa0</p> <p>In
```

this talk, we'll examine Spark SQL, a new Alpha component that is part of the Apache Spark 1.0 release. Spark SQL lets developers natively query data stored in both existing RDDs and external sources such as Apache Hive. A key feature of Spark SQL is the ability to blur the lines between relational tables and RDDs, making it easy for developers to intermix SQL commands that query external data with complex analytics. In addition to Spark SQL, we'll explore the Catalyst optimizer framework, which allows Spark SQL to automatically rewrite query plans to execute more efficiently.</p>","  
u'event\_url': u'http://www.meetup.com/London-Machine-Learning-Meetup/events/186883262/','  
u'group': {u'created': 1322826414000,  
u'group\_lat': 51.52000045776367,  
u'group\_lon': -0.18000000715255737,  
u'id': 2894492,  
u'join\_mode': u'open',  
u'name': u'London Machine Learning Meetup',  
u'urlname': u'London-Machine-Learning-Meetup',  
u'who': u'Machine Learning Enthusiasts'},  
u'headcount': 0,  
u'id': u'186883262',  
u'maybe\_rsvp\_count': 0,  
u'name': u'Joint Spark London and Machine Learning Meetup',  
u'rating': {u'average': 4.800000190734863, u'count': 5},  
u'rsvp\_limit': 70,  
u'status': u'past',  
u'time': 1403200800000,  
u'updated': 1403450844000,  
u'utc\_offset': 3600000,  
u'venue': {u'address\_1': u'12 Errol St, London',  
u'city': u'EC1Y 8LX',  
u'country': u'gb',  
u'id': 19504802,  
u'lat': 51.522533,  
u'lon': -0.090934,  
u'name': u'Royal Statistical Society',  
u'repinned': False},  
u'visibility': u'public',  
u'waitlist\_count': 84,  
u'yes\_rsvp\_count': 70}

3. Get information about the Meetup members:

```
members = m.get_members()

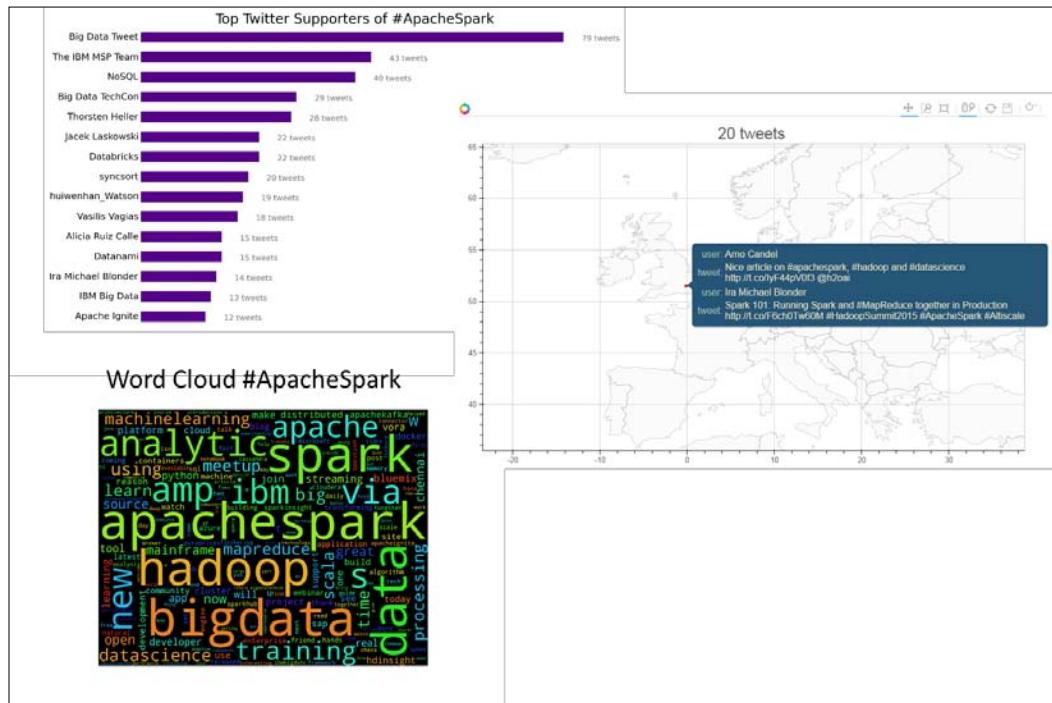
{u'city': u'London',
 u'country': u'gb',
 u'hometown': u'London',
 u'id': 11337881,
 u'joined': 1421418896000,
 u'lat': 51.53,
 u'link': u'http://www.meetup.com/members/11337881',
 u'lon': -0.09,
 u'name': u'Abhishek Shivkumar',
 u'other_services': {u'twitter': {u'identifier': u'@abhisemweb'}},
 u'photo': {u'highres_link': u'http://photos3.meetupstatic.com/photos/member/9/6/f/3/highres_10898643.jpeg',
            u'photo_id': 10898643,
            u'photo_link': u'http://photos3.meetupstatic.com/photos/member/9/6/f/3/member_10898643.jpeg',
            u'thumb_link': u'http://photos3.meetupstatic.com/photos/member/9/6/f/3/thumb_10898643.jpeg'},
 u'self': {u'common': {}},
 u'state': u'17',
 u'status': u'active',
 u'topics': [{u'id': 1372, u'name': u'Semantic Web', u'urlkey': u'semweb'},
             {u'id': 1512, u'name': u'XML', u'urlkey': u'xml'},
             {u'id': 49585,
              u'name': u'Semantic Social Networks',
              u'urlkey': u'semantic-social-networks'},
             {u'id': 24553,
              u'name': u'Natural Language Processing',
              ... (snip) ...
              u'name': u'Android Development',
              u'urlkey': u'android-developers'}],
 u'visited': 1429281599000}
```

## Previewing our app

Our challenge is to make sense of the data retrieved from these social networks, finding the key relationships and deriving insights. Some of the elements of interest are as follows:

- Visualizing the top influencers: Discover the top influencers in the community:
  - Heavy Twitter users on *Apache Spark*
  - Committers in GitHub
  - Leading Meetup presentations
- Understanding the Network: Network graph of GitHub committers, watchers, and stargazers
- Identifying the Hot Locations: Locating the most active location for Spark

The following screenshot provides a preview of our app:



## Summary

In this chapter, we laid out the overall architecture of our app. We explained the two main paradigms of processing data: batch processing, also called data at rest, and streaming analytics, referred to as data in motion. We proceeded to establish connections to three social networks of interest: Twitter, GitHub, and Meetup. We sampled the data and provided a preview of what we are aiming to build. The remainder of the book will focus on the Twitter dataset. We provided here the tools and API to access three social networks, so you can at a later stage create your own data mashups. We are now ready to investigate the data collected, which will be the topic of the next chapter.

In the next chapter, we will delve deeper into data analysis, extracting the key attributes of interest for our purposes and managing the storage of the information for batch and stream processing.

# 3

## Juggling Data with Spark

As per the batch and streaming architecture laid out in the previous chapter, we need data to fuel our applications. We will harvest data focused on Apache Spark from Twitter. The objective of this chapter is to prepare data to be further used by the machine learning and streaming applications. This chapter focuses on how to exchange code and data across the distributed network. We will get practical insights into serialization, persistence, marshaling, and caching. We will get to grips with on Spark SQL, the key Spark module to interactively explore structured and semi-structured data. The fundamental data structure powering Spark SQL is the Spark dataframe. The Spark dataframe is inspired by the Python Pandas dataframe and the R dataframe. It is a powerful data structure, well understood and appreciated by data scientists with a background in R or Python.

In this chapter, we will cover the following points:

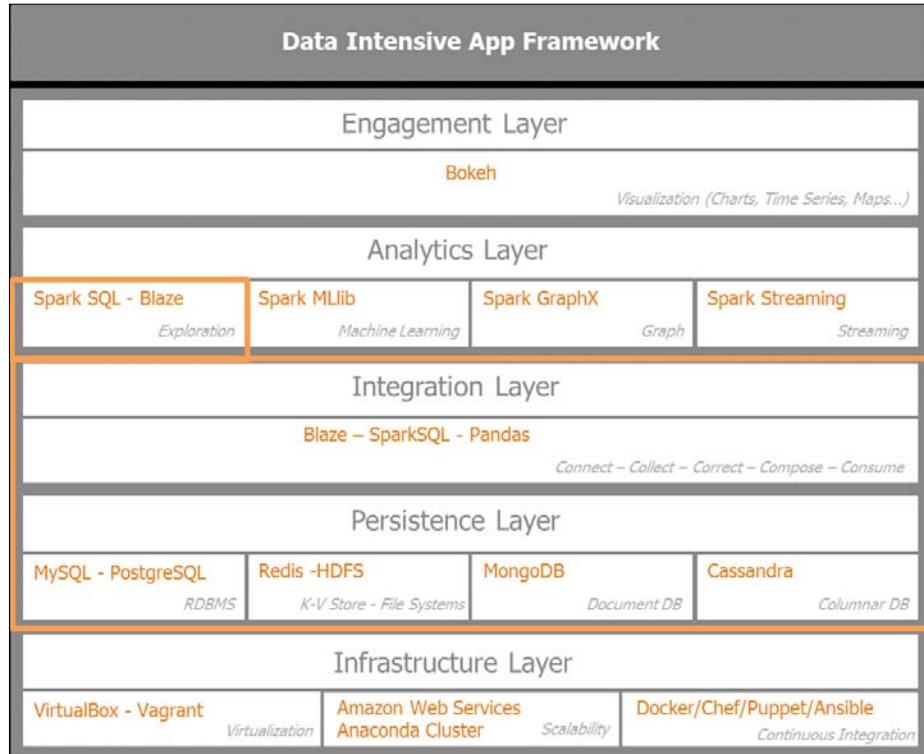
- Connect to Twitter, collect the relevant data, and then persist it in various formats such as JSON and CSV and data stores such as MongoDB
- Analyze the data using Blaze and Odo, a spin-off library from Blaze, in order to connect and transfer data from various sources and destinations
- Introduce Spark dataframes as the foundation for data interchange between the various Spark modules and explore data interactively using Spark SQL

# Revisiting the data-intensive app architecture

Let's first put in context the focus of this chapter with respect to the data-intensive app architecture. We will concentrate our attention on the integration layer and essentially run through iterative cycles of the acquisition, refinement, and persistence of the data. This cycle was termed the five Cs. The five Cs stand for *connect*, *collect*, *correct*, *compose*, and *consume*. They are the essential processes we run through in the integration layer in order to get to the right quality and quantity of data retrieved from Twitter. We will also delve deeper in the persistence layer and set up a data store such as MongoDB to collect our data for processing later.

We will explore the data with Blaze, a Python library for data manipulation, and Spark SQL, the interactive module of Spark for data discovery powered by the Spark dataframe. The dataframe paradigm is shared by Python Pandas, Python Blaze, and Spark SQL. We will get a feel for the nuances of the three dataframe flavors.

The following diagram sets the context of the chapter's focus, highlighting the integration layer and the persistence layer:



## Serializing and deserializing data

As we are harvesting data from web APIs under rate limit constraints, we need to store them. As the data is processed on a distributed cluster, we need consistent ways to save state and retrieve it for later usage.

Let's now define serialization, persistence, marshaling, and caching or memorization.

Serializing a Python object converts it into a stream of bytes. The Python object needs to be retrieved beyond the scope of its existence, when the program is shut. The serialized Python object can be transferred over a network or stored in a persistent storage. Deserialization is the opposite and converts the stream of bytes into the original Python object so the program can carry on from the saved state. The most popular serialization library in Python is Pickle. As a matter of fact, the PySpark commands are transferred over the wire to the worker nodes via pickled data.

Persistence saves a program's state data to disk or memory so that it can carry on where it left off upon restart. It saves a Python object from memory to a file or a database and loads it later with the same state.

Marshalling sends Python code or data over a network TCP connection in a multicore or distributed system.

Caching converts a Python object to a string in memory so that it can be used as a dictionary key later on. Spark supports pulling a dataset into a cluster-wide, in-memory cache. This is very useful when data is accessed repeatedly such as when querying a small reference dataset or running an iterative algorithm such as Google PageRank.

Caching is a crucial concept for Spark as it allows us to save RDDs in memory or with a spillage to disk. The caching strategy can be selected based on the lineage of the data or the **DAG** (short for **Directed Acyclic Graph**) of transformations applied to the RDDs in order to minimize shuffle or cross network heavy data exchange. In order to achieve good performance with Spark, beware of data shuffling. A good partitioning policy and use of RDD caching, coupled with avoiding unnecessary action operations, leads to better performance with Spark.

## Harvesting and storing data

Before delving into database persistent storage such as MongoDB, we will look at some useful file storages that are widely used: **CSV** (short for **comma-separated values**) and **JSON** (short for **JavaScript Object Notation**) file storage. The enduring popularity of these two file formats lies in a few key reasons: they are human readable, simple, relatively lightweight, and easy to use.

## Persisting data in CSV

The CSV format is lightweight, human readable, and easy to use. It has delimited text columns with an inherent tabular schema.

Python offers a robust `csv` library that can serialize a `csv` file into a Python dictionary. For the purpose of our program, we have written a python class that manages to persist data in CSV format and read from a given CSV.

Let's run through the code of the class `IO_csv` object. The `__init__` section of the class basically instantiates the file path, the filename, and the file suffix (in this case, `.csv`):

```
class IO_csv(object):

    def __init__(self, filepath, filename, filesuffix='csv'):
        self.filepath = filepath      # /path/to/file without the '/'
        at the end
        self.filename = filename      # FILE_NAME
        self.filesuffix = filesuffix
```

The `save` method of the class uses a Python named tuple and the header fields of the `csv` file in order to impart a schema while persisting the rows of the CSV. If the `csv` file already exists, it will be appended and not overwritten otherwise; it will be created:

```
def save(self, data, NTname, fields):
    # NTname = Name of the NamedTuple
    # fields = header of CSV - list of the fields name
    NTuple = namedtuple(NTname, fields)

    if os.path.isfile('{0}/{1}.{2}'.format(self.filepath, self.
    filename, self.filesuffix)):
        # Append existing file
        with open('{0}/{1}.{2}'.format(self.filepath, self.
        filename, self.filesuffix), 'ab') as f:
            writer = csv.writer(f)
            # writer.writerow(fields) # fields = header of CSV
            writer.writerows([row for row in map(NTuple._make,
            data)])
        # list comprehension using map on the NamedTuple._
        make() iterable and the data file to be saved
        # Notice writer.writerows and not writer.writerow
        (i.e. list of multiple rows sent to csv file
        else:
            # Create new file
```

---

```

        with open('{0}/{1}.{2}'.format(self.filepath, self.
filename, self.filesuffix), 'wb') as f:
            writer = csv.writer(f)
            writer.writerow(fields) # fields = header of CSV -
list of the fields name
            writer.writerows([row for row in map(NTuple._make,
data)])
# list comprehension using map on the NamedTuple._make() iterable and the data file to be saved
# Notice writer.writerows and not writer.writerow
(i.e. list of multiple rows sent to csv file)

```

The load method of the class also uses a Python named tuple and the header fields of the csv file in order to retrieve the data using a consistent schema. The load method is a memory-efficient generator to avoid loading a huge file in memory: hence we use `yield` in place of `return`:

```

def load(self, NTname, fields):
    # NTname = Name of the NamedTuple
    # fields = header of CSV - list of the fields name
    NTuple = namedtuple(NTname, fields)
    with open('{0}/{1}.{2}'.format(self.filepath, self.filename,
self.filesuffix), 'rU') as f:
        reader = csv.reader(f)
        for row in map(NTuple._make, reader):
            # Using map on the NamedTuple._make() iterable and the
reader file to be loaded
            yield row

```

Here's the named tuple. We are using it to parse the tweet in order to save or retrieve them to and from the csv file:

```

fields01 = ['id', 'created_at', 'user_id', 'user_name', 'tweet_text',
'url']
Tweet01 = namedtuple('Tweet01', fields01)

def parse_tweet(data):
"""
Parse a ``tweet`` from the given response data.
"""
return Tweet01(
    id=data.get('id', None),
    created_at=data.get('created_at', None),
    user_id=data.get('user_id', None),
    user_name=data.get('user_name', None),
    tweet_text=data.get('tweet_text', None),
    url=data.get('url')
)

```

## Persisting data in JSON

JSON is one of the most popular data formats for Internet-based applications. All the APIs we are dealing with, Twitter, GitHub, and Meetup, deliver their data in JSON format. The JSON format is relatively lightweight compared to XML and human readable, and the schema is embedded in JSON. As opposed to the CSV format, where all records follow exactly the same tabular structure, JSON records can vary in their structure. JSON is semi-structured. A JSON record can be mapped into a Python dictionary of dictionaries.

Let's run through the code of the class `IO_json` object. The `__init__` section of the class basically instantiates the file path, the filename, and the file suffix (in this case, `.json`):

```
class IO_json(object):
    def __init__(self, filepath, filename, filesuffix='json'):
        self.filepath = filepath          # /path/to/file without the /
        at the end
        self.filename = filename         # FILE_NAME
        self.filesuffix = filesuffix
        # self.file_io = os.path.join(dir_name, ..join((base_
        filename, filename_suffix)))
```

The `save` method of the class uses `utf-8` encoding in order to ensure read and write compatibility of the data. If the JSON file already exists, it will be appended and not overwritten; otherwise it will be created:

```
def save(self, data):
    if os.path.isfile('{0}/{1}.{2}'.format(self.filepath, self.
    filename, self.filesuffix)):
        # Append existing file
        with io.open('{0}/{1}.{2}'.format(self.filepath, self.
        filename, self.filesuffix), 'a', encoding='utf-8') as f:
            f.write(unicode(json.dumps(data, ensure_ascii=
        False))) # In python 3, there is no "unicode" function
            # f.write(json.dumps(data, ensure_ascii= False)) #
        create a \" escape char for " in the saved file
    else:
        # Create new file
        with io.open('{0}/{1}.{2}'.format(self.filepath, self.
        filename, self.filesuffix), 'w', encoding='utf-8') as f:
            f.write(unicode(json.dumps(data, ensure_ascii=
        False)))
            # f.write(json.dumps(data, ensure_ascii= False))
```

The `load` method of the class just returns the file that has been read. A further `json.loads` function needs to be applied in order to retrieve the json out of the file read:

```
def load(self):
    with io.open('{0}/{1}.{2}'.format(self.filepath, self.
        filename, self.filesuffix), encoding='utf-8') as f:
        return f.read()
```

## Setting up MongoDB

It is crucial to store the information harvested. Thus, we set up MongoDB as our main document data store. As all the information collected is in JSON format and MongoDB stores information in **BSON** (short for **Binary JSON**), it is therefore a natural choice.

We will run through the following steps now:

- Installing the MongoDB server and client
- Running the MongoDB server
- Running the Mongo client
- Installing the PyMongo driver
- Creating the Python Mongo client

## Installing the MongoDB server and client

In order to install the MongoDB package, perform through the following steps:

1. Import the public key used by the package management system (in our case, Ubuntu's `apt`). To import the MongoDB public key, we issue the following command:

```
sudo apt-key adv --keyserver hkp://keyserver.ubuntu.com:80 --recv
7F0CEB10
```

2. Create a list file for MongoDB. To create the list file, we use the following command:

```
echo "deb http://repo.mongodb.org/apt/ubuntu ${("lsb_release
-sc)}/ mongodb-org/3.0 multiverse" | sudo tee /etc/apt/sources.
list.d/mongodb-org-3.0.list
```

3. Update the local package database as `sudo`:

```
sudo apt-get update
```

4. Install the MongoDB packages. We install the latest stable version of MongoDB with the following command:

```
sudo apt-get install -y mongodb-org
```

## Running the MongoDB server

Let's start the MongoDB server:

1. To start MongoDB server, we issue the following command to start mongod:

```
sudo service mongodb start
```

2. To check whether mongod has started properly, we issue the command:

```
an@an-VB:/usr/bin$ ps -ef | grep mongo
mongodb    967      1  4 07:03 ?          00:02:02 /usr/bin/mongod
--config /etc/mongod.conf
an        3143  3085  0 07:45 pts/3      00:00:00 grep --color=auto
mongo
```

In this case, we see that mongodb is running in process 967.

3. The mongod server sends a message to the effect that it is waiting for connection on port 27017. This is the default port for MongoDB.

It can be changed in the configuration file.

4. We can check the contents of the log file at /var/log/mongod/mongod.log:

```
an@an-VB:/var/lib/mongodb$ ls -lru
total 81936
drwxr-xr-x 2 mongodb nogroup      4096 Apr 25 11:19 _tmp
-rw-r--r-- 1 mongodb nogroup       69 Apr 25 11:19 storage.bson
-rwxr-xr-x 1 mongodb nogroup        5 Apr 25 11:19 mongod.lock
-rw----- 1 mongodb nogroup 16777216 Apr 25 11:19 local.ns
-rw----- 1 mongodb nogroup 67108864 Apr 25 11:19 local.0
drwxr-xr-x 2 mongodb nogroup      4096 Apr 25 11:19 journal
```

5. In order to stop the mongodb server, just issue the following command:

```
sudo service mongodb stop
```

## Running the Mongo client

Running the Mongo client in the console is as easy as calling `mongo`, as highlighted in the following command:

```
an@an-VB:/usr/bin$ mongo
MongoDB shell version: 3.0.2
connecting to: test
Server has startup warnings:
2015-05-30T07:03:49.387+0200 I CONTROL  [initandlisten]
2015-05-30T07:03:49.388+0200 I CONTROL  [initandlisten]
```

At the mongo client console prompt, we can see the databases with the following commands:

```
> show dbs
local 0.078GB
test   0.078GB
```

We select the test database using `use test`:

```
> use test
switched to db test
```

We display the collections within the test database:

```
> show collections
restaurants
system.indexes
```

We check a sample record in the restaurant collection listed previously:

```
> db.restaurants.find()
{ "_id" : ObjectId("553b70055e82e7b824ae0e6f"), "address" : { "building" :
: "1007", "coord" : [ -73.856077, 40.848447 ], "street" : "Morris Park
Ave", "zipcode" : "10462" }, "borough" : "Bronx", "cuisine" : "Bakery",
"grades" : [ { "grade" : "A", "score" : 2, "date" : ISODate("2014-
03-03T00:00:00Z" ) }, { "date" : ISODate("2013-09-11T00:00:00Z"),
"grade" : "A", "score" : 6 }, { "score" : 10, "date" : ISODate("2013-
01-24T00:00:00Z" ), "grade" : "A" }, { "date" : ISODate("2011-11-
23T00:00:00Z" ), "grade" : "A", "score" : 9 }, { "date" : ISODate("2011-
03-10T00:00:00Z" ), "grade" : "B", "score" : 14 } ], "name" : "Morris
Park Bake Shop", "restaurant_id" : "30075445" }
```

## Installing the PyMongo driver

Installing the Python driver with anaconda is easy. Just run the following command at the terminal:

```
conda install pymongo
```

## Creating the Python client for MongoDB

We are creating a `IO_mongo` class that will be used in our harvesting and processing programs to store the data collected and retrieved saved information. In order to create the `mongo` client, we will import the `MongoClient` module from `pymongo`. We connect to the `mongodb` server on localhost at port 27017. The command is as follows:

```
from pymongo import MongoClient as MCli

class IO_mongo(object):
    conn={'host':'localhost', 'ip':'27017'}
```

We initialize our class with the client connection, the database (in this case, `twtr_db`), and the collection (in this case, `twtr_coll`) to be accessed:

```
def __init__(self, db='twtr_db', coll='twtr_coll', **conn):
    # Connects to the MongoDB server
    self.client = MCli(**conn)
    self.db = self.client[db]
    self.coll = self.db[coll]
```

The `save` method inserts new records in the preinitialized collection and database:

```
def save(self, data):
    # Insert to collection in db
    return self.coll.insert(data)
```

The `load` method allows the retrieval of specific records according to criteria and projection. In the case of large amount of data, it returns a cursor:

```
def load(self, return_cursor=False, criteria=None,
projection=None):

    if criteria is None:
        criteria = {}

    if projection is None:
        cursor = self.coll.find(criteria)
    else:
```

```
cursor = self.coll.find(criteria, projection)

# Return a cursor for large amounts of data
if return_cursor:
    return cursor
else:
    return [ item for item in cursor ]
```

## Harvesting data from Twitter

Each social network poses its limitations and challenges. One of the main obstacles for harvesting data is an imposed rate limit. While running repeated or long-running connections between rates limit pauses, we have to be careful to avoid collecting duplicate data.

We have redesigned our connection programs outlined in the previous chapter to take care of the rate limits.

In this `TwitterAPI` class that connects and collects the tweets according to the search query we specify, we have added the following:

- Logging capability using the Python logging library with the aim of collecting any errors or warning in the case of program failure
- Persistence capability using MongoDB, with the `IO_mongo` class exposed previously as well as JSON file using the `IO_json` class
- API rate limit and error management capability, so we can ensure more resilient calls to Twitter without getting barred for tapping into the firehose

Let's go through the steps:

1. We initialize by instantiating the Twitter API with our credentials:

```
class TwitterAPI(object):
    """
    TwitterAPI class allows the Connection to Twitter via OAuth
    once you have registered with Twitter and receive the
    necessary credentials
    """

    def __init__(self):
        consumer_key = 'get_your_credentials'
        consumer_secret = get_your_credentials()
        access_token = 'get_your_credentials'
```

```
access_secret = 'get your_credentials'
self.consumer_key = consumer_key
self.consumer_secret = consumer_secret
self.access_token = access_token
self.access_secret = access_secret
self.retries = 3
self.auth = twitter.oauth.OAuth(access_token, access_
secret, consumer_key, consumer_secret)
self.api = twitter.Twitter(auth=self.auth)
```

2. We initialize the logger by providing the log level:

- logger.debug(debug message)
- logger.info(info message)
- logger.warn(warn message)
- logger.error(error message)
- logger.critical(critical message)

3. We set the log path and the message format:

```
# logger initialisation
appName = 'twt150530'
self.logger = logging.getLogger(appName)
#self.logger.setLevel(logging.DEBUG)
# create console handler and set level to debug
logPath = '/home/an/spark/spark-1.3.0-bin-hadoop2.4/
examples/AN_Spark/data'
fileName = appName
fileHandler = logging.FileHandler("{0}/{1}.log".
format(logPath, fileName))
formatter = logging.Formatter('%(asctime)s - %(name)s - 
%(levelname)s - %(message)s')
fileHandler.setFormatter(formatter)
self.logger.addHandler(fileHandler)
self.logger.setLevel(logging.DEBUG)
```

4. We initialize the JSON file persistence instruction:

```
# Save to JSON file initialisation
jsonFpath = '/home/an/spark/spark-1.3.0-bin-hadoop2.4/
examples/AN_Spark/data'
jsonFname = 'twtr15053001'
self.jsonSaver = IO_json(jsonFpath, jsonFname)
```

5. We initialize the MongoDB database and collection for persistence:

```
# Save to MongoDB Intitialisation
self.mongoSaver = IO_mongo(db='twtr01_db', coll='twtr01_
coll')
```

6. The method `searchTwitter` launches the search according to the query specified:

```
def searchTwitter(self, q, max_res=10, **kwargs):
    search_results = self.api.search.tweets(q=q, count=10,
**kwargs)
    statuses = search_results['statuses']
    max_results = min(1000, max_res)

    for _ in range(10):
        try:
            next_results = search_results['search_metadata']
            ['next_results']
            # self.logger.info('info' in searchTwitter - next_
            results:%s'% next_results[1:])
            except KeyError as e:
                self.logger.error('error' in searchTwitter: %s',
%(e))
                break

            # next_results = urlparse.parse_qsl(next_results[1:])
# python 2.7
            next_results = urllib.parse.parse_qsl(next_
            results[1:])
            # self.logger.info('info' in searchTwitter - next_
            results[max_id]:', next_results[0:])
            kwargs = dict(next_results)
            # self.logger.info('info' in searchTwitter - next_
            results[max_id]:%s'% kwargs['max_id'])
            search_results = self.api.search.tweets(**kwargs)
            statuses += search_results['statuses']
            self.saveTweets(search_results['statuses'])

            if len(statuses) > max_results:
                self.logger.info('info' in searchTwitter - got %i
tweets - max: %i' %(len(statuses), max_results))
                break
        return statuses
```

7. The `saveTweets` method actually saves the collected tweets in JSON and in MongoDB:

```
def saveTweets(self, statuses):  
    # Saving to JSON File  
    self.jsonSaver.save(statuses)  
  
    # Saving to MongoDB  
    for s in statuses:  
        self.mongoSaver.save(s)
```

8. The `parseTweets` method allows us to extract the key tweet information from the vast amount of information provided by the Twitter API:

```
def parseTweets(self, statuses):  
    return [ (status['id'],  
              status['created_at'],  
              status['user']['id'],  
              status['user']['name'],  
              status['text'],  
              url['expanded_url'])  
            for status in statuses  
            for url in status['entities']['urls']]
```

9. The `getTweets` method calls the `searchTwitter` method described previously. The `getTweets` method ensures that API calls are made reliably whilst respecting the imposed rate limit. The code is as follows:

```
def getTweets(self, q, max_res=10):  
    """  
    Make a Twitter API call whilst managing rate limit and errors.  
    """  
    def handleError(e, wait_period=2, sleep_when_rate_limited=True):  
        if wait_period > 3600: # Seconds  
            self.logger.error('Too many retries in getTweets: %s', %(e))  
            raise e  
        if e.e.code == 401:  
            self.logger.error('error 401 * Not Authorised * in getTweets: %s', %(e))  
            return None  
        elif e.e.code == 404:  
            self.logger.error('error 404 * Not Found * in getTweets: %s', %(e))
```

```
        return None
    elif e.e.code == 429:
        self.logger.error('error 429 * API Rate Limit
Exceeded * in getTweets: %s', %(e))
        if sleep_when_rate_limited:
            self.logger.error('error 429 * Retrying in 15
minutes * in getTweets: %s', %(e))
            sys.stderr.flush()
            time.sleep(60*15 + 5)
            self.logger.info('error 429 * Retrying now *
in getTweets: %s', %(e))
        return 2
    else:
        raise e # Caller must handle the rate limiting
issue
    elif e.e.code in (500, 502, 503, 504):
        self.logger.info('Encountered %i Error. Retrying
in %i seconds' % (e.e.code, wait_period))
        time.sleep(wait_period)
        wait_period *= 1.5
        return wait_period
    else:
        self.logger.error('Exit - aborting - %s', %(e))
        raise e
```

10. Here, we are calling the `searchTwitter` API with the relevant query based on the parameters specified. If we encounter any error such as rate limitation from the provider, this will be processed by the `handleError` method:

```
while True:
    try:
        self.searchTwitter( q, max_res=10)
    except twitter.api.TwitterHTTPError as e:
        error_count = 0
        wait_period = handleError(e, wait_period)
        if wait_period is None:
            return
```

## Exploring data using Blaze

Blaze is an open source Python library, primarily developed by Continuum.io, leveraging Python Numpy arrays and Pandas dataframe. Blaze extends to out-of-core computing, while Pandas and Numpy are single-core.

Blaze offers an adaptable, unified, and consistent user interface across various backends. Blaze orchestrates the following:

- **Data:** Seamless exchange of data across storages such as CSV, JSON, HDF5, HDFS, and Bcolz files.
- **Computation:** Using the same query processing against computational backends such as Spark, MongoDB, Pandas, or SQL Alchemy.
- **Symbolic expressions:** Abstract expressions such as join, group-by, filter, selection, and projection with a syntax similar to Pandas but limited in scope. Implements the split-apply-combine methods pioneered by the R language.

Blaze expressions are lazily evaluated and in that respect share a similar processing paradigm with Spark RDDs transformations.

Let's dive into Blaze by first importing the necessary libraries: `numpy`, `pandas`, `blaze` and `odo`. `Odo` is a spin-off of Blaze and ensures data migration from various backends. The commands are as follows:

```
import numpy as np
import pandas as pd
from blaze import Data, by, join, merge
from odo import odo
BokehJS successfully loaded.
```

We create a Pandas Dataframe by reading the parsed tweets saved in a CSV file, `twts_csv`:

```
twts_pd_df = pd.DataFrame(twts_csv_read, columns=Tweet01._fields)
twts_pd_df.head()

Out[65]:
id      created_at    user_id    user_name    tweet_text    url
1  59883111406510082  2015-05-14 12:43:57  14755521
    raulsaeztapia    RT @pacoid: Great recap of @StrataConf EU in L...
    http://www.mango-solutions.com/wp/2015/05/the-...
2  59883111406510082  2015-05-14 12:43:57  14755521
    raulsaeztapia    RT @pacoid: Great recap of @StrataConf EU in L...
    http://www.mango-solutions.com/wp/2015/05/the-...
3  98808944719593472  2015-05-14 11:15:52  14755521
    raulsaeztapia    RT @alvaroagea: Simply @ApacheSpark http://t.c...
    http://www.webex.com/ciscospark/
4  598808944719593472  2015-05-14 11:15:52  14755521
    raulsaeztapia    RT @alvaroagea: Simply @ApacheSpark http://t.c...
    http://sparkjava.com/
```

We run the Tweets Panda Dataframe to the `describe()` function to get some overall information on the dataset:

```
twts_pd_df.describe()
Out[66]:
   id    created_at     user_id     user_name    tweet_text      url
count  19    19    19    19    19    19
unique     7     7     6     6     6     7
top      598808944719593472  2015-05-14 11:15:52  14755521
          raulsaeztapia  RT @alvaroagea: Simply @ApacheSpark http://t.c...
          http://bit.ly/1Hfd0Xm
freq      6     6     9     9     6     6
```

We convert the Pandas dataframe into a Blaze dataframe by simply passing it through the `Data()` function:

```
# 
# Blaze dataframe
#
twts_bz_df = Data(twts_pd_df)
```

We can retrieve the schema representation of the Blaze dataframe by passing the `schema` function:

```
twts_bz_df.schema
Out[73]:
dshape("""
  id: ?string,
  created_at: ?string,
  user_id: ?string,
  user_name: ?string,
  tweet_text: ?string,
  url: ?string
  """")
```

The `.dshape` function gives a record count and the schema:

```
twts_bz_df.dshape
Out[74]:
dshape("19 * {
  id: ?string,
  created_at: ?string,
  user_id: ?string,
  user_name: ?string,
  tweet_text: ?string,
  url: ?string
  }")
```

We can print the Blaze dataframe content:

```
twts_bz_df.data
Out[75]:
id      created_at    user_id    user_name    tweet_text    url
1      59883111406510082    2015-05-14 12:43:57    14755521
      raulsaeztapia    RT @pacoid: Great recap of @StrataConf EU in L...
      http://www.mango-solutions.com/wp/2015/05/the-...
2      59883111406510082    2015-05-14 12:43:57    14755521
      raulsaeztapia    RT @pacoid: Great recap of @StrataConf EU in L...
      http://www.mango-solutions.com/wp/2015/05/the-...
...
18     598782970082807808    2015-05-14 09:32:39    1377652806
      embeddedcomputer.nl    RT @BigDataTechCon: Moving Rating
      Prediction w...    http://buff.ly/1QBpk8J
19     598777933730160640    2015-05-14 09:12:38    294862170    Ellen
      Friedman    I'm still on Euro time. If you are too check o...
      http://bit.ly/1Hfd0Xm
```

We extract the column `tweet_text` and take the unique values:

```
twts_bz_df.tweet_text.distinct()
Out[76]:
tweet_text
0  RT @pacoid: Great recap of @StrataConf EU in L...
1  RT @alvaroagea: Simply @ApacheSpark http://t.c...
2  RT @PrabhaGana: What exactly is @ApacheSpark a...
3  RT @Ellen_Friedman: I'm still on Euro time. If...
4  RT @BigDataTechCon: Moving Rating Prediction w...
5  I'm still on Euro time. If you are too check o...
```

We extract multiple columns `['id', 'user_name', 'tweet_text']` from the dataframe and take the unique records:

```
twts_bz_df[['id', 'user_name', 'tweet_text']].distinct()
Out[78]:
id      user_name    tweet_text
0      59883111406510082    raulsaeztapia    RT @pacoid: Great recap of @
      StrataConf EU in L...
1      598808944719593472    raulsaeztapia    RT @alvaroagea: Simply @
      ApacheSpark http://t.c...
2      598796205091500032    John Humphreys    RT @PrabhaGana: What exactly
      is @ApacheSpark a...
3      598788561127735296    Leonardo D'Ambrosi    RT @Ellen_Friedman: I'm
      still on Euro time. If...
4      598785545557438464    Alexey Kosenkov    RT @Ellen_Friedman: I'm
      still on Euro time. If...
```

```
5 598782970082807808 embeddedcomputer.nl RT @BigDataTechCon:  
Moving Rating Prediction w...  
6 598777933730160640 Ellen Friedman I'm still on Euro time. If  
you are too check o...
```

## Transferring data using Odo

Odo is a spin-off project of Blaze. Odo allows the interchange of data. Odo ensures the migration of data across different formats (CSV, JSON, HDFS, and more) and across different databases (SQL databases, MongoDB, and so on) using a very simple predicate:

```
Odo(source, target)
```

To transfer to a database, the address is specified using a URL. For example, for a MongoDB database, it would look like this:

```
mongodb://username:password@hostname:port/database_name::collection_  
name
```

Let's run some examples of using Odo. Here, we illustrate odo by reading a CSV file and creating a Blaze dataframe:

```
filepath = csvFpath  
filename = csvFname  
filesuffix = csvSuffix  
twts_odo_df = Data('{0}/{1}.{2}'.format(filepath, filename,  
filesuffix))
```

Count the number of records in the dataframe:

```
twts_odo_df.count()  
Out[81]:  
19
```

Display the five initial records of the dataframe:

```
twts_odo_df.head(5)  
Out[82]:  
   id created_at user_id user_name tweet_text url  
0 59883111406510082 2015-05-14 12:43:57 14755521  
raulsaeztapia RT @pacoid: Great recap of @StrataConf EU in L...  
http://www.mango-solutions.com/wp/2015/05/the-...  
1 59883111406510082 2015-05-14 12:43:57 14755521  
raulsaeztapia RT @pacoid: Great recap of @StrataConf EU in L...  
http://www.mango-solutions.com/wp/2015/05/the-...  
2 598808944719593472 2015-05-14 11:15:52 14755521  
raulsaeztapia RT @alvaroagea: Simply @ApacheSpark http://t.c...
```

```
http://www.webex.com/ciscospark/
3 598808944719593472 2015-05-14 11:15:52 14755521
raulsaeztapia RT @alvaroagea: Simply @ApacheSpark http://t.c...
http://sparkjava.com/
4 598808944719593472 2015-05-14 11:15:52 14755521
raulsaeztapia RT @alvaroagea: Simply @ApacheSpark http://t.c...
https://www.sparkfun.com/
```

Get dshape information from the dataframe, which gives us the number of records and the schema:

```
twts_odo_df.dshape
Out[83]:
dshape("var * {
    id: int64,
    created_at: ?datetime,
    user_id: int64,
    user_name: ?string,
    tweet_text: ?string,
    url: ?string
} "")")
```

Save a processed Blaze dataframe into JSON:

```
odo(twts_odo_distinct_df, '{0}/{1}.{2}'.format(jsonPath, jsonFname,
jsonSuffix))
Out[92]:
<odo.backends.json.JSONLines at 0x7f77f0abfc50>
```

Convert a JSON file to a CSV file:

```
odo('{0}/{1}.{2}'.format(jsonPath, jsonFname, jsonSuffix), '{0}/{1}.
{2}'.format(csvPath, csvFname, csvSuffix))
Out[94]:
<odo.backends.csv.CSV at 0x7f77f0abfe10>
```

## Exploring data using Spark SQL

Spark SQL is a relational query engine built on top of Spark Core. Spark SQL uses a query optimizer called **Catalyst**.

Relational queries can be expressed using SQL or HiveQL and executed against JSON, CSV, and various databases. Spark SQL gives us the full expressiveness of declarative programming with Spark dataframes on top of functional programming with RDDs.

## Understanding Spark dataframes

Here's a tweet from @bigdata announcing Spark 1.3.0, the advent of Spark SQL and dataframes. It also highlights the various data sources in the lower part of the diagram. On the top part, we can notice R as the new language that will be gradually supported on top of Scala, Java, and Python. Ultimately, the Data Frame philosophy is pervasive between R, Python, and Spark.

**Big Data** Ben Lorica  
@bigdata

@matei\_zaharia & team have done such a great job fostering an active Apache Spark ecosystem/community #sparksummit

Scala Java python R

DataFrames ML Pipelines

Spark Core

Total contributors: 150 → 500  
Lines of code: 190K → 370K  
500+ active production deployments

RETWEETS 16 FAVOURITES 11

6:18 am - 18 Mar 2015

Spark dataframes originate from SchemaRDDs. It combines RDD with a schema that can be inferred by Spark, if requested, when registering the dataframe. It allows us to query complex nested JSON data with plain SQL. Lazy evaluation, lineage, partitioning, and persistence apply to dataframes.

Let's query the data with Spark SQL, by first importing `SparkContext` and `SQLContext`:

```
from pyspark import SparkConf, SparkContext
from pyspark.sql import SQLContext, Row
In [95]:
sc
Out[95]:
<pyspark.context.SparkContext at 0x7f7829581890>
In [96]:
sc.master
Out[96]:
u'local[*]'
''In [98]:
# Instantiate Spark SQL context
sqlc = SQLContext(sc)
```

We read in the JSON file we saved with Odo:

```
twts_sql_df_01 = sqlc.jsonFile ("/home/an/spark/spark-1.3.0-bin-
hadoop2.4/examples/AN_Spark/data/twtr15051401_distinct.json")
In [101]:
twts_sql_df_01.show()
+-----+-----+-----+
| created_at | id | tweet_text | user_id |
+-----+-----+-----+
| 2015-05-14T12:43:57Z | 598831111406510082 | RT @pacoid: Great... | 14755521 |
| raulsaeztapia |
| 2015-05-14T11:15:52Z | 598808944719593472 | RT @alvaroagea: S... | 14755521 |
| raulsaeztapia |
| 2015-05-14T10:25:15Z | 598796205091500032 | RT @PrabhaGana: W... | 48695135 |
| John Humphreys |
| 2015-05-14T09:54:52Z | 598788561127735296 | RT @Ellen_Friedma... |
| 2385931712 Leonardo D'Ambrosi |
| 2015-05-14T09:42:53Z | 598785545557438464 | RT @Ellen_Friedma... | 461020977 |
| Alexey Kosenkov |
| 2015-05-14T09:32:39Z | 598782970082807808 | RT @BigDataTechCo... |
| 1377652806 embeddedcomputer.nl |
| 2015-05-14T09:12:38Z | 598777933730160640 | I'm still on Euro... | 294862170 |
| Ellen Friedman |
```

We print the schema of the Spark dataframe:

```
twts_sql_df_01.printSchema()
root
 |-- created_at: string (nullable = true)
 |-- id: long (nullable = true)
```

```
|-- tweet_text: string (nullable = true)
|-- user_id: long (nullable = true)
|-- user_name: string (nullable = true)
```

We select the `user_name` column from the dataframe:

```
twts_sql_df_01.select('user_name').show()
user_name
raulsaeztapia
raulsaeztapia
John Humphreys
Leonardo D'Ambrosi
Alexey Kosenkov
embeddedcomputer.nl
Ellen Friedman
```

We register the dataframe as a table, so we can execute a SQL query on it:

```
twts_sql_df_01.registerAsTable('tweets_01')
```

We execute a SQL statement against the dataframe:

```
twts_sql_df_01_selection = sqlc.sql("SELECT * FROM tweets_01 WHERE
user_name = 'raulsaeztapia'")
In [109]:
twts_sql_df_01_selection.show()
created_at           id           tweet_text          user_id
user_name
2015-05-14T12:43:57Z 598831111406510082 RT @pacoid: Great... 14755521
raulsaeztapia
2015-05-14T11:15:52Z 598808944719593472 RT @alvaroagea: S... 14755521
raulsaeztapia
```

Let's process some more complex JSON; we read the original Twitter JSON file:

```
tweets_sqlc_inf = sqlc.jsonFile(infile)
```

Spark SQL is able to infer the schema of a complex nested JSON file:

```
tweets_sqlc_inf.printSchema()
root
|-- contributors: string (nullable = true)
|-- coordinates: string (nullable = true)
|-- created_at: string (nullable = true)
|-- entities: struct (nullable = true)
|   |-- hashtags: array (nullable = true)
|   |   |-- element: struct (containsNull = true)
```

```
|      |      |      |-- indices: array (nullable = true)
|      |      |      |      |-- element: long (containsNull = true)
|      |      |      |      |-- text: string (nullable = true)
|      |      |-- media: array (nullable = true)
|      |      |      |-- element: struct (containsNull = true)
|      |      |      |      |-- display_url: string (nullable = true)
|      |      |      |      |-- expanded_url: string (nullable = true)
|      |      |      |      |-- id: long (nullable = true)
|      |      |      |      |-- id_str: string (nullable = true)
|      |      |      |      |-- indices: array (nullable = true)
...
... (snip) ...
|      |-- statuses_count: long (nullable = true)
|      |-- time_zone: string (nullable = true)
|      |-- url: string (nullable = true)
|      |-- utc_offset: long (nullable = true)
|      |-- verified: boolean (nullable = true)
```

We extract the key information of interest from the wall of data by selecting specific columns in the dataframe (in this case, ['created\_at', 'id', 'text', 'user.id', 'user.name', 'entities.urls.expanded\_url']):

```
tweets_extract_sqlc = tweets_sqlc_inf[['created_at', 'id', 'text',
'user.id', 'user.name', 'entities.urls.expanded_url']].distinct()
In [145]:
tweets_extract_sqlc.show()
+-----+-----+-----+
| created_at | id | text |
|-----+-----+-----+
| Thu May 14 09:32:... | 598782970082807808 | RT @BigDataTechCo...
| 1377652806 | embeddedcomputer.nl | ArrayBuffer(http:...)
| Thu May 14 12:43:... | 59883111406510082 | RT @pacoid: Great... 14755521
| raulsaeztapia | | ArrayBuffer(http:...)
| Thu May 14 12:18:... | 598824733086523393 | @rabbitonweb spea...
| ...
| Thu May 14 12:28:... | 598827171168264192 | RT @baandrzejczak... 20909005
| Paweł Szulc | | ArrayBuffer()
```

## Understanding the Spark SQL query optimizer

We execute a SQL statement against the dataframe:

```
tweets_extract_sqlc_sel = sqlc.sql("SELECT * from Tweets_xtr_001 WHERE
name='raulsaeztapia'")
```

We get a detailed view of the query plans executed by Spark SQL:

- Parsed logical plan
- Analyzed logical plan
- Optimized logical plan
- Physical plan

The query plan uses Spark SQL's Catalyst optimizer. In order to generate the compiled bytecode from the query parts, the Catalyst optimizer runs through logical plan parsing and optimization followed by physical plan evaluation and optimization based on cost.

This is illustrated in the following tweet:

**Big Data** Ben Lorica [@bigdata](#)

Must-read, new [@databricks](#) post on the internals of Apache Spark SQL's Catalyst optimizer [goo.gl/dpmrvU](http://goo.gl/dpmrvU)

```

graph LR
    SQ[SQL Query] --> ULP[Unresolved Logical Plan]
    DF[DataFrame] --> ULP
    Catalog[Catalog] --> ULP
    ULP -- Analysis --> LP[Logical Plan]
    LP -- Logical Optimization --> OLP[Optimized Logical Plan]
    OLP -- Physical Planning --> PP[Physical Plans]
    CostModel[Cost Model] --> PP
    PP -- Code Generation --> SPP[Selected Physical Plan]
    SPP --> RDDs[RDDs]
  
```

RETWEETS 8 LIKES 12

7:52 a.m. - 13 Apr 2015

Looking back at our code, we call the `.explain` function on the Spark SQL query we just executed, and it delivers the full details of the steps taken by the Catalyst optimizer in order to assess and optimize the logical plan and the physical plan and get to the result RDD:

```
tweets_extract_sqlc_sel.explain(extended = True)
== Parsed Logical Plan ==
'Project [*]
  'Filter ('name = raulsaeztapia)'name' 'UnresolvedRelation' [Tweets_xtr_001], None
== Analyzed Logical Plan ==
Project [created_at#7,id#12L,text#27,id#80L,name#81,expanded_url#82]
  Filter (name#81 = raulsaeztapia)
  Distinct
    Project [created_at#7,id#12L,text#27,user#29.id AS id#80L,user#29.
      name AS name#81,entities#8.urls.expanded_url AS expanded_url#82]
      Relation[contributors#5,coordinates#6,created_
        at#7,entities#8,favorite_count#9L,favorited#10,geo#11,id#12L,id_
        str#13,in_reply_to_screen_name#14,in_reply_to_status_id#15,in_reply_
        to_status_id_str#16,in_reply_to_user_id#17L,in_reply_to_user_id_str#
        18,lang#19,metadata#20,place#21,possibly_sensitive#22,retweet_count#2
        3L,retweeted#24,retweeted_status#25,source#26,text#27,truncated#28,us
        er#29] JSONRelation(/home/an/spark/spark-1.3.0-bin-hadoop2.4/examples/
      AN_Spark/data/twtr15051401.json,1.0,None)
== Optimized Logical Plan ==
  Filter (name#81 = raulsaeztapia)
  Distinct
    Project [created_at#7,id#12L,text#27,user#29.id AS id#80L,user#29.
      name AS name#81,entities#8.urls.expanded_url AS expanded_url#82]
      Relation[contributors#5,coordinates#6,created_
        at#7,entities#8,favorite_count#9L,favorited#10,geo#11,id#12L,id_
        str#13,in_reply_to_screen_name#14,in_reply_to_status_id#15,in_reply_
        to_status_id_str#16,in_reply_to_user_id#17L,in_reply_to_user_id_str#
        18,lang#19,metadata#20,place#21,possibly_sensitive#22,retweet_count#2
        3L,retweeted#24,retweeted_status#25,source#26,text#27,truncated#28,us
        er#29] JSONRelation(/home/an/spark/spark-1.3.0-bin-hadoop2.4/examples/
      AN_Spark/data/twtr15051401.json,1.0,None)
== Physical Plan ==
  Filter (name#81 = raulsaeztapia)
  Distinct false
    Exchange (HashPartitioning [created_at#7,id#12L,text#27,id#80L,name#
      81,expanded_url#82], 200)
    Distinct true
      Project [created_at#7,id#12L,text#27,user#29.id AS id#80L,user#29.
        name AS name#81,entities#8.urls.expanded_url AS expanded_url#82]
        PhysicalRDD [contributors#5,coordinates#6,created_
          at#7,entities#8,favorite_count#9L,favorited#10,geo#11,id#12L,id_
```

```
str#13,in_reply_to_screen_name#14,in_reply_to_status_id#15,in_reply_
to_status_id_str#16,in_reply_to_user_id#17L,in_reply_to_user_id_str#
18,lang#19,metadata#20,place#21,possibly_sensitive#22,retweet_count#2
3L,retweeted#24,retweeted_status#25,source#26,text#27,truncated#28,us
er#29], MapPartitionsRDD[165] at map at JsonRDD.scala:41
Code Generation: false
== RDD ==
```

Finally, here's the result of the query:

```
tweets_extract_sqlc_sel.show()
+-----+-----+-----+
| created_at | id | name | expanded_url |
+-----+-----+-----+
| Thu May 14 12:43:... | 59883111406510082 | RT @pacoid: Great... | 14755521 |
| raulsaeztapia | ArrayBuffer(http:...) |
| Thu May 14 11:15:... | 598808944719593472 | RT @alvaroagea: S... | 14755521 |
| raulsaeztapia | ArrayBuffer(http:...) |
In [148]:
```

## Loading and processing CSV files with Spark SQL

We will use the Spark package `spark-csv_2.11:1.2.0`. The command to be used to launch PySpark with the IPython Notebook and the `spark-csv` package should explicitly state the `-packages` argument:

```
$ IPYTHON_OPTS='notebook' /home/an/spark/spark-1.5.0-bin-hadoop2.6/bin/
pyspark --packages com.databricks:spark-csv_2.11:1.2.0
```

This will trigger the following output; we can see that the `spark-csv` package is installed with all its dependencies:

```
an@an-VB:~/spark/spark-1.5.0-bin-hadoop2.6/examples/AN_Spark$ IPYTHON_
OPTS='notebook' /home/an/spark/spark-1.5.0-bin-hadoop2.6/bin/pyspark
--packages com.databricks:spark-csv_2.11:1.2.0

... (snip) ...
Ivy Default Cache set to: /home/an/.ivy2/cache
The jars for the packages stored in: /home/an/.ivy2/jars
:: loading settings :: url = jar:file:/home/an/spark/spark-1.5.0-bin-
hadoop2.6/lib/spark-assembly-1.5.0-hadoop2.6.0.0.jar!/org/apache/ivy/
core/settings/ivysettings.xml
com.databricks#spark-csv_2.11 added as a dependency
:: resolving dependencies :: org.apache.spark#spark-submit-parent;1.0
  confs: [default]
  found com.databricks#spark-csv_2.11;1.2.0 in central
  found org.apache.commons#commons-csv;1.1 in central
```

```
found com.univocity#univocity-parsers;1.5.1 in central
:: resolution report :: resolve 835ms :: artifacts dl 48ms
:: modules in use:
com.databricks#spark-csv_2.11;1.2.0 from central in [default]
com.univocity#univocity-parsers;1.5.1 from central in [default]
org.apache.commons#commons-csv;1.1 from central in [default]
-----
|           |           modules      ||   artifacts   |
| conf     | number | search|dwnlded|evicted|| number|dwnlded|
-----|-----|-----|-----|-----|-----|-----|-----|-----|
| default  |    3   |    0   |    0   |    0   ||    3   |    0   |
-----|-----|-----|-----|-----|-----|-----|-----|-----|
:: retrieving :: org.apache.spark#spark-submit-parent
confs: [default]
0 artifacts copied, 3 already retrieved (0kB/45ms)
```

We are now ready to load our csv file and process it. Let's first import the SQLContext:

```
# 
# Read csv in a Spark DF
#
sqlContext = SQLContext(sc)
spdf_in = sqlContext.read.format('com.databricks.spark.csv')\
                    .options(delimiter=";")\
                    .options(header="true")\
                    .options(header='true').load(csv_
in)
```

We access the schema of the dataframe created from the loaded csv:

```
In [10]:
spdf_in.printSchema()
root
 |-- : string (nullable = true)
 |-- id: string (nullable = true)
 |-- created_at: string (nullable = true)
 |-- user_id: string (nullable = true)
 |-- user_name: string (nullable = true)
 |-- tweet_text: string (nullable = true)
```

We check the columns of the dataframe:

```
In [12]:
spdf_in.columns
Out[12]:
['', 'id', 'created_at', 'user_id', 'user_name', 'tweet_text']
```

We introspect the dataframe content:

```
In [13]:
spdf_in.show()
+-----+-----+-----+
| name |          id | created_at | user_id | user_
+-----+-----+-----+
| 0 | 638830426971181057 | Tue Sep 01 21:46:... | 3276255125 | True
Equality|ernestsgantt: Bey... |
| 1 | 638830426727911424 | Tue Sep 01 21:46:... | 3276255125 | True
Equality|ernestsgantt: Bey... |
| 2 | 638830425402556417 | Tue Sep 01 21:46:... | 3276255125 | True
Equality|ernestsgantt: Bey... |
... (snip) ...
| 41 | 638830280988426250 | Tue Sep 01 21:46:... | 951081582 | Jack
Baldwin|RT @cloudaus: We ... |
| 42 | 638830276626399232 | Tue Sep 01 21:46:... | 6525302 | Masayoshi
Nakamura|PynamoDB |
+-----+-----+-----+
-----+
only showing top 20 rows
```

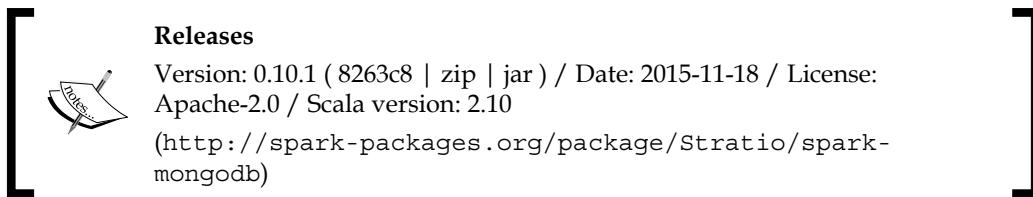
## Querying MongoDB from Spark SQL

There are two major ways to interact with MongoDB from Spark: the first is through the Hadoop MongoDB connector, and the second one is directly from Spark to MongoDB.

The first approach to interact with MongoDB from Spark is to set up a Hadoop environment and query through the Hadoop MongoDB connector. The connector details are hosted on GitHub at <https://github.com/mongodb/mongo-hadoop/wiki/Spark-Usage>. An actual use case is described in the series of blog posts from MongoDB:

- *Using MongoDB with Hadoop & Spark: Part 1 - Introduction & Setup* (<https://www.mongodb.com/blog/post/using-mongodb-hadoop-spark-part-1-introduction-setup>)
- *Using MongoDB with Hadoop and Spark: Part 2 - Hive Example* (<https://www.mongodb.com/blog/post/using-mongodb-hadoop-spark-part-2-hive-example>)
- *Using MongoDB with Hadoop & Spark: Part 3 - Spark Example & Key Takeaways* (<https://www.mongodb.com/blog/post/using-mongodb-hadoop-spark-part-3-spark-example-key-takeaways>)

Setting up a full Hadoop environment is bit elaborate. We will favor the second approach. We will use the spark-mongodb connector developed and maintained by Stratio. We are using the Stratio spark-mongodb package hosted at spark.packages.org. The packages information and version can be found in spark.packages.org:



The command to launch PySpark with the IPython Notebook and the spark-mongodb package should explicitly state the packages argument:

```
$ IPYTHON_OPTS='notebook' /home/an/spark/spark-1.5.0-bin-hadoop2.6/bin/pyspark --packages com.stratio.datasource:spark-mongodb_2.10:0.10.1
```

This will trigger the following output; we can see that the spark-mongodb package is installed with all its dependencies:

```
an@an-VB:~/spark/spark-1.5.0-bin-hadoop2.6/examples/AN_Spark$ IPYTHON_OPTS='notebook' /home/an/spark/spark-1.5.0-bin-hadoop2.6/bin/pyspark --packages com.stratio.datasource:spark-mongodb_2.10:0.10.1
... (snip) ...
Ivy Default Cache set to: /home/an/.ivy2/cache
The jars for the packages stored in: /home/an/.ivy2/jars
:: loading settings :: url = jar:file:/home/an/spark/spark-1.5.0-bin-hadoop2.6/lib/spark-assembly-1.5.0-hadoop2.6.0.0.jar!/org/apache/ivy/core/settings/ivysettings.xml
com.stratio.datasource#spark-mongodb_2.10 added as a dependency
:: resolving dependencies :: org.apache.spark#spark-submit-parent;1.0
  confs: [default]
    found com.stratio.datasource#spark-mongodb_2.10;0.10.1 in central
[W 22:10:50.910 NotebookApp] Timeout waiting for kernel_info reply
from 764081d3-baf9-4978-ad89-7735e6323cb6
    found org.mongodb#casbah-commons_2.10;2.8.0 in central
    found com.github.nscala-time#nscala-time_2.10;1.0.0 in central
    found joda-time#joda-time;2.3 in central
    found org.joda#joda-convert;1.2 in central
    found org.slf4j#slf4j-api;1.6.0 in central
    found org.mongodb#mongo-java-driver;2.13.0 in central
    found org.mongodb#casbah-query_2.10;2.8.0 in central
    found org.mongodb#casbah-core_2.10;2.8.0 in central
downloading https://repo1.maven.org/maven2/com/stratio/datasource/spark-mongodb_2.10/0.10.1/spark-mongodb_2.10-0.10.1.jar ...
```

```
[SUCCESSFUL ] com.stratio.datasource#spark-
mongodb_2.10;0.10.1!spark-mongodb_2.10.jar (3130ms)
downloading https://repo1.maven.org/maven2/org/mongodb/casbah-
commons_2.10/2.8.0/casbah-commons_2.10-2.8.0.jar ...
[SUCCESSFUL ] org.mongodb#casbah-commons_2.10;2.8.0!casbah-
commons_2.10.jar (2812ms)
downloading https://repo1.maven.org/maven2/org/mongodb/casbah-
query_2.10/2.8.0/casbah-query_2.10-2.8.0.jar ...
[SUCCESSFUL ] org.mongodb#casbah-query_2.10;2.8.0!casbah-query_2.10.
jar (1432ms)
downloading https://repo1.maven.org/maven2/org/mongodb/casbah-
core_2.10/2.8.0/casbah-core_2.10-2.8.0.jar ...
[SUCCESSFUL ] org.mongodb#casbah-core_2.10;2.8.0!casbah-core_2.10.
jar (2785ms)
downloading https://repo1.maven.org/maven2/com/github/nscala-time/
nscala-time_2.10/1.0.0/nscala-time_2.10-1.0.0.jar ...
[SUCCESSFUL ] com.github.nscala-time#nscala-time_2.10;1.0.0!nscala-
time_2.10.jar (2725ms)
downloading https://repo1.maven.org/maven2/org/slf4j/slf4j-api/1.6.0/
slf4j-api-1.6.0.jar ...
[SUCCESSFUL ] org.slf4j#slf4j-api;1.6.0!slf4j-api.jar (371ms)
downloading https://repo1.maven.org/maven2/org/mongodb/mongo-java-
driver/2.13.0/mongo-java-driver-2.13.0.jar ...
[SUCCESSFUL ] org.mongodb#mongo-java-driver;2.13.0!mongo-java-
driver.jar (5259ms)
downloading https://repo1.maven.org/maven2/joda-time/joda-time/2.3/
joda-time-2.3.jar ...
[SUCCESSFUL ] joda-time#joda-time;2.3!joda-time.jar (6949ms)
downloading https://repo1.maven.org/maven2/org/joda/joda-convert/1.2/
joda-convert-1.2.jar ...
[SUCCESSFUL ] org.joda#joda-convert;1.2!joda-convert.jar (548ms)
:: resolution report :: resolve 11850ms :: artifacts dl 26075ms
:: modules in use:
com.github.nscala-time#nscala-time_2.10;1.0.0 from central in
[default]
com.stratio.datasource#spark-mongodb_2.10;0.10.1 from central in
[default]
joda-time#joda-time;2.3 from central in [default]
org.joda#joda-convert;1.2 from central in [default]
org.mongodb#casbah-commons_2.10;2.8.0 from central in [default]
org.mongodb#casbah-core_2.10;2.8.0 from central in [default]
org.mongodb#casbah-query_2.10;2.8.0 from central in [default]
org.mongodb#mongo-java-driver;2.13.0 from central in [default]
org.slf4j#slf4j-api;1.6.0 from central in [default]
-----
--
```

```
|           |           |           modules           ||   artifacts
|           |           |           number| search|dwnlded|evicted|||
number|dwnlded|
```

---

```
--|       default    |   9   |   9   |   9   |   0   ||   9   |   9
```

---

```
-- :: retrieving :: org.apache.spark#spark-submit-parent
  confs: [default]
  9 artifacts copied, 0 already retrieved (2335kB/51ms)
... (snip) ...
```

We are now ready to query MongoDB on localhost:27017 from the collection twtr01\_coll in the database twtr01\_db.

We first import the SQLContext:

```
In [5]:
from pyspark.sql import SQLContext
sqlContext.sql("CREATE TEMPORARY TABLE tweet_table USING com.stratio.
datasource.mongodb OPTIONS (host 'localhost:27017', database 'twtr01_
db', collection 'twtr01_coll')")
sqlContext.sql("SELECT * FROM tweet_table where id=598830778269769728
").collect()
```

Here's the output of our query:

```
Out[5]:
[Row(text=u'@spark_io is now @particle - awesome news - now I can
enjoy my Particle Cores/Photons + @sparkfun sensors + @ApacheSpark
analytics :-)', _id=u'55aa640fd770871cba74cb88', contributors=None,
retweeted=False, user=Row(contributors_enabled=False, created_at=u'Mon
Aug 25 14:01:26 +0000 2008', default_profile=True, default_profile_
image=False, description=u'Building open source tools for and teaching
enterprise software developers', entities=Row(description=Row(ur
ls=[]), url=Row(urls=[Row(url=u'http://t.co/TShp13EWeu', indices=[0,
22],
... (snip) ...
```

```
9], name=u'Spark is Particle', screen_name=u'spark_io'),  
Row(id=487010011, id_str=u'487010011', indices=[17, 26],  
name=u'Particle', screen_name=u'particle'), Row(id=17877351,  
id_str=u'17877351', indices=[88, 97], name=u'SparkFun  
Electronics', screen_name=u'sparkfun'), Row(id=1551361069, id_  
str=u'1551361069', indices=[108, 120], name=u'Apache Spark', screen_  
name=u'ApacheSpark'))], is_quote_status=None, lang=u'en', quoted_  
status_id=None, quoted_status_id=None, created_at=u'Thu May  
14 12:42:37 +0000 2015', retweeted_status=None, truncated=False,  
place=None, id=598830778269769728, in_reply_to_user_id=3187046084,  
retweet_count=0, in_reply_to_status_id=None, in_reply_to_screen_  
name=u'spark_io', in_reply_to_user_id_str=u'3187046084', source=u'<a  
href="http://twitter.com" rel="nofollow">Twitter Web Client</a>',  
id_str=u'598830778269769728', coordinates=None, metadata=Row(iso_  
language_code=u'en', result_type=u'recent'), quoted_status=None)]  
#
```

## Summary

In this chapter, we harvested data from Twitter. Once the data was acquired, we explored the information using Continuum.io's Blaze and Odo libraries. Spark SQL is an important module for interactive data exploration, analysis, and transformation, leveraging the Spark dataframe datastructure. The dataframe concept originates from R and then was adopted by Python Pandas with great success. The dataframe is the workhorse of the data scientist. The combination of Spark SQL and dataframe creates a powerful engine for data processing.

We are now gearing up for extracting the insights from the datasets using machine learning from Spark MLlib.



# 4

## Learning from Data Using Spark

As we have laid the foundation for data to be harvested in the previous chapter, we are now ready to learn from the data. Machine learning is about drawing insights from data. Our objective is to give an overview of the Spark **Mlib** (short for **Machine Learning library**) and apply the appropriate algorithms to our dataset in order to derive insights. From the Twitter dataset, we will be applying an unsupervised clustering algorithm in order to distinguish between Apache Spark-relevant tweets versus the rest. We have as initial input a mixed bag of tweets. We first need to preprocess the data in order to extract the relevant features, then apply the machine learning algorithm to our dataset, and finally evaluate the results and the performance of our model.

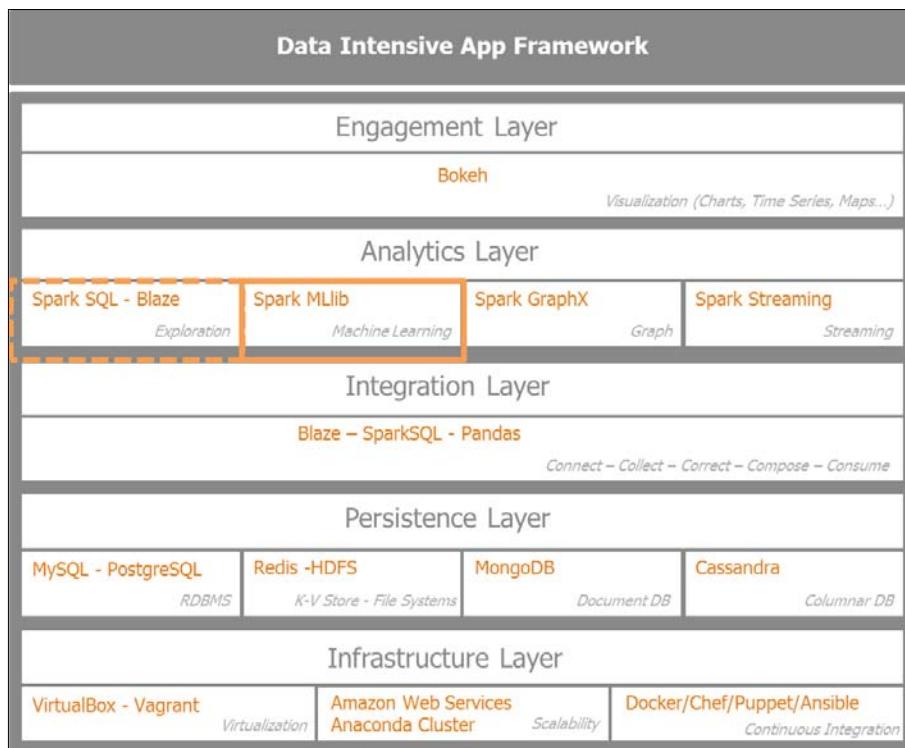
In this chapter, we will cover the following points:

- Providing an overview of the Spark Mlib module with its algorithms and the typical machine learning workflow.
- Preprocessing the Twitter harvested dataset to extract the relevant features, applying an unsupervised clustering algorithm to identify *Apache Spark*-relevant tweets. Then, evaluating the model and the results obtained.
- Describing the Spark machine learning pipeline.

## Contextualizing Spark MLlib in the app architecture

Let's first contextualize the focus of this chapter on data-intensive app architecture. We will concentrate our attention on the analytics layer and more precisely machine learning. This will serve as a foundation for streaming apps as we want to apply the learning from the batch processing of data as inference rules for the streaming analysis.

The following diagram sets the context of the chapter's focus, highlighting the machine learning module within the analytics layer while using tools for exploratory data analysis, Spark SQL, and Pandas.



# Classifying Spark MLlib algorithms

Spark MLlib is a rapidly evolving module of Spark with new algorithms added with each release of Spark.

The following diagram provides a high-level overview of Spark MLlib algorithms grouped in the traditional broad machine learning techniques and following the categorical or continuous nature of the data:

Spark MLlib		
	Categorical	Continuous
	Qualitative	Quantitative
<b>Unsupervised</b> Extracting structure	Clustering K-means	Dimension Reduction Singular Value Decomposition (SVD) Principal Component Analysis (PCA)
<b>Supervised</b> Making prediction	Classification Naive Bayes Decision Trees Ensembles of Trees (Random Forests and Gradient-Boosted Trees)	Regression linear models Support Vector Machines logistic regression linear regression
<b>Recommender</b> Associating user item	Collaborative Filtering Alternating Least Squares (ALS)	
<b>Optimization</b> Finding minima		Optimization Stochastic Gradient Descent Limited-memory BFGS (L-BFGS)
<b>Feature Extraction</b> Processing text	Feature Extraction Transformation TF-IDF - Word2Vec Standard Scaler - Normalizer	

We categorize the Spark MLlib algorithms in two columns, categorical or continuous, depending on the type of data. We distinguish between data that is categorical or more qualitative in nature versus continuous data, which is quantitative in nature. An example of qualitative data is predicting the weather; given the atmospheric pressure, the temperature, and the presence and type of clouds, the weather will be sunny, dry, rainy, or overcast. These are discrete values. On the other hand, let's say we want to predict house prices, given the location, square meterage, and the number of beds; the real estate value can be predicted using linear regression. In this case, we are talking about continuous or quantitative values.

The horizontal grouping reflects the types of machine learning method used. Unsupervised versus supervised machine learning techniques are dependent on whether the training data is labeled. In an unsupervised learning challenge, no labels are given to the learning algorithm. The goal is to find the hidden structure in its input. In the case of supervised learning, the data is labeled. The focus is on making predictions using regression if the data is continuous or classification if the data is categorical.

An important category of machine learning is recommender systems, which leverage collaborative filtering techniques. The Amazon web store and Netflix have very powerful recommender systems powering their recommendations.

**Stochastic Gradient Descent** is one of the machine learning optimization techniques that is well suited for Spark distributed computation.

For processing large amounts of text, Spark offers crucial libraries for feature extraction and transformation such as **TF-IDF** (short for **Term Frequency – Inverse Document Frequency**), Word2Vec, standard scaler, and normalizer.

## Supervised and unsupervised learning

We delve more deeply here in to the traditional machine learning algorithms offered by Spark MLlib. We distinguish between supervised and unsupervised learning depending on whether the data is labeled. We distinguish between categorical or continuous depending on whether the data is discrete or continuous.

The following diagram explains the Spark MLlib supervised and unsupervised machine learning algorithms and preprocessing techniques:

Spark MLlib		
	Categorical	Continuous
Unsupervised	Qualitative Clustering K-means	Quantitative Dimension Reduction Singular Value Decomposition (SVD) Principal Component Analysis (PCA)
Supervised	Making prediction Classification Naive Bayes Decision Trees Ensembles of Trees (Random Forests and Gradient-Boosted Trees)	Regression linear models Support Vector Machines logistic regression linear regression

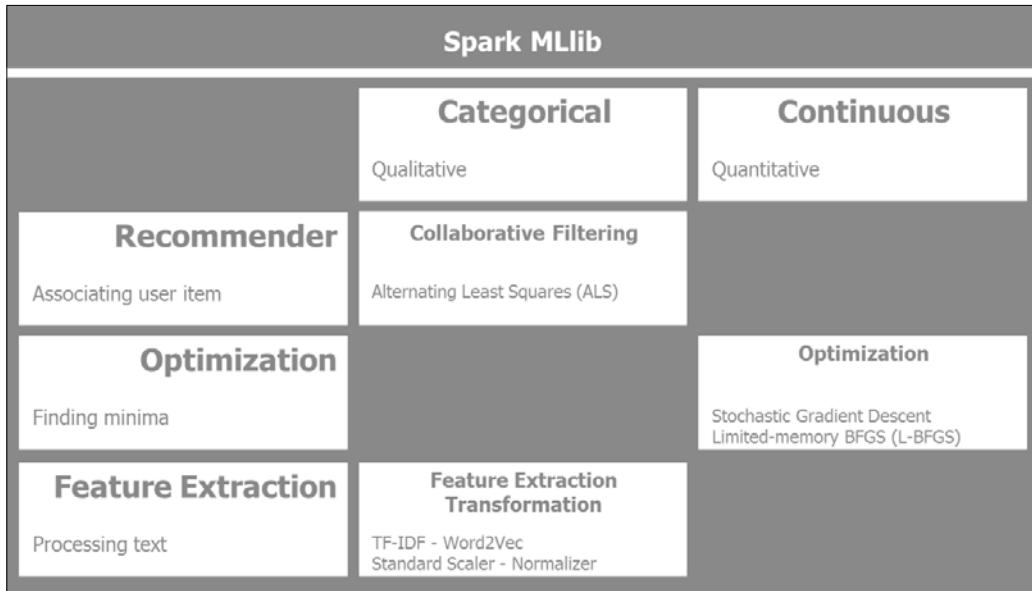
The following supervised and unsupervised MLlib algorithms and preprocessing techniques are currently available in Spark:

- **Clustering:** This is an unsupervised machine learning technique where the data is not labeled. The aim is to extract structure from the data:
  - **K-Means:** This partitions the data in K distinct clusters
  - **Gaussian Mixture:** Clusters are assigned based on the maximum posterior probability of the component
  - **Power Iteration Clustering (PIC):** This groups vertices of a graph based on pairwise edge similarities
  - **Latent Dirichlet Allocation (LDA):** This is used to group collections of text documents into topics
  - **Streaming K-Means:** This means clusters dynamically streaming data using a windowing function on the incoming data
- **Dimensionality Reduction:** This aims to reduce the number of features under consideration. Essentially, this reduces noise in the data and focuses on the key features:
  - **Singular Value Decomposition (SVD):** This breaks the matrix that contains the data into simpler meaningful pieces. It factorizes the initial matrix into three matrices.
  - **Principal Component Analysis (PCA):** This approximates a high dimensional dataset with a low dimensional sub space.

- **Regression and Classification:** Regression predicts output values using labeled training data, while Classification groups the results into classes. Classification has dependent variables that are categorical or unordered whilst Regression has dependent variables that are continuous and ordered:
  - **Linear Regression Models** (linear regression, logistic regression, and support vector machines): Linear regression algorithms can be expressed as convex optimization problems that aim to minimize an objective function based on a vector of weight variables. The objective function controls the complexity of the model through the regularized part of the function and the error of the model through the loss part of the function.
  - **Naive Bayes:** This makes predictions based on the conditional probability distribution of a label given an observation. It assumes that features are mutually independent of each other.
  - **Decision Trees:** This performs recursive binary partitioning of the feature space. The information gain at the tree node level is maximized in order to determine the best split for the partition.
  - **Ensembles of trees** (Random Forests and Gradient-Boosted Trees): Tree ensemble algorithms combine base decision tree models in order to build a performant model. They are intuitive and very successful for classification and regression tasks.
- **Isotonic Regression:** This minimizes the mean squared error between given data and observed responses.

## Additional learning algorithms

Spark MLlib offers more algorithms than the supervised and unsupervised learning ones. We have broadly three more additional types of machine learning methods: recommender systems, optimization algorithms, and feature extraction.



The following additional MLlib algorithms are currently available in Spark:

- **Collaborative filtering:** This is the basis for recommender systems. It creates a user-item association matrix and aims to fill the gaps. Based on other users and items along with their ratings, it recommends an item that the target user has no ratings for. In distributed computing, one of the most successful algorithms is **ALS** (short for **Alternating Least Square**):
  - **Alternating Least Squares:** This matrix factorization technique incorporates implicit feedback, temporal effects, and confidence levels. It decomposes the large user item matrix into a lower dimensional user and item factors. It minimizes a quadratic loss function by fixing alternatively its factors.
- **Feature extraction and transformation:** These are essential techniques for large text document processing. It includes the following techniques:
  - **Term Frequency:** Search engines use TF-IDF to score and rank document relevance in a vast corpus. It is also used in machine learning to determine the importance of a word in a document or corpus. Term frequency statistically determines the weight of a term relative to its frequency in the corpus. Term frequency on its own can be misleading as it overemphasizes words such as *the*, *of*, or *and* that give little information. Inverse Document Frequency provides the specificity or the measure of the amount of information, whether the term is rare or common across all documents in the corpus.

- **Word2Vec:** This includes two models, **Skip-Gram** and **Continuous Bag of Word**. The Skip-Gram predicts neighboring words given a word, based on sliding windows of words, while Continuous Bag of Words predicts the current word given the neighboring words.
- **Standard Scaler:** As part of preprocessing, the dataset must often be standardized by mean removal and variance scaling. We compute the mean and standard deviation on the training data and apply the same transformation to the test data.
- **Normalizer:** We scale the samples to have unit norm. It is useful for quadratic forms such as the dot product or kernel methods.
- **Feature selection:** This reduces the dimensionality of the vector space by selecting the most relevant features for the model.
- **Chi-Square Selector:** This is a statistical method to measure the independence of two events.
- **Optimization:** These specific Spark MLlib optimization algorithms focus on various techniques of gradient descent. Spark provides very efficient implementation of gradient descent on a distributed cluster of machines. It looks for the local minima by iteratively going down the steepest descent. It is compute-intensive as it iterates through all the data available:
  - **Stochastic Gradient Descent:** We minimize an objective function that is the sum of differentiable functions. Stochastic Gradient Descent uses only a sample of the training data in order to update a parameter in a particular iteration. It is used for large-scale and sparse machine learning problems such as text classification.
- **Limited-memory BFGS (L-BFGS):** As the name says, L-BFGS uses limited memory and suits the distributed optimization algorithm implementation of Spark MLlib.

## Spark MLlib data types

MLlib supports four essential data types: **local vector**, **labeled point**, **local matrix**, and **distributed matrix**. These data types are widely used in Spark MLlib algorithms:

- **Local vector:** This resides in a single machine. It can be dense or sparse:
  - Dense vector is a traditional array of doubles. An example of dense vector is [5.0, 0.0, 1.0, 7.0].
  - Sparse vector uses integer indices and double values. So the sparse representation of the vector [5.0, 0.0, 1.0, 7.0] would be (4, [0, 2, 3], [5.0, 1.0, 7.0]), where represent the dimension of the vector.

Here's an example of local vector in PySpark:

```
import numpy as np
import scipy.sparse as sps
from pyspark.mllib.linalg import Vectors

# NumPy array for dense vector.
dvect1 = np.array([5.0, 0.0, 1.0, 7.0])
# Python list for dense vector.
dvect2 = [5.0, 0.0, 1.0, 7.0]
# SparseVector creation
svect1 = Vectors.sparse(4, [0, 2, 3], [5.0, 1.0, 7.0])
# Sparse vector using a single-column SciPy csc_matrix
svect2 = sps.csc_matrix((np.array([5.0, 1.0, 7.0])), np.array([0,
2, 3])), shape = (4, 1)
```

- **Labeled point.** A labeled point is a dense or sparse vector with a label used in supervised learning. In the case of binary labels, 0.0 represents the negative label whilst 1.0 represents the positive value.

Here's an example of a labeled point in PySpark:

```
from pyspark.mllib.linalg import SparseVector
from pyspark.mllib.regression import LabeledPoint

# Labeled point with a positive label and a dense feature vector.
lp_pos = LabeledPoint(1.0, [5.0, 0.0, 1.0, 7.0])

# Labeled point with a negative label and a sparse feature vector.
lp_neg = LabeledPoint(0.0, SparseVector(4, [0, 2, 3], [5.0, 1.0,
7.0]))
```

- **Local Matrix:** This local matrix resides in a single machine with integer-type indices and values of type double.

Here's an example of a local matrix in PySpark:

```
from pyspark.mllib.linalg import Matrix, Matrices

# Dense matrix ((1.0, 2.0, 3.0), (4.0, 5.0, 6.0))
dMatrix = Matrices.dense(2, 3, [1, 2, 3, 4, 5, 6])

# Sparse matrix ((9.0, 0.0), (0.0, 8.0), (0.0, 6.0))
sMatrix = Matrices.sparse(3, 2, [0, 1, 3], [0, 2, 1], [9, 6, 8])
```

- **Distributed Matrix:** Leveraging the distributed nature of the RDD, distributed matrices can be shared in a cluster of machines. We distinguish four distributed matrix types: `RowMatrix`, `IndexedRowMatrix`, `CoordinateMatrix`, and `BlockMatrix`:
  - `RowMatrix`: This takes an RDD of vectors and creates a distributed matrix of rows with meaningless indices, called `RowMatrix`, from the RDD of vectors.
  - `IndexedRowMatrix`: In this case, row indices are meaningful. First, we create an RDD of indexed rows using the class `IndexedRow` and then create an `IndexedRowMatrix`.
  - `CoordinateMatrix`: This is useful to represent very large and very sparse matrices. `CoordinateMatrix` is created from RDDs of the `MatrixEntry` points, represented by a tuple of type (long, long, or float)
  - `BlockMatrix`: These are created from RDDs of sub-matrix blocks, where a sub-matrix block is `((blockRowIndex, blockColIndex), sub-matrix)`.

## Machine learning workflows and data flows

Beyond algorithms, machine learning is also about processes. We will discuss the typical workflows and data flows of supervised and unsupervised machine learning.

### Supervised machine learning workflows

In supervised machine learning, the input training dataset is labeled. One of the key data practices is to split input data into training and test sets, and validate the mode accordingly.

We typically go through a six-step process flow in supervised learning:

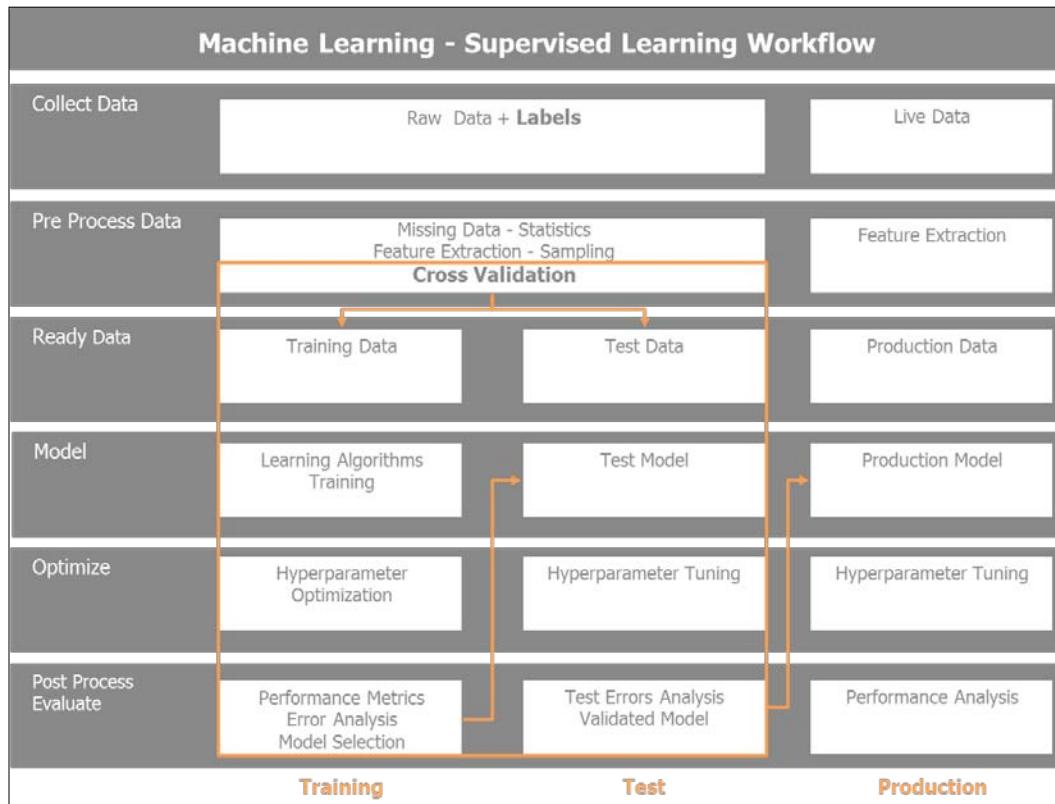
- **Collect the data:** This step essentially ties in with the previous chapter and ensures we collect the right data with the right volume and granularity in order to enable the machine learning algorithm to provide reliable answers.

- **Preprocess the data:** This step is about checking the data quality by sampling, filling in the missing values if any, scaling and normalizing the data. We also define the feature extraction process. Typically, in the case of large text-based datasets, we apply tokenization, stop words removal, stemming, and TF-IDF.

In the case of supervised learning, we separate the input data into a training and test set. We can also implement various strategies of sampling and splitting the dataset for cross-validation purposes.

- **Ready the data:** In this step, we get the data in the format or data type expected by the algorithms. In the case of Spark MLlib, this includes local vector, dense or sparse vectors, labeled points, local matrix, distributed matrix with row matrix, indexed row matrix, coordinate matrix, and block matrix.
- **Model:** In this step, we apply the algorithms that are suitable for the problem at hand and get the results for evaluation of the most suitable algorithm in the evaluate step. We might have multiple algorithms suitable for the problem; their respective performance will be scored in the evaluate step to select the best performing ones. We can implement an ensemble or combination of models in order to reach the best results.
- **Optimize:** We may need to run a grid search for the optimal parameters of certain algorithms. These parameters are determined during training, and fine-tuned during the testing and production phase.
- **Evaluate:** We ultimately score the models and select the best one in terms of accuracy, performance, reliability, and scalability. We move the best performing model to test with the held out test data in order to ascertain the prediction accuracy of our model. Once satisfied with the fine-tuned model, we move it to production to process live data.

The supervised machine learning workflow and dataflow are represented in the following diagram:

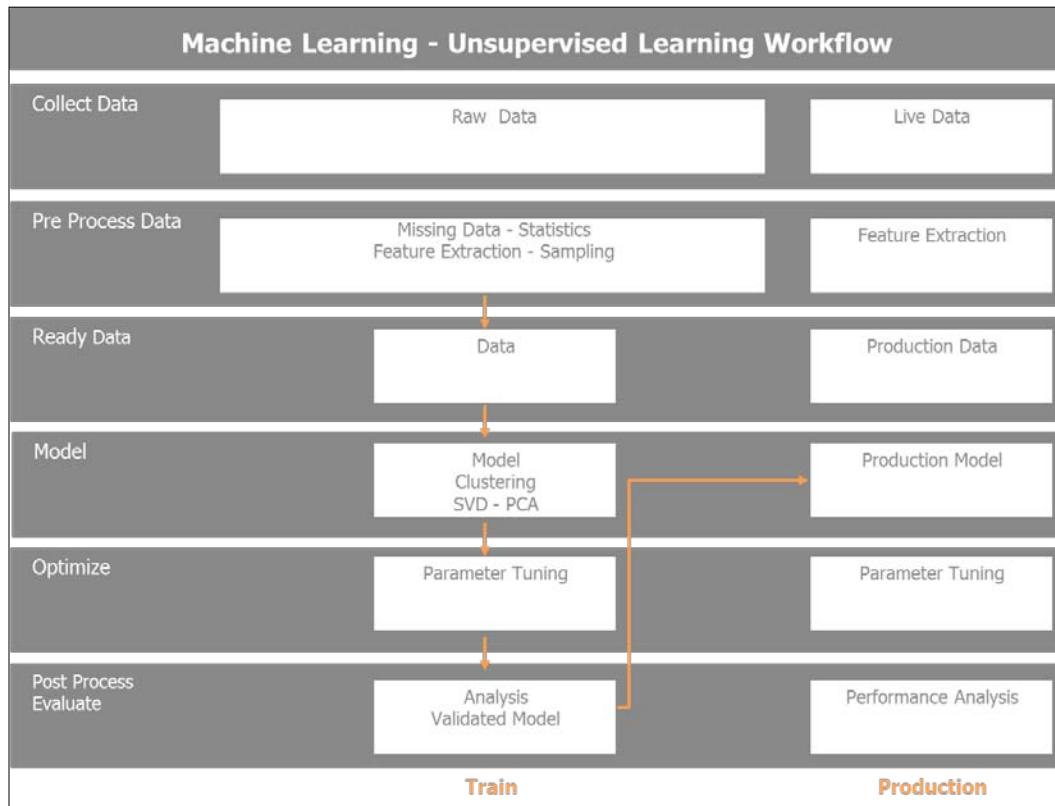


## Unsupervised machine learning workflows

As opposed to supervised learning, our initial data is not labeled in the case of unsupervised learning, which is most often the case in real life. We will extract the structure from the data by using clustering or dimensionality reduction algorithms. In the unsupervised learning case, we do not split the data into training and test, as we cannot make any prediction because the data is not labeled. We will train the data along six steps similar to those in supervised learning. Once the model is trained, we will evaluate the results and fine-tune the model and then release it for production.

Unsupervised learning can be a preliminary step to supervised learning. Namely, we look at reducing the dimensionality of the data prior to attacking the learning phase.

The unsupervised machine learning workflows and dataflow are represented as follows:



## Clustering the Twitter dataset

Let's first get a feel for the data extracted from Twitter and get an understanding of the data structure in order to prepare and run it through the K-Means clustering algorithms. Our plan of attack uses the process and dataflow depicted earlier for unsupervised learning. The steps are as follows:

1. Combine all tweet files into a single dataframe.
2. Parse the tweets, remove stop words, extract emoticons, extract URL, and finally normalize the words (for example, mapping them to lowercase and removing punctuation and numbers).

3. Feature extraction includes the following:
  - **Tokenization:** This breaks down the parsed tweet text into individual words or tokens
  - **TF-IDF:** This applies the TF-IDF algorithm to create feature vectors from the tokenized tweet texts
  - **Hash TF-IDF:** This applies a hashing function to the token vectors
4. Run the K-Means clustering algorithm.
5. Evaluate the results of the K-Means clustering:
  - Identify tweet membership to clusters
  - Perform dimensionality reduction to two dimensions with the Multi-Dimensional Scaling or the Principal Component Analysis algorithm
  - Plot the clusters
6. Pipeline:
  - Fine-tune the number of relevant clusters K
  - Measure the model cost
  - Select the optimal model

## Applying Scikit-Learn on the Twitter dataset

Python's own Scikit-Learn machine learning library is one of the most reliable, intuitive, and robust tools around. Let's run through a preprocessing and unsupervised learning using Pandas and Scikit-Learn. It is often beneficial to explore a sample of the data using Scikit-Learn before spinning off clusters with Spark MLlib.

We have a mixed bag of 7,540 tweets. It contains tweets related to Apache Spark, Python, the upcoming presidential election with Hillary Clinton and Donald Trump as protagonists, and some tweets related to fashion and music with Lady Gaga and Justin Bieber. We are running the K-Means clustering algorithm using Python Scikit-Learn on the Twitter dataset harvested. We first load the sample data into a Pandas dataframe:

```
import pandas as pd

csv_in = 'C:\\\\Users\\\\Amit\\\\Documents\\\\IPython Notebooks\\\\AN00_Data\\\\
unq_tweets.txt.csv'
twts_df01 = pd.read_csv(csv_in, sep=';', encoding='utf-8')

In [24]:
```

```
twts_df01.count()
Out[24]:
Unnamed: 0    7540
id            7540
created_at    7540
user_id       7540
user_name     7538
tweet_text    7540
dtype: int64

#
# Introspecting the tweets text
#
In [82]: twtstxt_ls01[6910:6920]
Out[82]:
['RT @deroach_Ismoke: I am NOT voting for #hilaryclinton http://t.co/jaZZpcHkkJ',
 'RT @AnimalRightsJen: #HillaryClinton What do Bernie Sanders and Donald Trump Have in Common?: He has so far been th... http://t.co/t2YRcGCh6...', 
 'I understand why Bill was out banging other chicks.....I mean look at what he is married to.....\n@HillaryClinton',
 '#HillaryClinton What do Bernie Sanders and Donald Trump Have in Common?: He has so far been th... http://t.co/t2YRcGCh67 #Tcot #UniteBlue']
```

We first perform a feature extraction from the tweets' text. We apply a sparse vectorizer to the dataset using a TF-IDF vectorizer with 10,000 features and English stop words:

```
In [37]: print("Extracting features from the training dataset using a sparse vectorizer")
t0 = time()
Extracting features from the training dataset using a sparse vectorizer
In [38]: vectorizer = TfidfVectorizer(max_df=0.5, max_features=10000,
                                 min_df=2, stop_words='english',
                                 use_idf=True)
X = vectorizer.fit_transform(twtstxt_ls01)
#
```

```
# Output of the TFIDF Feature vectorizer
#
print("done in %fs" % (time() - t0))
print("n_samples: %d, n_features: %d" % X.shape)
print()
done in 5.232165s
n_samples: 7540, n_features: 6638
```

As the dataset is now broken into a 7540 sample with vectors of 6,638 features, we are ready to feed this sparse matrix to the K-Means clustering algorithm. We will choose seven clusters and 100 maximum iterations initially:

In [47] :

```
km = KMeans(n_clusters=7, init='k-means++', max_iter=100, n_init=1,
            verbose=1)

print("Clustering sparse data with %s" % km)
t0 = time()
km.fit(X)
print("done in %0.3fs" % (time() - t0))

Clustering sparse data with KMeans(copy_x=True, init='k-means++', max_
iter=100, n_clusters=7, n_init=1,
        n_jobs=1, precompute_distances='auto', random_state=None,
tol=0.0001,
        verbose=1)
Initialization complete
Iteration 0, inertia 13635.141
Iteration 1, inertia 6943.485
Iteration 2, inertia 6924.093
Iteration 3, inertia 6915.004
Iteration 4, inertia 6909.212
Iteration 5, inertia 6903.848
Iteration 6, inertia 6888.606
Iteration 7, inertia 6863.226
Iteration 8, inertia 6860.026
Iteration 9, inertia 6859.338
Iteration 10, inertia 6859.213
Iteration 11, inertia 6859.102
Iteration 12, inertia 6859.080
Iteration 13, inertia 6859.060
Iteration 14, inertia 6859.047
Iteration 15, inertia 6859.039
Iteration 16, inertia 6859.032
```

```
Iteration 17, inertia 6859.031
Iteration 18, inertia 6859.029
Converged at iteration 18
done in 1.701s
```

The K-Means clustering algorithm converged after 18 iterations. We see in the following results the seven clusters with their respective key words. Clusters 0 and 6 are about music and fashion with Justin Bieber and Lady Gaga-related tweets. Clusters 1 and 5 are related to the U.S.A. presidential elections with Donald Trump- and Hilary Clinton-related tweets. Clusters 2 and 3 are the ones of interest to us as they are about Apache Spark and Python. Cluster 4 contains Thailand-related tweets:

```
#  
# Introspect top terms per cluster  
#  
  
In [49]:  
  
print("Top terms per cluster:")  
order_centroids = km.cluster_centers_.argsort()[:, ::-1]  
terms = vectorizer.get_feature_names()  
for i in range(7):  
    print("Cluster %d:" % i, end='')  
    for ind in order_centroids[i, :20]:  
        print(' %s' % terms[ind], end='')  
    print()  
Top terms per cluster:  
Cluster 0: justinbieber love mean rt follow thank hi https  
whatdoyoumean video wanna hear whatdoyoumeanviral rorykramer happy lol  
making person dream justin  
Cluster 1: donaldtrump hilaryclinton rt https trump2016  
realdonaldtrump trump gop amp justinbieber president clinton emails  
oy8ltkstze tcot like berniesanders hilary people email  
Cluster 2: bigdata apachespark hadoop analytics rt spark training  
chennai ibm datascience apache processing cloudera mapreduce data sap  
https vora transforming development  
Cluster 3: apachespark python https rt spark data amp databricks using  
new learn hadoop ibm big apache continuumio bluemix learning join open  
Cluster 4: ernestsgant simbata3 jdhm2015 elsahe12 phuketdailynews  
dreamintentions beyhiveinfrance almtorta18 civipartnership 9_a_6  
25whu72ep0 k7erhvu7wn fdmxxxxcm3h osxuh2fxnt 5o5rmb0xhp jnbgkqn0dj  
ovap57ujdh dtzs3lb6x sunnysai12345 sdcvulih6g  
Cluster 5: trump donald donaldtrump starbucks trumpquote  
trumpforpresident oy8ltkstze https zfn57pxysx silly goy stump  
trump2016 news jeremy coffee corbyn ok7vc8aetz rt tonight  
Cluster 6: ladygaga gaga lady rt https love follow horror cd story  
ahshotel american japan hotel human trafficking music fashion diet  
queen ahs
```

We will visualize the results by plotting the cluster. We have 7,540 samples with 6,638 features. It will be impossible to visualize that many dimensions. We will use the **Multi-Dimensional Scaling (MDS)** algorithm to bring down the multidimensional features of the clusters into two tractable dimensions to be able to picture them:

```
import matplotlib.pyplot as plt
import matplotlib as mpl
from sklearn.manifold import MDS

MDS()

#
# Bring down the MDS to two dimensions (components) as we will plot
# the clusters
#
mds = MDS(n_components=2, dissimilarity="precomputed", random_state=1)

pos = mds.fit_transform(dist) # shape (n_components, n_samples)

xs, ys = pos[:, 0], pos[:, 1]

In [67]:
```

```
# 
# Set up colors per clusters using a dict
#
cluster_colors = {0: '#1b9e77', 1: '#d95f02', 2: '#7570b3', 3:
 '#e7298a', 4: '#66a61e', 5: '#9990b3', 6: '#e8888a'}
```

```
#
#set up cluster names using a dict
#
cluster_names = {0: 'Music, Pop',
                  1: 'USA Politics, Election',
                  2: 'BigData, Spark',
                  3: 'Spark, Python',
                  4: 'Thailand',
                  5: 'USA Politics, Election',
                  6: 'Music, Pop'}
```

```
In [115]:
#
# ipython magic to show the matplotlib plots inline
#
```

```
%matplotlib inline

#
# Create data frame which includes MDS results, cluster numbers and
# tweet texts to be displayed
#
df = pd.DataFrame(dict(x=xs, y=ys, label=clusters, txt=twtstxt_ls02_
    utf8))
ix_start = 2000
ix_stop = 2050
df01 = df[ix_start:ix_stop]

print(df01[['label','txt']])
print(len(df01))
print()

# Group by cluster

groups = df.groupby('label')
groups01 = df01.groupby('label')

# Set up the plot

fig, ax = plt.subplots(figsize=(17, 10))
ax.margins(0.05)

#
# Build the plot object
#
for name, group in groups01:
    ax.plot(group.x, group.y, marker='o', linestyle='', ms=12,
            label=cluster_names[name], color=cluster_colors[name],
            mec='none')
    ax.set_aspect('auto')
    ax.tick_params(\n        axis= 'x',           # settings for x-axis\n        which= 'both',\n        bottom= 'off',\n        top= 'off',\n        labelbottom= 'off')
    ax.tick_params(\n        axis= 'y',           # settings for y-axis\n        which= 'both',\n
```

## Learning from Data Using Spark

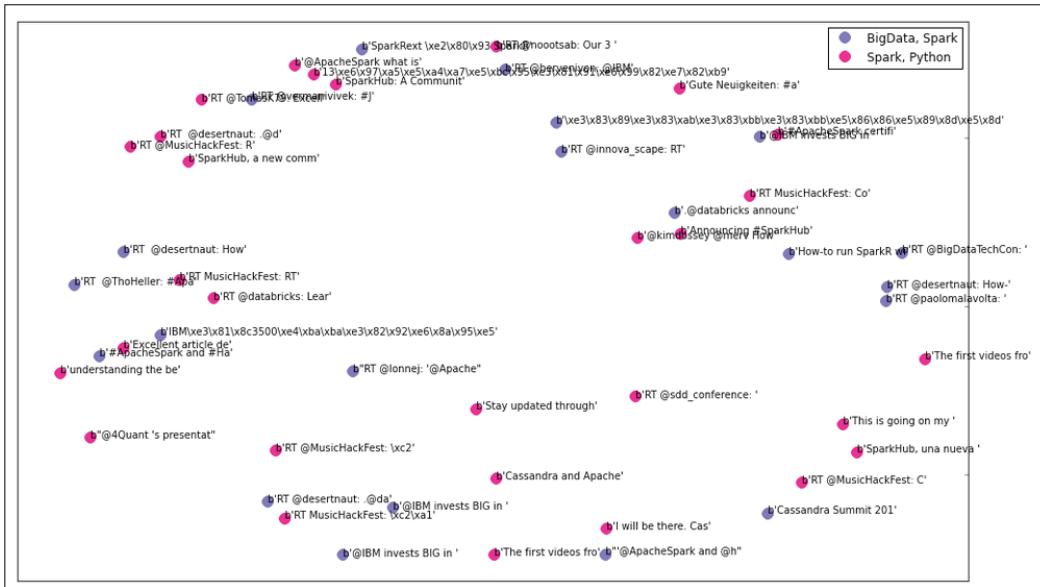
```
    left='off',           #
    top='off',           #
    labelleft='off')

ax.legend(numpoints=1)      #
#
# Add label in x,y position with tweet text
#
for i in range(ix_start, ix_stop):
    ax.text(df01.ix[i]['x'], df01.ix[i]['y'], df01.ix[i]['txt'],
size=10)

plt.show()                  # Display the plot
```

label	text
2000	b'RT @BigDataTechCon: '
2001	b'"@4Quant 's presentat"
2002	b'Cassandra Summit 201'

Here's a plot of Cluster 2, *Big Data* and *Spark*, represented by blue dots along with Cluster 3, *Spark* and *Python*, represented by red dots, and some sample tweets related to the respective clusters:



We have gained some good insights into the data with the exploration and processing done with Scikit-Learn. We will now focus our attention on Spark MLlib and take it for a ride on the Twitter dataset.

## Preprocessing the dataset

Now, we will focus on feature extraction and engineering in order to ready the data for the clustering algorithm run. We instantiate the Spark Context and read the Twitter dataset into a Spark dataframe. We will then successively tokenize the tweet text data, apply a hashing Term frequency algorithm to the tokens, and finally apply the Inverse Document Frequency algorithm and rescale the data. The code is as follows:

```
In [3]:  
#  
# Read csv in a Panda DF  
#  
#  
import pandas as pd  
csv_in = '/home/an/spark/spark-1.5.0-bin-hadoop2.6/examples/AN_Spark/  
data/unq_tweetstxt.csv'  
pddf_in = pd.read_csv(csv_in, index_col=None, header=0, sep=';',  
encoding='utf-8')  
  
In [4]:  
  
sqlContext = SQLContext(sc)  
  
In [5]:  
  
#  
# Convert a Panda DF to a Spark DF  
#  
#  
#  
  
spdf_02 = sqlContext.createDataFrame(pddf_in[['id', 'user_id', 'user_  
name', 'tweet_text']])  
  
In [8]:  
  
spdf_02.show()  
  
In [7]:
```

```
spdf_02.take(3)
```

Out [7] :

```
[Row(id=638830426971181057, user_id=3276255125, user_name=u'True  
Equality', tweet_text=u'ernestsgantt: BeyHiveInFrance: 9_A_6:  
dreamintentions: elsahe12: simbata3: JDHM2015: almtorta18:  
dreamintentions:\u2026 http://t.co/VpD7FoqMr0'),  
 Row(id=638830426727911424, user_id=3276255125, user_name=u'True  
Equality', tweet_text=u'ernestsgantt: BeyHiveInFrance:  
PhuketDailyNews: dreamintentions: elsahe12: simbata3: JDHM2015:  
almtorta18: CiviPa\u2026 http://t.co/VpD7FoqMr0'),  
 Row(id=638830425402556417, user_id=3276255125, user_name=u'True  
Equality', tweet_text=u'ernestsgantt: BeyHiveInFrance: 9_A_6:  
ernestsgantt: elsahe12: simbata3: JDHM2015: almtorta18:  
CiviPartnership: dr\u2026 http://t.co/EMDOOn8chPK')]
```

In [9] :

```
from pyspark.ml.feature import HashingTF, IDF, Tokenizer
```

In [10] :

```
#  
# Tokenize the tweet_text  
#  
tokenizer = Tokenizer(inputCol="tweet_text", outputCol="tokens")  
tokensData = tokenizer.transform(spdf_02)
```

In [11] :

```
tokensData.take(1)
```

Out [11] :

```
[Row(id=638830426971181057, user_id=3276255125, user_name=u'True  
Equality', tweet_text=u'ernestsgantt: BeyHiveInFrance:  
9_A_6: dreamintentions: elsahe12: simbata3: JDHM2015:  
almtorta18: dreamintentions:\u2026 http://t.co/VpD7FoqMr0',  
tokens=[u'ernestsgantt:', u'beyhiveinfrance:', u'9_a_6:',  
u'dreamintentions:', u'elsahe12:', u'simbata3:', u'jdhm2015:',  
u'almtorta18:', u'dreamintentions:\u2026', u'http://t.co/  
vpd7foqmr0'])]
```

In [14] :

```
#  
# Apply Hashing TF to the tokens  
#  
hashingTF = HashingTF(inputCol="tokens", outputCol="rawFeatures",  
numFeatures=2000)  
featuresData = hashingTF.transform(tokensData)  
  
In [15] :  
  
featuresData.take(1)  
  
Out[15] :  
  
[Row(id=638830426971181057, user_id=3276255125, user_name=u'True  
Equality', tweet_text=u'ernestsgantt: BeyHiveInFrance:  
9_A_6: dreamintentions: elsahe12: simbata3: JDHM2015:  
almtorta18: dreamintentions:\u2026 http://t.co/VpD7FoqMr0',  
tokens=[u'ernestsgantt:', u'beyhiveinfrance:', u'9_a_6:',  
u'dreamintentions:', u'elsahe12:', u'simbata3:', u'jdhm2015:',  
u'almtorta18:', u'dreamintentions:\u2026', u'http://t.co/vpd7foqmr0'],  
rawFeatures=SparseVector(2000, {74: 1.0, 97: 1.0, 100: 1.0, 160: 1.0,  
185: 1.0, 742: 1.0, 856: 1.0, 991: 1.0, 1383: 1.0, 1620: 1.0}))]  
  
In [16] :  
  
#  
# Apply IDF to the raw features and rescale the data  
#  
idf = IDF(inputCol="rawFeatures", outputCol="features")  
idfModel = idf.fit(featuresData)  
rescaledData = idfModel.transform(featuresData)  
  
for features in rescaledData.select("features").take(3):  
    print(features)  
  
In [17] :  
  
rescaledData.take(2)  
  
Out[17] :  
  
[Row(id=638830426971181057, user_id=3276255125, user_name=u'True  
Equality', tweet_text=u'ernestsgantt: BeyHiveInFrance:  
9_A_6: dreamintentions: elsahe12: simbata3: JDHM2015:  
almtorta18: dreamintentions:\u2026 http://t.co/VpD7FoqMr0',  
tokens=[u'ernestsgantt:', u'beyhiveinfrance:', u'9_a_6:',
```

```
u'dreamintentions:', u'elsahel12:', u'simbata3:', u'jdhm2015:',  
u'almtorta18:', u'dreamintentions:\u2026', u'http://t.co/vpd7foqmr0'],  
rawFeatures=SparseVector(2000, {74: 1.0, 97: 1.0, 100: 1.0, 160:  
1.0, 185: 1.0, 742: 1.0, 856: 1.0, 991: 1.0, 1383: 1.0, 1620: 1.0}),  
features=SparseVector(2000, {74: 2.6762, 97: 1.8625, 100: 2.6384, 160:  
2.9985, 185: 2.7481, 742: 5.5269, 856: 4.1406, 991: 2.9518, 1383:  
4.694, 1620: 3.073})),  
Row(id=638830426727911424, user_id=3276255125, user_name=u'True  
Equality', tweet_text=u'ernestsgantt: BeyHiveInFrance:  
PhuketDailyNews: dreamintentions: elsahe12: simbata3:  
JDHM2015: almtorta18: CiviPa\u2026 http://t.co/VpD7FoqMr0',  
tokens=[u'ernestsgantt:', u'beyhiveinfrance:', u'phuketdailynews:',  
u'dreamintentions:', u'elsahel12:', u'simbata3:', u'jdhm2015:',  
u'almtorta18:', u'civipa\u2026', u'http://t.co/vpd7foqmr0'],  
rawFeatures=SparseVector(2000, {74: 1.0, 97: 1.0, 100: 1.0, 160:  
1.0, 185: 1.0, 460: 1.0, 987: 1.0, 991: 1.0, 1383: 1.0, 1620: 1.0}),  
features=SparseVector(2000, {74: 2.6762, 97: 1.8625, 100: 2.6384,  
160: 2.9985, 185: 2.7481, 460: 6.4432, 987: 2.9959, 991: 2.9518, 1383:  
4.694, 1620: 3.073}))]
```

In [21]:

```
rs_pddf = rescaledData.toPandas()
```

In [22]:

```
rs_pddf.count()
```

Out[22]:

```
id          7540  
user_id     7540  
user_name   7540  
tweet_text  7540  
tokens      7540  
rawFeatures 7540  
features    7540  
dtype: int64
```

In [27]:

```
feat_lst = rs_pddf.features.tolist()
```

In [28]:

```
feat_lst[:2]

Out[28] :

[SparseVector(2000, {74: 2.6762, 97: 1.8625, 100: 2.6384, 160: 2.9985,
185: 2.7481, 742: 5.5269, 856: 4.1406, 991: 2.9518, 1383: 4.694, 1620:
3.073}),
 SparseVector(2000, {74: 2.6762, 97: 1.8625, 100: 2.6384, 160: 2.9985,
185: 2.7481, 460: 6.4432, 987: 2.9959, 991: 2.9518, 1383: 4.694, 1620:
3.073})]
```

## Running the clustering algorithm

We will use the K-Means algorithm against the Twitter dataset. As an unlabeled and shuffled bag of tweets, we want to see if the *Apache Spark* tweets are grouped in a single cluster. From the previous steps, the TF-IDF sparse vector of features is converted into an RDD that will be the input to the Spark MLlib program. We initialize the K-Means model with 5 clusters, 10 iterations of 10 runs:

```
In [32] :

from pyspark.mllib.clustering import KMeans, KMeansModel
from numpy import array
from math import sqrt

In [34] :

# Load and parse the data

in_Data = sc.parallelize(feat_lst)

In [35] :

in_Data.take(3)

Out[35] :

[SparseVector(2000, {74: 2.6762, 97: 1.8625, 100: 2.6384, 160: 2.9985,
185: 2.7481, 742: 5.5269, 856: 4.1406, 991: 2.9518, 1383: 4.694, 1620:
3.073}),
 SparseVector(2000, {74: 2.6762, 97: 1.8625, 100: 2.6384, 160: 2.9985,
185: 2.7481, 460: 6.4432, 987: 2.9959, 991: 2.9518, 1383: 4.694, 1620:
3.073}),
```

```
SparseVector(2000, {20: 4.3534, 74: 2.6762, 97: 1.8625, 100: 5.2768,
185: 2.7481, 856: 4.1406, 991: 2.9518, 1039: 3.073, 1620: 3.073, 1864:
4.6377})]
```

In [37] :

```
in_Data.count()
```

Out [37] :

```
7540
```

In [38] :

```
# Build the model (cluster the data)
```

```
clusters = KMeans.train(in_Data, 5, maxIterations=10,
                         runs=10, initializationMode="random")
```

In [53] :

```
# Evaluate clustering by computing Within Set Sum of Squared Errors
```

```
def error(point):
    center = clusters.centers[clusters.predict(point)]
    return sqrt(sum([x**2 for x in (point - center)]))
```

```
WSSSE = in_Data.map(lambda point: error(point)).reduce(lambda x, y: x
+ y)
```

```
print("Within Set Sum of Squared Error = " + str(WSSSE))
```

## Evaluating the model and the results

One way to fine-tune the clustering algorithm is by varying the number of clusters and verifying the output. Let's check the clusters and get a feel for the clustering results so far:

In [43] :

```
cluster_membership = in_Data.map(lambda x: clusters.predict(x))
```

In [54] :

```
cluster_idx = cluster_membership.zipWithIndex()
```

In [55] :

```
type(cluster_idx)
```

Out [55] :

```
pyspark.rdd.PipelinedRDD
```

In [58] :

```
cluster_idx.take(20)
```

Out [58] :

```
[(3, 0),  
 (3, 1),  
 (3, 2),  
 (3, 3),  
 (3, 4),  
 (3, 5),  
 (1, 6),  
 (3, 7),  
 (3, 8),  
 (3, 9),  
 (3, 10),  
 (3, 11),  
 (3, 12),  
 (3, 13),  
 (3, 14),  
 (1, 15),  
 (3, 16),  
 (3, 17),  
 (1, 18),  
 (1, 19)]
```

In [59] :

```
cluster_df = cluster_idx.toDF()
```

In [65] :

```
pddf_with_cluster = pd.concat([pddf_in, cluster_pddf], axis=1)

In [76] :

pddf_with_cluster._1.unique()

Out[76] :

array([3, 1, 4, 0, 2])

In [79] :

pddf_with_cluster[pddf_with_cluster['_1'] == 0].head(10)

Out[79] :
    Unnamed: 0      id      created_at      user_id      user_name      tweet_text      _1
_2
6227    3   642418116819988480   Fri Sep 11 19:23:09 +0000 2015
49693598  Ajinkya Kale      RT @bigdata: Distributed Matrix Computations
i...    0    6227
6257    45   642391207205859328   Fri Sep 11 17:36:13 +0000 2015
937467860  Angela Bassa      [Auto] I'm reading ""Distributed Matrix
Comput...    0    6257
6297    119   642348577147064320   Fri Sep 11 14:46:49 +0000
2015    18318677  Ben Lorica      Distributed Matrix Computations in @
ApacheSpar...    0    6297
In [80] :

pddf_with_cluster[pddf_with_cluster['_1'] == 1].head(10)

Out[80] :
    Unnamed: 0      id      created_at      user_id      user_name      tweet_text      _1
_2
6    6   638830419090079746   Tue Sep 01 21:46:55 +0000 2015
2241040634  Massimo Carrisi      Python:Python: Removing \xa0 from
string? - I ...    1    6
15    17   638830380578045953   Tue Sep 01 21:46:46 +0000 2015
57699376  Rafael Monnerat      RT @ramalhoorg: Noite de autógrafos do
Fluent ...    1    15
18    41   638830280988426250   Tue Sep 01 21:46:22 +0000 2015
951081582  Jack Baldwin      RT @cloudaus: We are 3/4 full! 2-day @
swcarpen...    1    18
19    42   638830276626399232   Tue Sep 01 21:46:21 +0000 2015
6525302  Masayoshi Nakamura      PynamoDB #AWS #DynamoDB #Python
http://...    1    19
```

```

20 43 638830213288235008 Tue Sep 01 21:46:06 +0000 2015
3153874869 Baltimore Python Flexx: Python UI toolkit based on web
technolog... 1 20
21 44 638830117645516800 Tue Sep 01 21:45:43 +0000 2015
48474625 Radio Free Denali Hmm, emerge --depclean wants to remove
somethi... 1 21
22 46 638829977014636544 Tue Sep 01 21:45:10 +0000 2015
154915461 Luciano Ramalho Noite de autógrafos do Fluent Python no
Garoa ... 1 22
23 47 638829882928070656 Tue Sep 01 21:44:47 +0000 2015
917320920 bsbafflesbrains @DanSWright Harper channeling Monty
Python. "... 1 23
24 48 638829868679954432 Tue Sep 01 21:44:44 +0000 2015
134280898 Lannick Technology RT @SergeyKalinish: I am #hiring:
Senior Back e... 1 24
25 49 638829707484508161 Tue Sep 01 21:44:05 +0000 2015
2839203454 Joshua Jones RT @LindseyPelas: Surviving Monty Python
in Fl... 1 25
In [81]:
```

pddf\_with\_cluster[pddf\_with\_cluster['\_1'] == 2].head(10)

Out[81]:

	Unnamed: 0	id	created_at	user_id	user_name	tweet_text	_1
_2	7280	688	639056941592014848	Wed Sep 02 12:47:02 +0000 2015	Chris	A true gay icon when will @ladygaga @Madonna @...	
2	7280						

In [82]:

pddf\_with\_cluster[pddf\_with\_cluster['\_1'] == 3].head(10)

Out[82]:

	Unnamed: 0	id	created_at	user_id	user_name	tweet_text	_1
_2	0	0	638830426971181057	Tue Sep 01 21:46:57 +0000 2015	3276255125	True Equality	ernestsgantt: BeyHiveInFrance: 9_A_6:
					dreamint...	3 0	
1	1	638830426727911424	Tue Sep 01 21:46:57 +0000 2015	3276255125	True Equality	ernestsgantt: BeyHiveInFrance:	
		PhuketDailyNews...	3 1				
2	2	638830425402556417	Tue Sep 01 21:46:56 +0000 2015	3276255125	True Equality	ernestsgantt: BeyHiveInFrance: 9_A_6:	
		ernestsg...	3 2				
3	3	638830424563716097	Tue Sep 01 21:46:56 +0000 2015	3276255125	True Equality	ernestsgantt: BeyHiveInFrance:	
		PhuketDailyNews...	3 3				

```
4   4   638830422256816132   Tue Sep 01 21:46:56 +0000 2015  
3276255125   True Equality ernestsgantt: elsahe12: 9_A_6:  
dreamintention... 3   4  
5   5   638830420159655936   Tue Sep 01 21:46:55 +0000 2015  
3276255125   True Equality ernestsgantt: BeyHiveInFrance:  
PhuketDailyNews... 3   5  
7   7   638830418330980352   Tue Sep 01 21:46:55 +0000 2015  
3276255125   True Equality ernestsgantt: elsahe12: 9_A_6:  
dreamintention... 3   7  
8   8   638830397648822272   Tue Sep 01 21:46:50 +0000 2015  
3276255125   True Equality ernestsgantt: BeyHiveInFrance:  
PhuketDailyNews... 3   8  
9   9   638830395375529984   Tue Sep 01 21:46:49 +0000 2015  
3276255125   True Equality ernestsgantt: elsahe12: 9_A_6:  
dreamintention... 3   9  
10  10  638830392389177344   Tue Sep 01 21:46:49 +0000 2015  
3276255125   True Equality ernestsgantt: BeyHiveInFrance:  
PhuketDailyNews... 3   10  
In [83]:  
  
pddf_with_cluster[pddf_with_cluster['_1'] == 4].head(10)  
  
Out[83]:  
    Unnamed: 0      id      created_at      user_id      user_name      tweet_text      _1  
_2  
1361     882  642648214454317056  Sat Sep 12 10:37:28 +0000 2015  
27415756  Raymond Enisuh LA Chosen For US 2024 Olympic Bid -  
LA2016 See... 4     1361  
1363     885  642647848744583168  Sat Sep 12 10:36:01 +0000 2015  
27415756  Raymond Enisuh Prison See: https://t.co/x3EKAExeFi ... ...  
...     ... 4     1363  
5412     11   640480770369286144  Sun Sep 06 11:04:49 +0000 2015  
3242403023 Donald Trump 2016 " igiboooy! @ Starbucks https://t.  
co/97wdL... 4     5412  
5428     27   640477140660518912  Sun Sep 06 10:50:24 +0000 2015  
3242403023 Donald Trump 2016 " @ Starbucks https://t.co/  
wsEYFIEfk7 " - D... 4     5428  
5455     61   640469542272110592  Sun Sep 06 10:20:12 +0000 2015  
3242403023 Donald Trump 2016 " starbucks @ Starbucks Mam Plaza  
https://t.co... 4     5455  
5456     62   640469541370372096  Sun Sep 06 10:20:12 +0000 2015  
3242403023 Donald Trump 2016 " Aaahhh the pumpkin spice latte is  
back, fall... 4     5456  
5457     63   640469539524898817  Sun Sep 06 10:20:12 +0000 2015  
3242403023 Donald Trump 2016 " RT kayyleighferry: Oh my goddd  
Harry Potter ... 4     5457  
5458     64   640469537176031232  Sun Sep 06 10:20:11 +0000 2015  
3242403023 Donald Trump 2016 " Starbucks https://t.co/3xYYXlwNkf  
" - Donald... 4     5458
```

```

5459   65   640469536119070720   Sun Sep 06 10:20:11 +0000 2015
3242403023 Donald Trump 2016   " A Starbucks is under construction
in my neig... 4 5459
5460   66   640469530435813376   Sun Sep 06 10:20:10 +0000 2015
3242403023 Donald Trump 2016   " Babam starbucks'tan fotogtaf atıiyor
bende du... 4 5460

```

We map the 5 clusters with some sample tweets. Cluster 0 is about Spark. Cluster 1 is about Python. Cluster 2 is about Lady Gaga. Cluster 3 is about Thailand's Phuket News. Cluster 4 is about Donald Trump.

## Building machine learning pipelines

We want to compose the feature extraction, preparatory activities, training, testing, and prediction activities while optimizing the best tuning parameter to get the best performing model.

The following tweet captures perfectly in five lines of code a powerful machine learning Pipeline implemented in Spark MLlib:

**Big Data** Ben Lorica @bigdata Follow

@matei\_zaharia on ML pipelines at #sparksummit; also see @amplab efforts [goo.gl/3iiEkW](http://goo.gl/3iiEkW)

Machine Learning Pipelines

High-level API inspired by SciKit-Learn

Featurization, evaluation, parameter search

```

tokenizer = Tokenizer()
tf = HashingTF(numFeatures=1000)
lr = LogisticRegression()

pipe = Pipeline([tokenizer, tf, lr])
model = pipe.fit(df)

```

RETWEETS 14 FAVOURITES 15

6:10 am - 18 Mar 2015

The Spark ML pipeline is inspired by Python's Scikit-Learn and creates a succinct, declarative statement of the successive transformations to the data in order to quickly deliver a tunable model.

## Summary

In this chapter, we got an overview of Spark MLlib's ever-expanding library of algorithms Spark MLlib. We discussed supervised and unsupervised learning, recommender systems, optimization, and feature extraction algorithms. We then put the harvested data from Twitter into the machine learning process, algorithms, and evaluation to derive insights from the data. We put the Twitter-harvested dataset through a Python Scikit-Learn and Spark MLlib K-means clustering in order to segregate the tweets relevant to *Apache Spark*. We also evaluated the performance of the model.

This gets us ready for the next chapter, which will cover Streaming Analytics using Spark. Let's jump right in.

# 5

## Streaming Live Data with Spark

In this chapter, we will focus on live streaming data flowing into Spark and processing it. So far, we have discussed machine learning and data mining with batch processing. We are now looking at processing continuously flowing data and detecting facts and patterns on the fly. We are navigating from a lake to a river.

We will first investigate the challenges arising from such a dynamic and ever changing environment. After laying the grounds on the prerequisite of a streaming application, we will investigate various implementations using live sources of data such as TCP sockets to the Twitter firehose and put in place a low latency, high throughput, and scalable data pipeline combining Spark, Kafka and Flume.

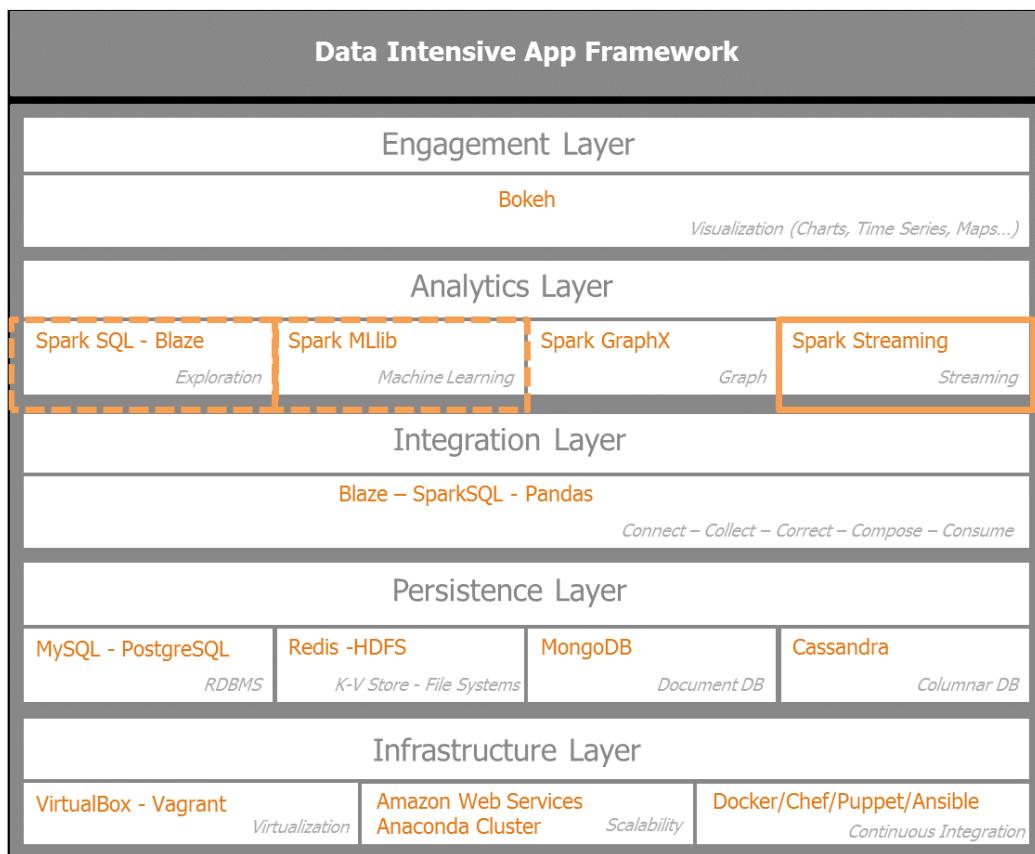
In this chapter, we will cover the following points:

- Analyzing a streaming application's architectural challenges, constraints, and requirements
- Processing live data from a TCP socket with Spark Streaming
- Connecting to the Twitter firehose directly to parse tweets in quasi real time
- Establishing a reliable, fault tolerant, scalable, high throughput, low latency integrated application using Spark, Kafka, and Flume
- Closing remarks on Lambda and Kappa architecture paradigms

# Laying the foundations of streaming architecture

As customary, let's first go back to our original drawing of the data-intensive apps architecture blueprint and highlight the Spark Streaming module that will be the topic of interest.

The following diagram sets the context by highlighting the Spark Streaming module and interactions with Spark SQL and Spark MLlib within the overall data-intensive apps framework.



Data flows from stock market time series, enterprise transactions, interactions, events, web traffic, click streams, and sensors. All events are time-stamped data and urgent. This is the case for fraud detection and prevention, mobile cross-sell and upsell, or traffic alerts. Those streams of data require immediate processing for monitoring purposes, such as detecting anomalies, outliers, spam, fraud, and intrusion; and also for providing basic statistics, insights, trends, and recommendations. In some cases, the summarized aggregated information is sufficient to be stored for later usage. From an architecture paradigm perspective, we are moving from a service-oriented architecture to an event-driven architecture.

Two models emerge for processing streams of data:

- Processing one record at a time as they come in. We do not buffer the incoming records in a container before processing them. This is the case of Twitter's Storm, Yahoo's S4, and Google's MillWheel.
- Micro-batching or batch computations on small intervals as performed by Spark Streaming and Storm Trident. In this case, we buffer the incoming records in a container according to the time window prescribed in the micro-batching settings.

Spark Streaming has often been compared against Storm. They are two different models of streaming data. Spark Streaming is based on micro-batching. Storm is based on processing records as they come in. Storm also offers a micro-batching option, with its Storm Trident option.

The driving factor in a streaming application is latency. Latency varies from the milliseconds range in the case of **RPC** (short for **Remote Procedure Call**) to several seconds or minutes for micro batching solution such as Spark Streaming.

RPC allows synchronous operations between the requesting programs waiting for the results from the remote server's procedure. Threads allow concurrency of multiple RPC calls to the server.

An example of software implementing a distributed RPC model is Apache Storm.

Storm implements stateless sub millisecond latency processing of unbounded tuples using topologies or directed acyclic graphs combining spouts as source of data streams and bolts for operations such as filter, join, aggregation, and transformation. Storm also implements a higher level abstraction called **Trident** which, similarly to Spark, processes data streams in micro batches.

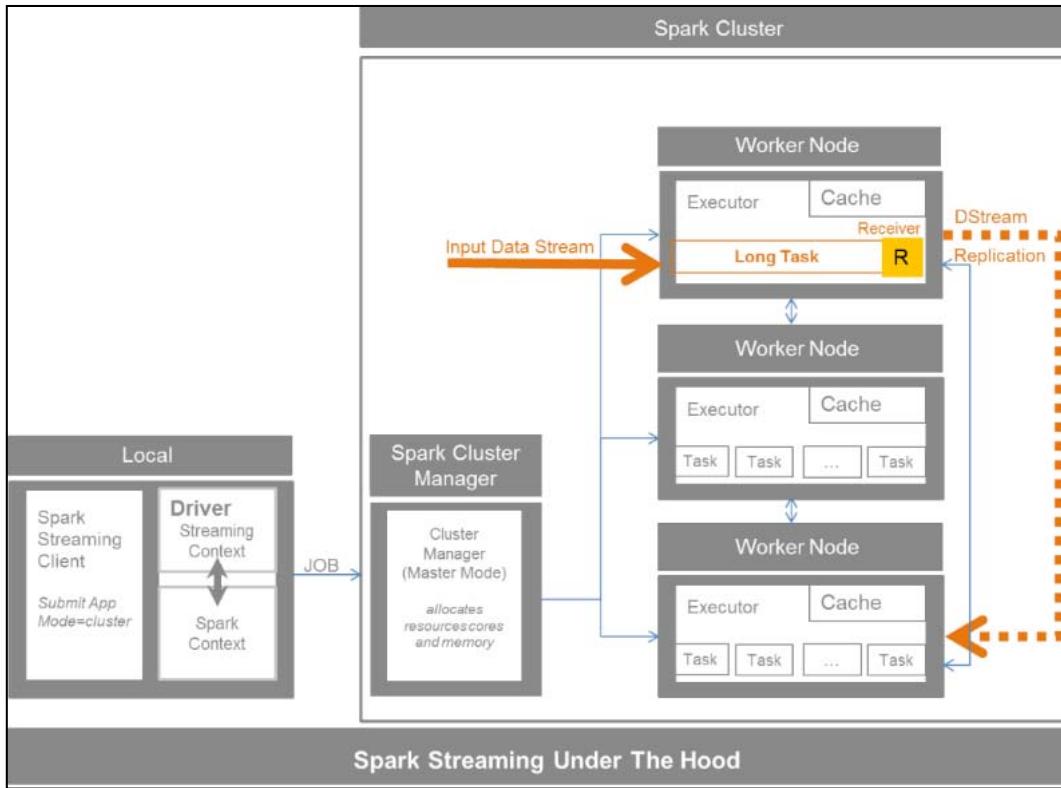
So, looking at the latency continuum, from sub millisecond to second, Storm is a good candidate. For seconds to minutes scale, Spark Streaming and Storm Trident are excellent fits. For several minutes onward, Spark and a NoSQL database such as Cassandra or HBase are adequate solutions. For ranges beyond the hour and with high volume of data, Hadoop is the ideal contender.

Although throughput is correlated to latency, it is not a simple inversely linear relationship. If processing a message takes 2 ms, which determines the latency, then one would assume the throughput is limited to 500 messages per sec. Batching messages allows for higher throughput if we allow our messages to be buffered for 8 ms more. With a latency of 10 ms, the system can buffer up to 10,000 messages. For a bearable increase in latency, we have substantially increased throughput. This is the magic of micro-batching that Spark Streaming exploits.

## **Spark Streaming inner working**

The Spark Streaming architecture leverages the Spark core architecture. It overlays on the **SparkContext** a **StreamingContext** as the entry point to the Stream functionality. The Cluster Manager will dedicate at least one worker node as Receiver, which will be an executor with a *long task* to process the incoming stream. The Executor creates Discretized Streams or DStreams from input data stream and replicates by default, the DStream to the cache of another worker. One receiver serves one input data stream. Multiple receivers improve parallelism and generate multiple DStreams that Spark can unite or join Resilient Distributed Datasets (RDD).

The following diagram gives an overview of the inner working of Spark Streaming. The client interacts with the Spark Cluster via the cluster manager, while Spark Streaming has a dedicated worker with a long running task ingesting the input data stream and transforming it into discretized streams or DStreams. The data is collected, buffered and replicated by a receiver and then pushed to a stream of RDDs.



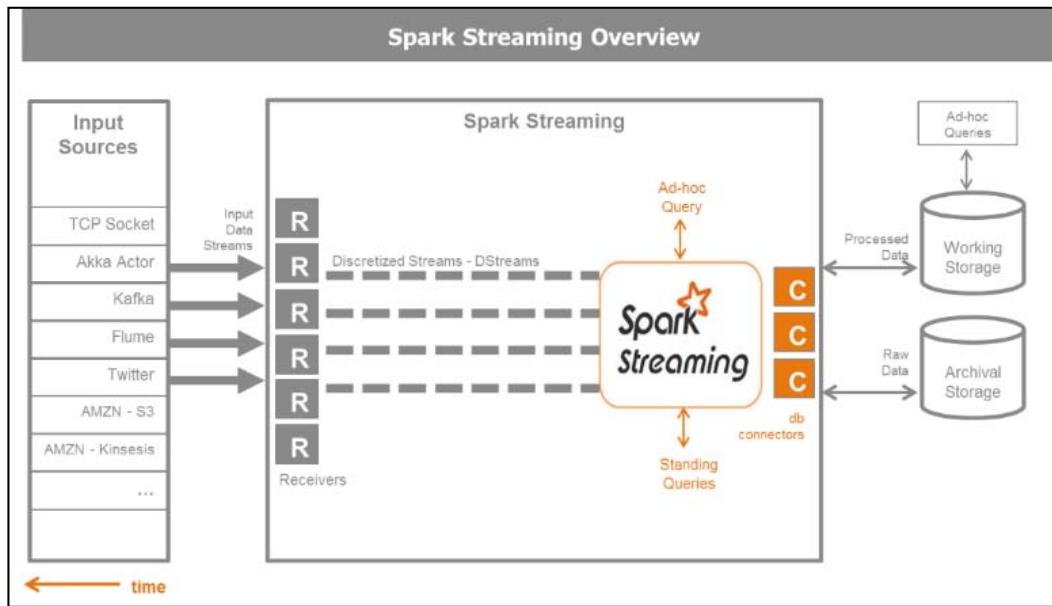
Spark receivers can ingest data from many sources. Core input sources range from TCP socket and HDFS/Amazon S3 to Akka Actors. Additional sources include Apache Kafka, Apache Flume, Amazon Kinesis, ZeroMQ, Twitter, and custom or user-defined receivers.

We distinguish between reliable resources that acknowledge receipt of data to the source and replication for possible resend, versus unreliable receivers who do not acknowledge receipt of the message. Spark scales out in terms of the number of workers, partition and receivers.

## *Streaming Live Data with Spark*

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The following diagram gives an overview of Spark Streaming with the possible sources and the persistence options:

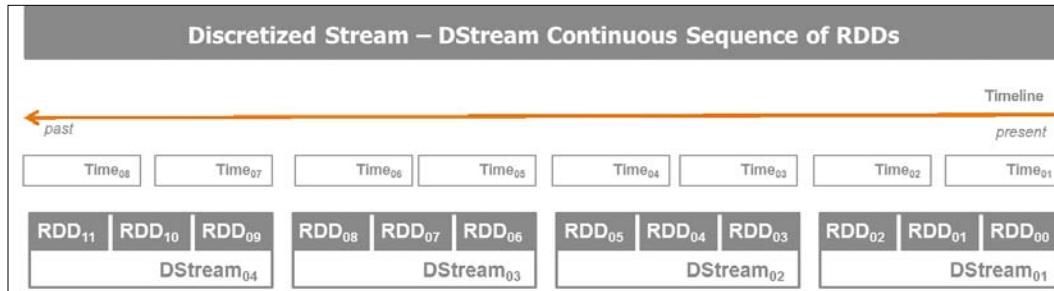


## **Going under the hood of Spark Streaming**

Spark Streaming is composed of Receivers and powered by Discretized Streams and Spark Connectors for persistence.

As for Spark Core, the essential data structure is the RDD, the fundamental programming abstraction for Spark Streaming is the Discretized Stream or DStream.

The following diagram illustrates the Discretized Streams as continuous sequences of RDDs. The batch intervals of DStream are configurable.



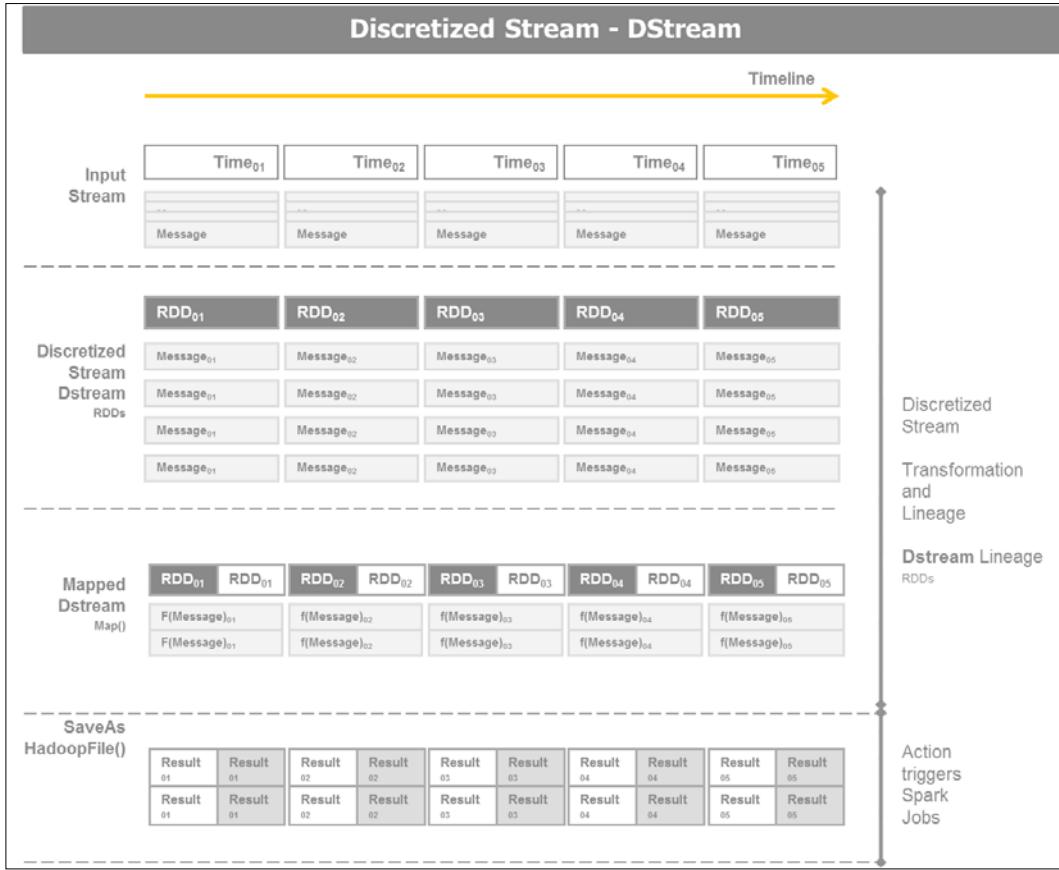
DStreams snapshots the incoming data in batch intervals. Those time steps typically range from 500 ms to several seconds. The underlying structure of a DStream is an RDD.

A DStream is essentially a continuous sequence of RDDs. This is powerful as it allows us to leverage from Spark Streaming all the traditional functions, transformations and actions available in Spark Core and allows us to dialogue with Spark SQL, performing SQL queries on incoming streams of data and Spark MLlib. Transformations similar to those on generic and key-value pair RDDs are applicable. The DStreams benefit from the inner RDDs lineage and fault tolerance. Additional transformation and output operations exist for discretized stream operations. Most generic operations on DStream are **transform** and **foreachRDD**.

The following diagram gives an overview of the lifecycle of DStreams. From creation of the micro-batches of messages materialized to RDDs on which `transformation` function and actions that trigger Spark jobs are applied. Breaking down the steps illustrated in the diagram, we read the diagram top down:

1. In the Input Stream, the incoming messages are buffered in a container according to the time window allocated for the micro-batching.
2. In the discretized stream step, the buffered micro-batches are transformed as DStream RDDs.
3. The Mapped DStream step is obtained by applying a transformation function to the original DStream. These first three steps constitute the transformation of the original data received in predefined time windows. As the underlying data structure is the RDD, we conserve the data lineage of the transformations.

- The final step is an action on the RDD. It triggers the Spark job.



Transformation can be stateless or stateful. *Stateless* means that no state is maintained by the program, while *stateful* means the program keeps a state, in which case previous transactions are remembered and may affect the current transaction. A stateful operation modifies or requires some state of the system, and a stateless operation does not.

Stateless transformations process each batch in a DStream at a time. Stateful transformations process multiple batches to obtain results. Stateful transformations require the checkpoint directory to be configured. Checkpointing is the main mechanism for fault tolerance in Spark Streaming to periodically save data and metadata about an application.

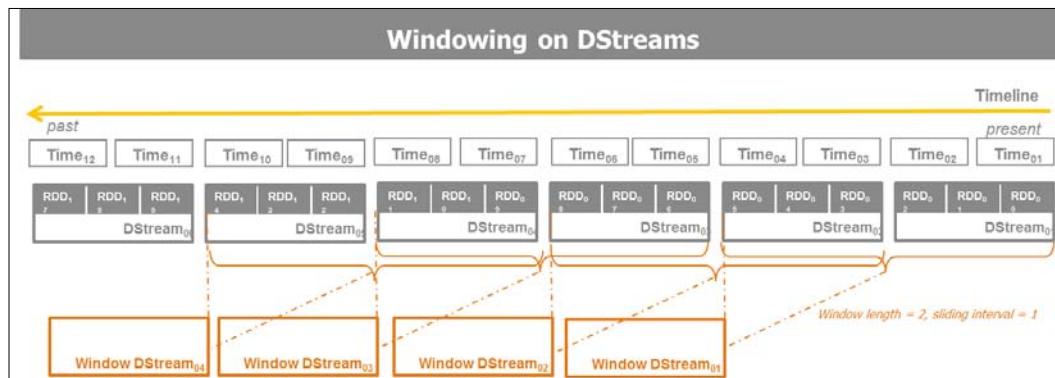
There are two types of stateful transformations for Spark Streaming:  
`updateStateByKey` and windowed transformations.

`updateStateByKey` are transformations that maintain state for each key in a stream of Pair RDDs. It returns a new *state* DStream where the state for each key is updated by applying the given function on the previous state of the key and the new values of each key. An example would be a running count of given hashtags in a stream of tweets.

Windowed transformations are carried over multiple batches in a sliding window. A window has a defined length or duration specified in time units. It must be a multiple of a DStream batch interval. It defines how many batches are included in a windowed transformation.

A window has a sliding interval or sliding duration specified in time units. It must be a multiple of a DStream batch interval. It defines how many batches to slide a window or how frequently to compute a windowed transformation.

The following schema depicts the windowing operation on DStreams to derive window DStreams with a given length and sliding interval:



A sample function is `countByWindow(windowLength, slideInterval)`. It returns a new DStream in which each RDD has a single element generated by counting the number of elements in a sliding window over this DStream. An illustration in this case would be a running count of given hashtags in a stream of tweets every 60 seconds. The window time frame is specified.

Minute scale window length is reasonable. Hour scale window length is not recommended as it is compute and memory intensive. It would be more convenient to aggregate the data in a database such as Cassandra or HBase.

Windowed transformations compute results based on window length and window slide interval. Spark performance is primarily affected by on window length, window slide interval, and persistence.

## Building in fault tolerance

Real-time stream processing systems must be operational 24/7. They need to be resilient to all sorts of failures in the system. Spark and its RDD abstraction are designed to seamlessly handle failures of any worker nodes in the cluster.

Main Spark Streaming fault tolerance mechanisms are check pointing, automatic driver restart, and automatic failover. Spark enables recovery from driver failure using check pointing, which preserves the application state.

Write ahead logs, reliable receivers, and file streams guarantees zero data loss as of Spark Version 1.2. Write ahead logs represent a fault tolerant storage for received data.

Failures require recomputing results. DStream operations have exactly-one semantics. Transformations can be recomputed multiple times but will yield the same result. DStream output operations have at least once semantics. Output operations may be executed multiple times.

## Processing live data with TCP sockets

As a stepping stone to the overall understanding of streaming operations, we will first experiment with TCP socket. TCP socket establishes two-way communication between client and server, and it can exchange data through the established connection. WebSocket connections are long lived, unlike typical HTTP connections. HTTP is not meant to keep an open connection from the server to push continuously data to the web browsers. Most web applications hence resorted to long polling via frequent **Asynchronous JavaScript (AJAX)** and XML requests. WebSockets, standardized and implemented in HTML5, are moving beyond web browsers and are becoming a cross-platform standard for real-time communication between client and server.

## Setting up TCP sockets

We create a TCP Socket Server by running `netcat`, a small utility found in most Linux systems, as a data server with the command `> nc -l k 9999`, where 9999 is the port where we are sending data:

```
#  
# Socket Server  
#  
an@an-VB:~$ nc -l k 9999
```

```
hello world
how are you
hello world
cool it works
```

Once netcat is running, we will open a second console with our Spark Streaming client to receive the data and process. As soon as the Spark Streaming client console is listening, we start typing the words to be processed, that is, hello world.

## Processing live data

We will be using the example program provided in the Spark bundle for Spark Streaming called `network_wordcount.py`. It can be found on the GitHub repository under [https://github.com/apache/spark/blob/master/examples/src/main/python/streaming/network\\_wordcount.py](https://github.com/apache/spark/blob/master/examples/src/main/python/streaming/network_wordcount.py). The code is as follows:

```
"""
Counts words in UTF8 encoded, '\n' delimited text received from the
network every second.

Usage: network_wordcount.py <hostname> <port>
<hostname> and <port> describe the TCP server that Spark Streaming
would connect to receive data.

To run this on your local machine, you need to first run a Netcat
server
`$ nc -lk 9999`
and then run the example
`$ bin/spark-submit examples/src/main/python/streaming/network_
wordcount.py localhost 9999`
"""

from __future__ import print_function

import sys

from pyspark import SparkContext
from pyspark.streaming import StreamingContext

if __name__ == "__main__":
    if len(sys.argv) != 3:
        print("Usage: network_wordcount.py <hostname> <port>",
file=sys.stderr)
        exit(-1)
    sc = SparkContext(appName="PythonStreamingNetworkWordCount")
    ssc = StreamingContext(sc, 1)
```

```
lines = ssc.socketTextStream(sys.argv[1], int(sys.argv[2]))
counts = lines.flatMap(lambda line: line.split(" "))\
    .map(lambda word: (word, 1))\
    .reduceByKey(lambda a, b: a+b)
counts.pprint()

ssc.start()
ssc.awaitTermination()
```

Here, we explain the steps of the program:

1. The code first initializes a Spark Streaming Context with the command:

```
ssc = StreamingContext(sc, 1)
```

2. Next, the streaming computation is set up.

3. One or more DStream objects that receive data are defined to connect to localhost or 127.0.0.1 on port 9999:

```
stream = ssc.socketTextStream("127.0.0.1", 9999)
```

4. The DStream computation is defined: transformations and output operations:

```
stream.map(x: lambda (x,1))
    .reduce(a+b)
    .print()
```

5. Computation is started:

```
ssc.start()
```

6. Program termination is pending manual or error processing completion:

```
ssc.awaitTermination()
```

7. Manual completion is an option when a completion condition is known:

```
ssc.stop()
```

We can monitor the Spark Streaming application by visiting the Spark monitoring home page at localhost:4040.

Here's the result of running the program and feeding the words on the netcat 4server console:

```
#
# Socket Client
# an@an-VB:~/spark/spark-1.5.0-bin-hadoop2.6$ ./bin/spark-submit
examples/src/main/python/streaming/network_wordcount.py localhost 9999
```

Run the Spark Streaming network\_count program by connecting to the socket localhost on port 9999:

```
an@an-VB:~/spark/spark-1.5.0-bin-hadoop2.6$ ./bin/spark-submit examples/
src/main/python/streaming/network_wordcount.py localhost 9999
-----
Time: 2015-10-18 20:06:06
-----
(u'world', 1)
(u'hello', 1)

-----
Time: 2015-10-18 20:06:07
-----
...
-----
Time: 2015-10-18 20:06:17
-----
(u'you', 1)
(u'how', 1)
(u'are', 1)

-----
Time: 2015-10-18 20:06:18
-----
...
-----
Time: 2015-10-18 20:06:26
-----
(u'', 1)
(u'world', 1)
(u'hello', 1)
```

```
-----  
Time: 2015-10-18 20:06:27  
-----  
 . . .  
-----
```

```
Time: 2015-10-18 20:06:37  
-----
```

```
(u'works', 1)  
(u'it', 1)  
(u'cool', 1)  
-----
```

```
Time: 2015-10-18 20:06:38  
-----
```

Thus, we have established connection through the socket on port 9999, streamed the data sent by the netcat server, and performed a word count on the messages sent.

## Manipulating Twitter data in real time

Twitter offers two APIs. One search API that essentially allows us to retrieve past tweets based on search terms. This is how we have been collecting our data from Twitter in the previous chapters of the book. Interestingly, for our current purpose, Twitter offers a live streaming API which allows to ingest tweets as they are emitted in the blogosphere.

## Processing Tweets in real time from the Twitter firehose

The following program connects to the Twitter firehose and processes the incoming tweets to exclude deleted or invalid tweets and parses on the fly only the relevant ones to extract screen name, the actual tweet, or tweet text, retweet count, geo-location information. The processed tweets are gathered into an RDD Queue by Spark Streaming and then displayed on the console at a one-second interval:

\*\*\*

```
Twitter Streaming API Spark Streaming into an RDD-Queue to process  
tweets live
```

```
Create a queue of RDDs that will be mapped/reduced one at a time in  
1 second intervals.
```

To run this example use

```
'$ bin/spark-submit examples/AN_Spark/AN_Spark_Code/s07_  
twitterstreaming.py'
```

```
"""  
#  
import time  
from pyspark import SparkContext  
from pyspark.streaming import StreamingContext  
import twitter  
import dateutil.parser  
import json  
  
# Connecting Streaming Twitter with Streaming Spark via Queue  
class Tweet(dict):  
    def __init__(self, tweet_in):  
        super(Tweet, self).__init__(self)  
        if tweet_in and 'delete' not in tweet_in:  
            self['timestamp'] = dateutil.parser.parse(tweet_  
in[u'created_at'])  
                .replace(tzinfo=None).isoformat()  
            self['text'] = tweet_in['text'].encode('utf-8')  
            #self['text'] = tweet_in['text']  
            self['hashtags'] = [x['text'].encode('utf-8') for x in  
tweet_in['entities']['hashtags']]  
                #self['hashtags'] = [x['text'] for x in tweet_  
in['entities']['hashtags']]  
            self['geo'] = tweet_in['geo']['coordinates'] if tweet_  
in['geo'] else None  
            self['id'] = tweet_in['id']  
            self['screen_name'] = tweet_in['user']['screen_name'].  
encode('utf-8')  
                #self['screen_name'] = tweet_in['user']['screen_name']  
            self['user_id'] = tweet_in['user']['id']  
  
    def connect_twitter():  
        twitter_stream = twitter.TwitterStream(auth=twitter.OAuth(  
            token = "get_your_own_credentials",  
            token_secret = "get_your_own_credentials",  
            consumer_key = "get_your_own_credentials",  
            consumer_secret = "get_your_own_credentials"))
```

```
    return twitter_stream

def get_next_tweet(twitter_stream):
    stream = twitter_stream.statuses.sample(block=True)
    tweet_in = None
    while not tweet_in or 'delete' in tweet_in:
        tweet_in = stream.next()
        tweet_parsed = Tweet(tweet_in)
    return json.dumps(tweet_parsed)

def process_rdd_queue(twitter_stream):
    # Create the queue through which RDDs can be pushed to
    # a QueueInputDStream
    rddQueue = []
    for i in range(3):
        rddQueue += [ssc.sparkContext.parallelize([get_next_
tweet(twitter_stream)], 5)]

    lines = ssc.queueStream(rddQueue)
    lines.pprint()

if __name__ == "__main__":
    sc = SparkContext(appName="PythonStreamingQueueStream")
    ssc = StreamingContext(sc, 1)

    # Instantiate the twitter_stream
    twitter_stream = connect_twitter()
    # Get RDD queue of the streams json or parsed
    process_rdd_queue(twitter_stream)

    ssc.start()
    time.sleep(2)
    ssc.stop(stopSparkContext=True, stopGraceFully=True)
```

When we run this program, it delivers the following output:

```
an@an-VB:~/spark/spark-1.5.0-bin-hadoop2.6$ bin/spark-submit examples/
AN_Spark/AN_Spark_Code/s07_twitterstreaming.py
-----
Time: 2015-11-03 21:53:14
-----
```

```
{"user_id": 3242732207, "screen_name": "cypugygoducu", "timestamp": "2015-11-03T20:53:04", "hashtags": [], "text": "RT @VIRalBuzzNewss: Our Distinctive Edition Holiday break Challenge Is In this article! Hooray!... - https://t.co/9d8wumrd5v https://t.co/\u2026", "geo": null, "id": 661647303678259200}
```

---

Time: 2015-11-03 21:53:15

---

```
{"user_id": 352673159, "screen_name": "melly_boo_orig", "timestamp": "2015-11-03T20:53:05", "hashtags": ["eminem"], "text": "#eminem https://t.co/G1EjPJnwxy", "geo": null, "id": 661647307847409668}
```

---

Time: 2015-11-03 21:53:16

---

```
{"user_id": 500620889, "screen_name": "NBAtheist", "timestamp": "2015-11-03T20:53:06", "hashtags": ["tehInterwebbies", "Nutters"], "text": "See? That didn't take long or any actual effort. This is #tehInterwebbies ... #Nutters Abound! https://t.co/QS8gLStYFO", "geo": null, "id": 661647312062709761}
```

So, we got an example of streaming tweets with Spark and processing them on the fly.

## Building a reliable and scalable streaming app

Ingesting data is the process of acquiring data from various sources and storing it for processing immediately or at a later stage. Data consuming systems are dispersed and can be physically and architecturally far from the sources. Data ingestion is often implemented manually with scripts and rudimentary automation. It actually calls for higher level frameworks like Flume and Kafka.

The challenges of data ingestion arise from the fact that the sources are physically spread out and are transient which makes the integration brittle. Data production is continuous for weather, traffic, social media, network activity, shop floor sensors, security, and surveillance. Ever increasing data volumes and rates coupled with ever changing data structure and semantics makes data ingestion ad hoc and error prone.

The aim is to become more agile, reliable, and scalable. Agility, reliability, and scalability of the data ingestion determine the overall health of the pipeline. Agility means integrating new sources as they arise and incorporating changes to existing sources as needed. In order to ensure safety and reliability, we need to protect the infrastructure against data loss and downstream applications from silent data corruption at ingress. Scalability avoids ingest bottlenecks while keeping cost tractable.

Ingest Mode	Description	Example
Manual or Scripted	File copy using command line interface or GUI interface	HDFS Client, Cloudera Hue
Batch Data Transport	Bulk data transport using tools	DistCp, Sqoop
Micro Batch	Transport of small batches of data	Sqoop, Sqoop2 Storm
Pipelining	Flow like transport of event streams	Flume Scribe
Message Queue	Publish Subscribe message bus of events	Kafka, Kinesis

In order to enable an event-driven business that is able to ingest multiple streams of data, process it in flight, and make sense of it all to get to rapid decisions, the key driver is the Unified Log.

A Unified Log is a centralized enterprise structured log available for real-time subscription. All the organization's data is put in a central log for subscription. Records are numbered beginning with zero in the order that they are written. It is also known as a commit log or journal. The concept of the *Unified Log* is the central tenet of the Kappa architecture.

The properties of the Unified Log are as follows:

- **Unified:** There is a single deployment for the entire organization
- **Append only:** Events are immutable and are appended
- **Ordered:** Each event has a unique offset within a shard
- **Distributed:** For fault tolerance purpose, the Unified Log is distributed redundantly on a cluster of computers
- **Fast:** The systems ingests thousands of messages per second

## Setting up Kafka

In order to isolate downstream particular consumption of data from the vagaries of upstream emission of data, we need to decouple the providers of data from the receivers or consumers of data. As they are living in two different worlds with different cycles and constraints, Kafka decouples the data pipelines.

Apache Kafka is a distributed publish subscribe messaging system rethought as a distributed commit log. The messages are stored by topic.

Apache Kafka has the following properties. It supports:

- High throughput for high volume of events feeds
- Real-time processing of new and derived feeds
- Large data backlogs and persistence for offline consumption
- Low latency as enterprise wide messaging system
- Fault tolerance thanks to its distributed nature

Messages are stored in partition with a unique sequential ID called `offset`. Consumers track their pointers via tuple of (`offset, partition, topic`).

Let's dive deeper in the anatomy of Kafka.

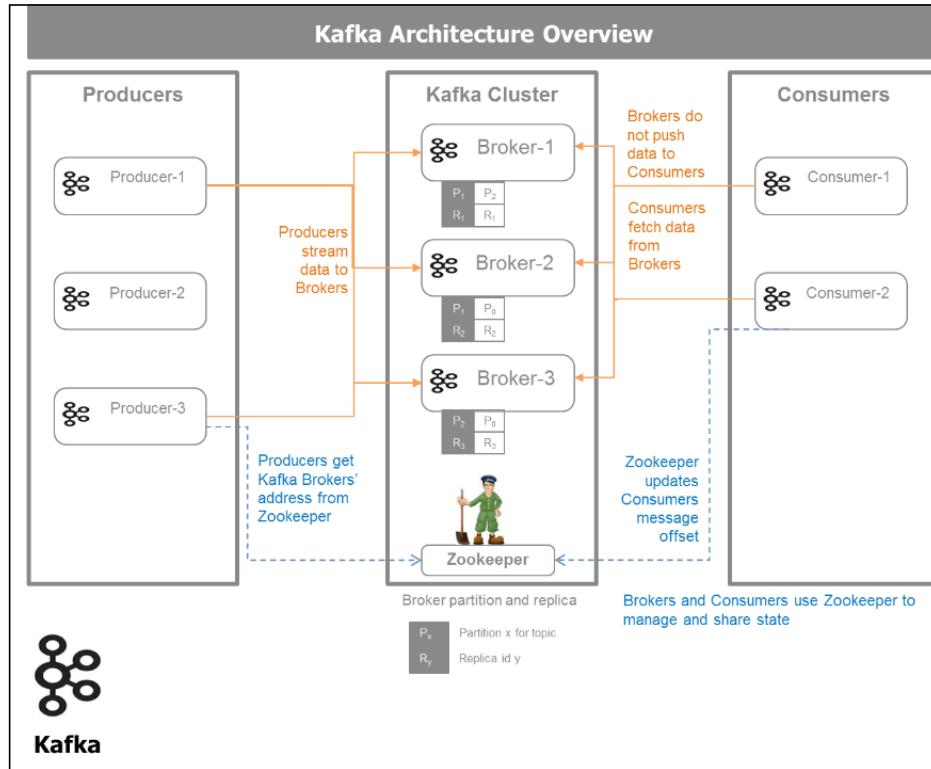
Kafka has essentially three components: *producers*, *consumers* and *brokers*. Producers push and write data to brokers. Consumers pull and read data from brokers. Brokers do not push messages to consumers. Consumers pull message from brokers. The setup is distributed and coordinated by Apache Zookeeper.

The brokers manage and store the data in topics. Topics are split in replicated partitions. The data is persisted in the broker, but not removed upon consumption, but until retention period. If a consumer fails, it can always go back to the broker to fetch the data.

Kafka requires Apache ZooKeeper. ZooKeeper is a high-performance coordination service for distributed applications. It centrally manages configuration, registry or naming service, group membership, lock, and synchronization for coordination between servers. It provides a hierarchical namespace with metadata, monitoring statistics, and state of the cluster. ZooKeeper can introduce brokers and consumers on the fly and then rebalances the cluster.

Kafka producers do not need ZooKeeper. Kafka brokers use ZooKeeper to provide general state information as well elect leader in case of failure. Kafka consumers use ZooKeeper to track message offset. Newer versions of Kafka will save the consumers to go through ZooKeeper and can retrieve the Kafka special topics information. Kafka provides automatic load balancing for producers.

The following diagram gives an overview of the Kafka setup:



## Installing and testing Kafka

We will download the Apache Kafka binaries from the dedicated web page at <http://kafka.apache.org/downloads.html> and install the software in our machine using the following steps:

1. Download the code.
2. Download the 0.8.2.0 release and un-tar it:

```
> tar -xzf kafka_2.10-0.8.2.0.tgz  
> cd kafka_2.10-0.8.2.0
```

3. Start zookeeper. Kafka uses ZooKeeper so we need to first start a ZooKeeper server. We will use the convenience script packaged with Kafka to get a single-node ZooKeeper instance.

```
> bin/zookeeper-server-start.sh config/zookeeper.properties  
an@an-VB:~/kafka/kafka_2.10-0.8.2.0$ bin/zookeeper-server-start.sh  
config/zookeeper.properties
```

```
[2015-10-31 22:49:14,808] INFO Reading configuration from:  
config/zookeeper.properties (org.apache.zookeeper.server.quorum.  
QuorumPeerConfig)  
[2015-10-31 22:49:14,816] INFO autopurge.snapRetainCount set to 3  
(org.apache.zookeeper.server.DatadirCleanupManager) ...
```

4. Now launch the Kafka server:

```
> bin/kafka-server-start.sh config/server.properties
```

```
an@an-VB:~/kafka/kafka_2.10-0.8.2.0$ bin/kafka-server-start.sh  
config/server.properties  
[2015-10-31 22:52:04,643] INFO Verifying properties (kafka.utils.  
VerifiableProperties)  
[2015-10-31 22:52:04,714] INFO Property broker.id is overridden to  
0 (kafka.utils.VerifiableProperties)  
[2015-10-31 22:52:04,715] INFO Property log.cleaner.enable is  
overridden to false (kafka.utils.VerifiableProperties)  
[2015-10-31 22:52:04,715] INFO Property log.dirs is overridden to  
/tmp/kafka-logs (kafka.utils.VerifiableProperties) [2013-04-22  
15:01:47,051] INFO Property socket.send.buffer.bytes is overridden  
to 1048576 (kafka.utils.VerifiableProperties)
```

5. Create a topic. Let's create a topic named test with a single partition and only one replica:

```
> bin/kafka-topics.sh --create --zookeeper localhost:2181  
--replication-factor 1 --partitions 1 --topic test
```

6. We can now see that topic if we run the list topic command:

```
> bin/kafka-topics.sh --list --zookeeper localhost:2181  
Test
```

```
an@an-VB:~/kafka/kafka_2.10-0.8.2.0$ bin/kafka-topics.sh --create  
--zookeeper localhost:2181 --replication-factor 1 --partitions 1  
--topic test
```

```
Created topic "test".
```

```
an@an-VB:~/kafka/kafka_2.10-0.8.2.0$ bin/kafka-topics.sh --list  
--zookeeper localhost:2181  
test
```

7. Check the Kafka installation by creating a producer and consumer. We first launch a producer and type a message in the console:

```
an@an-VB:~/kafka/kafka_2.10-0.8.2.0$ bin/kafka-console-producer.sh  
--broker-list localhost:9092 --topic test  
[2015-10-31 22:54:43,698] WARN Property topic is not valid (kafka.  
utils.VerifiableProperties)  
This is a message  
This is another message
```

8. We then launch a consumer to check that we receive the message:

```
an@an-VB:~$ cd kafka/  
an@an-VB:~/kafka$ cd kafka_2.10-0.8.2.0/  
an@an-VB:~/kafka/kafka_2.10-0.8.2.0$ bin/kafka-console-consumer.sh  
--zookeeper localhost:2181 --topic test --from-beginning  
This is a message  
This is another message
```

The messages were appropriately received by the consumer:

1. Check Kafka and Spark Streaming consumer. We will be using the Spark Streaming Kafka word count example provided in the Spark bundle. A word of caution: we have to bind the Kafka packages, --packages org.apache.spark:spark-streaming-kafka\_2.10:1.5.0, when we submit the Spark job. The command is as follows:

```
./bin/spark-submit --packages org.apache.spark:spark-streaming-  
kafka_2.10:1.5.0 \ examples/src/main/python/streaming/kafka_  
wordcount.py \  
localhost:2181 test
```

2. When we launch the Spark Streaming word count program with Kafka, we get the following output:

```
an@an-VB:~/spark/spark-1.5.0-bin-hadoop2.6$ ./bin/spark-submit  
--packages org.apache.spark:spark-streaming-kafka_2.10:1.5.0  
examples/src/main/python/streaming/kafka_wordcount.py  
localhost:2181 test
```

-----

Time: 2015-10-31 23:46:33

```
-----  
(u'', 1)  
(u'from', 2)  
(u'Hello', 2)  
(u'Kafka', 2)  
  
-----  
Time: 2015-10-31 23:46:34  
-----  
  
-----  
Time: 2015-10-31 23:46:35  
-----
```

3. Install the Kafka Python driver in order to be able to programmatically develop Producers and Consumers and interact with Kafka and Spark using Python. We will use the road-tested library from David Arthur, aka, Mumrah on GitHub (<https://github.com/mumrah>). We can pip install it as follows:

```
> pip install kafka-python  
an@an-VB:~$ pip install kafka-python  
Collecting kafka-python  
  Downloading kafka-python-0.9.4.tar.gz (63kB)  
  ...  
Successfully installed kafka-python-0.9.4
```

## Developing producers

The following program creates a Simple Kafka Producer that will emit the message *this is a message sent from the Kafka producer*: five times, followed by a time stamp every second:

```
#  
# kafka producer  
#  
#  
import time  
from kafka.common import LeaderNotAvailableError  
from kafka.client import KafkaClient  
from kafka.producer import SimpleProducer
```

```
from datetime import datetime

def print_response(response=None):
    if response:
        print('Error: {}'.format(response[0].error))
        print('Offset: {}'.format(response[0].offset))

def main():
    kafka = KafkaClient("localhost:9092")
    producer = SimpleProducer(kafka)
    try:
        time.sleep(5)
        topic = 'test'
        for i in range(5):
            time.sleep(1)
            msg = 'This is a message sent from the kafka producer: ' \
                  + str(datetime.now().time()) + ' -- '\
                  + str(datetime.now().strftime("%A, %d %B %Y\n\
%I:%M%p"))
            print_response(producer.send_messages(topic, msg))
    except LeaderNotAvailableError:
        # https://github.com/mumrah/kafka-python/issues/249
        time.sleep(1)
        print_response(producer.send_messages(topic, msg))

    kafka.close()

if __name__ == "__main__":
    main()
```

When we run this program, the following output is generated:

```
an@an-VB:~/spark/spark-1.5.0-bin-hadoop2.6/examples/AN_Spark/AN_Spark_
Code$ python s08_kafka_producer_01.py
Error: 0
Offset: 13
Error: 0
Offset: 14
Error: 0
Offset: 15
Error: 0
Offset: 16
```

```
Error: 0
Offset: 17
an@an-VB:~/spark/spark-1.5.0-bin-hadoop2.6/examples/AN_Spark/AN_Spark_
Code$
```

It tells us there were no errors and gives the offset of the messages given by the Kafka broker.

## Developing consumers

To fetch the messages from the Kafka brokers, we develop a Kafka consumer:

```
# kafka consumer
# consumes messages from "test" topic and writes them to console.
#
from kafka.client import KafkaClient
from kafka.consumer import SimpleConsumer

def main():
    kafka = KafkaClient("localhost:9092")
    print("Consumer established connection to kafka")
    consumer = SimpleConsumer(kafka, "my-group", "test")
    for message in consumer:
        # This will wait and print messages as they become available
        print(message)

if __name__ == "__main__":
    main()
```

When we run this program, we effectively confirm that the consumer received all the messages:

```
an@an-VB:~$ cd ~/spark/spark-1.5.0-bin-hadoop2.6/examples/AN_Spark/AN_Spark_
Code/
an@an-VB:~/spark/spark-1.5.0-bin-hadoop2.6/examples/AN_Spark/AN_Spark_
Code$ python s08_kafka_consumer_01.py
Consumer established connection to kafka
OffsetAndMessage(offset=13, message=Message(magic=0, attributes=0,
key=None, value='This is a message sent from the kafka producer:
11:50:17.867309Sunday, 01 November 2015 11:50AM'))
...
OffsetAndMessage(offset=17, message=Message(magic=0, attributes=0,
key=None, value='This is a message sent from the kafka producer:
11:50:22.051423Sunday, 01 November 2015 11:50AM'))
```

## Developing a Spark Streaming consumer for Kafka

Based on the example code provided in the Spark Streaming bundle, we will create a Spark Streaming consumer for Kafka and perform a word count on the messages stored with the brokers:

```
#  
# Kafka Spark Streaming Consumer  
#  
from __future__ import print_function  
  
import sys  
  
from pyspark import SparkContext  
from pyspark.streaming import StreamingContext  
from pyspark.streaming.kafka import KafkaUtils  
  
if __name__ == "__main__":  
    if len(sys.argv) != 3:  
        print("Usage: kafka_spark_consumer_01.py <zk> <topic>",  
file=sys.stderr)  
        exit(-1)  
  
    sc = SparkContext(appName="PythonStreamingKafkaWordCount")  
    ssc = StreamingContext(sc, 1)  
  
    zkQuorum, topic = sys.argv[1:]  
    kvs = KafkaUtils.createStream(ssc, zkQuorum, "spark-streaming-  
consumer", {topic: 1})  
    lines = kvs.map(lambda x: x[1])  
    counts = lines.flatMap(lambda line: line.split(" ")) \  
        .map(lambda word: (word, 1)) \  
        .reduceByKey(lambda a, b: a+b)  
    counts.pprint()  
  
    ssc.start()  
    ssc.awaitTermination()
```

Run this program with the following Spark submit command:

```
./bin/spark-submit --packages org.apache.spark:spark-streaming-  
kafka_2.10:1.5.0 examples/AN_Spark/AN_Spark_Code/s08_kafka_spark_  
consumer_01.py localhost:2181 test
```

We get the following output:

```
an@an-VB:~$ cd spark/spark-1.5.0-bin-hadoop2.6/
an@an-VB:~/spark/spark-1.5.0-bin-hadoop2.6$ ./bin/spark-submit \
>     --packages org.apache.spark:spark-streaming-kafka_2.10:1.5.0 \
>     examples/AN_Spark/AN_Spark_Code/s08_kafka_spark_consumer_01.py
localhost:2181 test
...
:: retrieving :: org.apache.spark#spark-submit-parent
  confs: [default]
    0 artifacts copied, 10 already retrieved (0kB/18ms)
-----
Time: 2015-11-01 12:13:16
-----

-----
Time: 2015-11-01 12:13:17
-----

-----
Time: 2015-11-01 12:13:18
-----

-----
Time: 2015-11-01 12:13:19
-----

(u'a', 5)
(u'the', 5)
(u'11:50AM', 5)
(u'from', 5)
(u'This', 5)
(u'11:50:21.044374Sunday,', 1)
(u'message', 5)
(u'11:50:20.036422Sunday,', 1)
(u'11:50:22.051423Sunday,', 1)
(u'11:50:17.867309Sunday,', 1)
...
-----

Time: 2015-11-01 12:13:20
-----

-----
Time: 2015-11-01 12:13:21
-----
```

## Exploring flume

Flume is a continuous ingestion system. It was originally designed to be a log aggregation system, but it evolved to handle any type of streaming event data.

Flume is a distributed, reliable, scalable, and available pipeline system for efficient collection, aggregation, and transport of large volumes of data. It has built-in support for contextual routing, filtering replication, and multiplexing. It is robust and fault tolerant, with tunable reliability mechanisms and many failover and recovery mechanisms. It uses a simple extensible data model that allows for real time analytic application.

Flume offers the following:

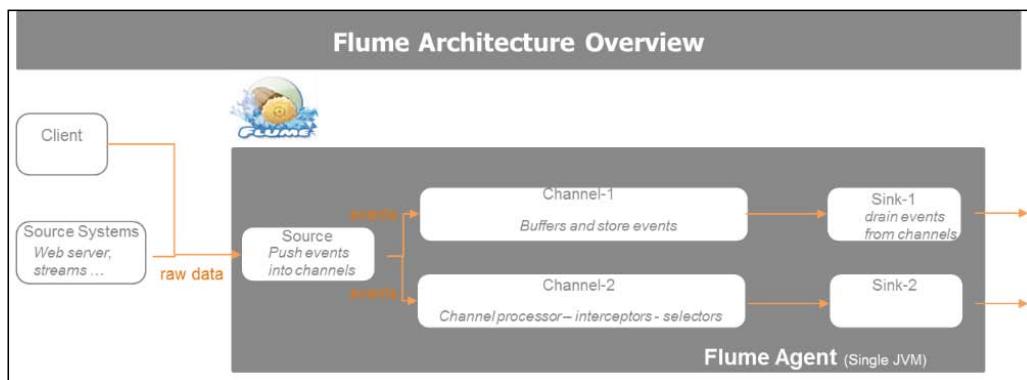
- Guaranteed delivery semantics
- Low latency reliable data transfer
- Declarative configuration with no coding required
- Extendable and customizable settings
- Integration with most commonly used end-points

The anatomy of Flume contains the following elements:

- **Event:** An event is the fundamental unit of data that is transported by Flume from source to destination. It is like a message with a byte array payload opaque to Flume and optional headers used for contextual routing.
- **Client:** A client produces and transmits events. A client decouples Flume from the data consumers. It is an entity that generates events and sends them to one or more agents. Custom client or Flume log4J append program or embedded application agent can be client.
- **Agent:** An agent is a container hosting sources, channels, sinks, and other elements that enable the transportation of events from one place to the other. It provides configuration, life cycle management and monitoring for hosted components. An agent is a physical Java virtual machine running Flume.
- **Source:** Source is the entity through which Flume receives events. Sources require at least one channel to function in order to either actively poll data or passively wait for data to be delivered to them. A variety of sources allow data to be collected, such as log4j logs and syslogs.
- **Sink:** Sink is the entity that drains data from the channel and delivers it to the next destination. A variety of sinks allow data to be streamed to a range of destinations. Sinks support serialization to user's format. One example is the HDFS sink that writes events to HDFS.

- **Channel:** Channel is the conduit between the source and the sink that buffers incoming events until drained by sinks. Sources feed events into the channel and the sinks drain the channel. Channels decouple the impedance of upstream and downstream systems. Burst of data upstream is damped by the channels. Failures downstream are transparently absorbed by the channels. Sizing the channel capacity to cope with these events is key to realizing these benefits. Channels offer two levels of persistence: either memory channel, which is volatile if the JVM crashes, or File channel backed by Write Ahead Log that stores the information to disk. Channels are fully transactional.

Let's illustrate all these concepts:



## Developing data pipelines with Flume, Kafka, and Spark

Building resilient data pipeline leverages the learnings from the previous sections. We are plumbing together data ingestion and transport with Flume, data brokerage with a reliable and sophisticated publish and subscribe messaging system such as Kafka, and finally process computation on the fly using Spark Streaming.

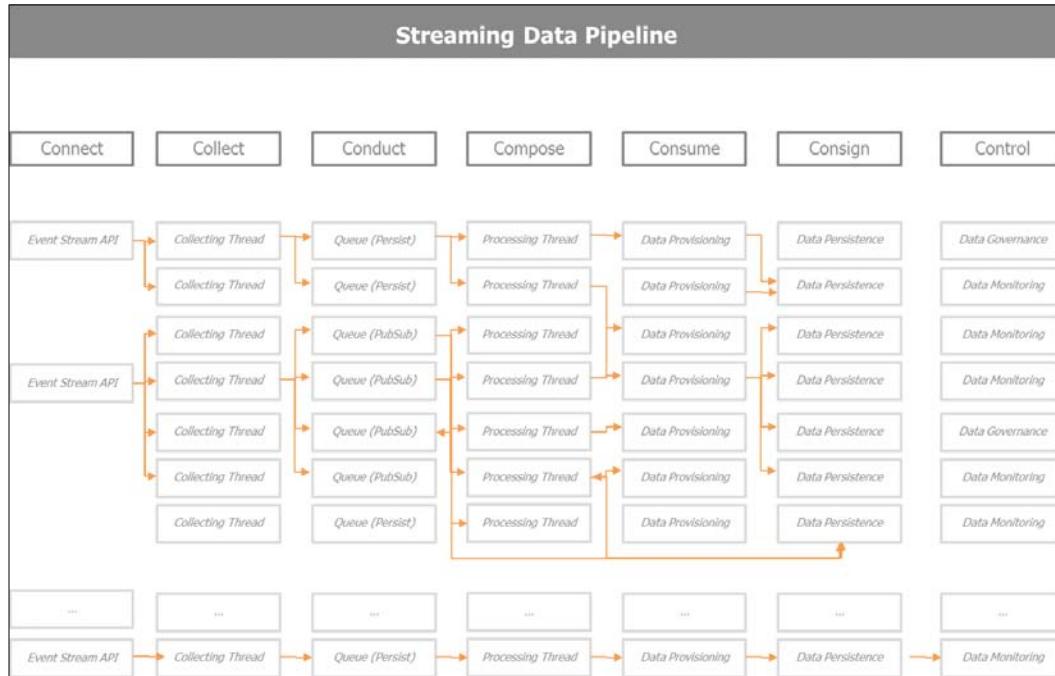
The following diagram illustrates the composition of streaming data pipelines as sequence of *connect*, *collect*, *conduct*, *compose*, *consume*, *consign*, and *control* activities. These activities are configurable based on the use case:

- Connect establishes the binding with the streaming API.
- Collect creates collection threads.
- Conduct decouples the data producers from the consumers by creating a buffer queue or publish-subscribe mechanism.

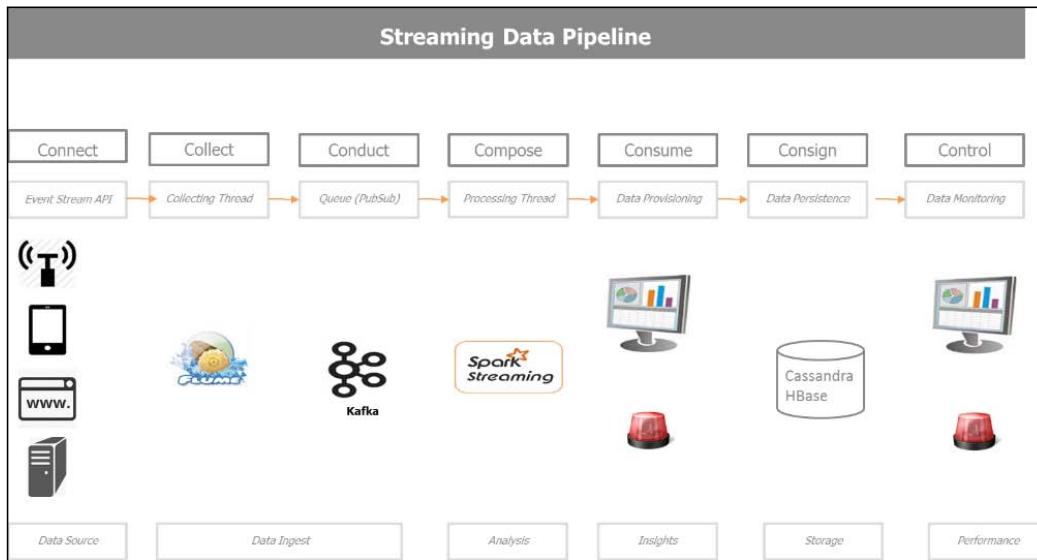
## *Streaming Live Data with Spark*

---

- Compose is focused on processing the data.
- Consume provisions the processed data for the consuming systems.  
Consign takes care of the data persistence.
- Control caters to governance and monitoring of the systems, data, and applications.

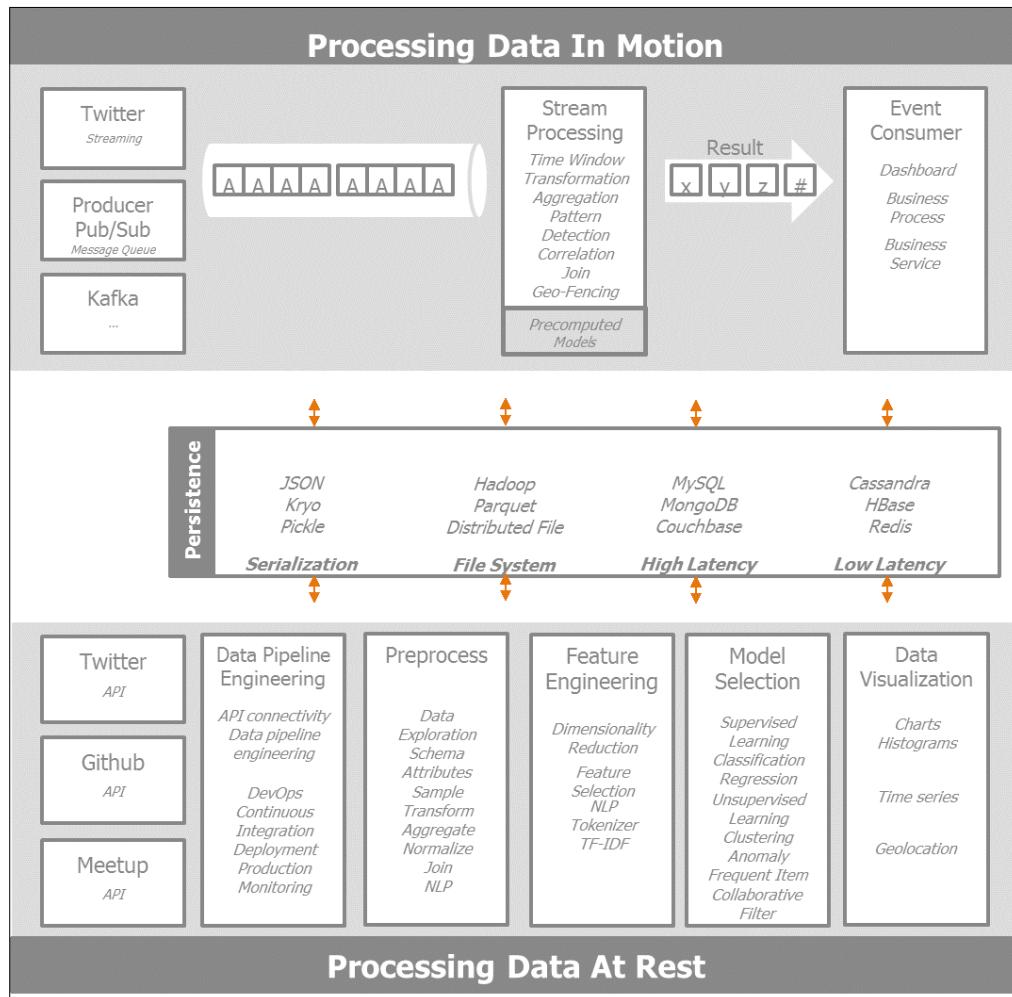


The following diagram illustrates the concepts of the streaming data pipelines with its key components: Spark Streaming, Kafka, Flume, and low latency databases. In the consuming or controlling applications, we are monitoring our systems in real time (depicted by a monitor) or sending real-time alerts (depicted by red lights) in case certain thresholds are crossed.



The following diagram illustrates Spark's unique ability to process in a single platform data in motion and data at rest while seamlessly interfacing with multiple persistence data stores as per the use case requirement.

This diagram brings in one unified whole all the concepts discussed up to now. The top part describes the streaming processing pipeline. The bottom part describes the batch processing pipeline. They both share a common persistence layer in the middle of the diagram depicting the various modes of persistence and serialization.



## Closing remarks on the Lambda and Kappa architecture

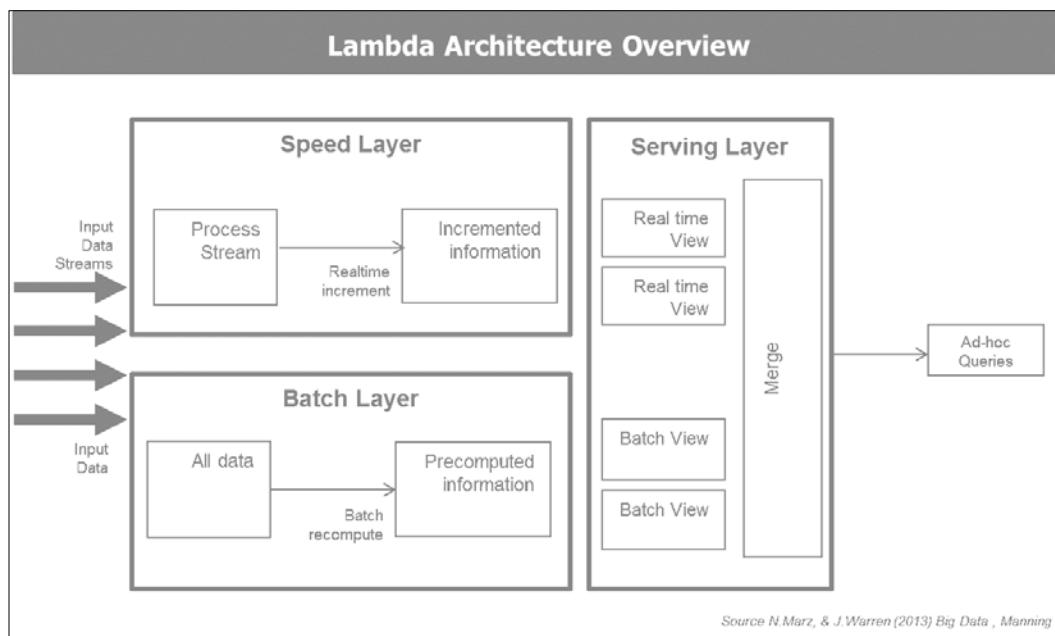
Two architecture paradigms are currently in vogue: the Lambda and Kappa architectures.

Lambda is the brainchild of the Storm creator and main committer, Nathan Marz. It essentially advocates building a functional architecture on all data. The architecture has two branches. The first is a batch arm envisioned to be powered by Hadoop, where historical, high-latency, high-throughput data are pre-processed and made ready for consumption. The real-time arm is envisioned to be powered by Storm, and it processes incrementally streaming data, derives insights on the fly, and feeds aggregated information back to the batch storage.

Kappa is the brainchild of one the main committer of Kafka, Jay Kreps, and his colleagues at Confluent (previously at LinkedIn). It is advocating a full streaming pipeline, effectively implementing, at the enterprise level, the unified log enounced in the previous pages.

## Understanding Lambda architecture

Lambda architecture combines batch and streaming data to provide a unified query mechanism on all available data. Lambda architecture envisions three layers: a batch layer where precomputed information are stored, a speed layer where real-time incremental information is processed as data streams, and finally the serving layer that merges batch and real-time views for ad hoc queries. The following diagram gives an overview of the Lambda architecture:



## Understanding Kappa architecture

The Kappa architecture proposes to drive the full enterprise in streaming mode. The Kappa architecture arose from a critique from Jay Kreps and his colleagues at LinkedIn at the time. Since then, they moved and created Confluent with Apache Kafka as the main enabler of the Kappa architecture vision. The basic tenet is to move in all streaming mode with a Unified Log as the main backbone of the enterprise information architecture.

A Unified Log is a centralized enterprise structured log available for real-time subscription. All the organization's data is put in a central log for subscription. Records are numbered beginning with zero so that they are written. It is also known as a commit log or journal. The concept of the Unified Log is the central tenet of the Kappa architecture.

The properties of the unified log are as follows:

- **Unified:** There is a single deployment for the entire organization
- **Append only:** Events are immutable and are appended
- **Ordered:** Each event has a unique offset within a shard
- **Distributed:** For fault tolerance purpose, the unified log is distributed redundantly on a cluster of computers
- **Fast:** The systems ingests thousands of messages per second

The following screenshot captures the moment Jay Kreps announced his reservations about the Lambda architecture. His main reservation about the Lambda architecture is implementing the same job in two different systems, Hadoop and Storm, with each of their specific idiosyncrasies, and with all the complexities that come along with it. Kappa architecture processes the real-time data and reprocesses historical data in the same framework powered by Apache Kafka.

Jay Kreps (@jaykreps) posted a tweet on July 2, 2014, at 6:23 AM. The tweet reads: "I wrote a new blog post on stream processing and an alternative to the Lambda Architecture [radar.oreilly.com/2014/07/questioning-the-lambda-architecture.html](http://radar.oreilly.com/2014/07/questioning-the-lambda-architecture.html)...". The tweet has 144 retweets and 174 favorites. Below the tweet is a summary of the blog post from O'Reilly RADAR, titled "Questioning the Lambda Architecture". The summary states: "Nathan Marz wrote a popular blog post describing an idea he called the Lambda Architecture (How to beat the CAP theorem). The Lambda Architecture is an approach to building..." and includes a link to [radar.oreilly.com](http://radar.oreilly.com). There are also social sharing icons for Twitter, Google+, Facebook, LinkedIn, and a magnifying glass.

## Summary

In this chapter, we laid out the foundations of streaming architecture apps and described their challenges, constraints, and benefits. We went under the hood and examined the inner working of Spark Streaming and how it fits with Spark Core and dialogues with Spark SQL and Spark MLlib. We illustrated the streaming concepts with TCP sockets, followed by live tweet ingestion and processing directly from the Twitter firehose. We discussed the notions of decoupling upstream data publishing from downstream data subscription and consumption using Kafka in order to maximize the resilience of the overall streaming architecture. We also discussed Flume – a reliable, flexible, and scalable data ingestion and transport pipeline system. The combination of Flume, Kafka, and Spark delivers unparalleled robustness, speed, and agility in an ever changing landscape. We closed the chapter with some remarks and observations on two streaming architectural paradigms, the Lambda and Kappa architectures.

The Lambda architecture combines batch and streaming data in a common query front-end. It was envisioned with Hadoop and Storm in mind initially. Spark has its own batch and streaming paradigms, and it offers a single environment with common code base to effectively bring this architecture paradigm to life.

The Kappa architecture promulgates the concept of the unified log, which creates an event-oriented architecture where all events in the enterprise are channeled in a centralized commit log that is available to all consuming systems in real time.

We are now ready for the visualization of the data collected and processed so far.

# 6

## Visualizing Insights and Trends

So far, we have focused on the collection, analysis, and processing of data from Twitter. We have set the stage to use our data for visual rendering and extracting insights and trends. We will give a quick lay of the land about visualization tools in the Python ecosystem. We will highlight Bokeh as a powerful tool for rendering and viewing large datasets. Bokeh is part of the Python Anaconda Distribution ecosystem.

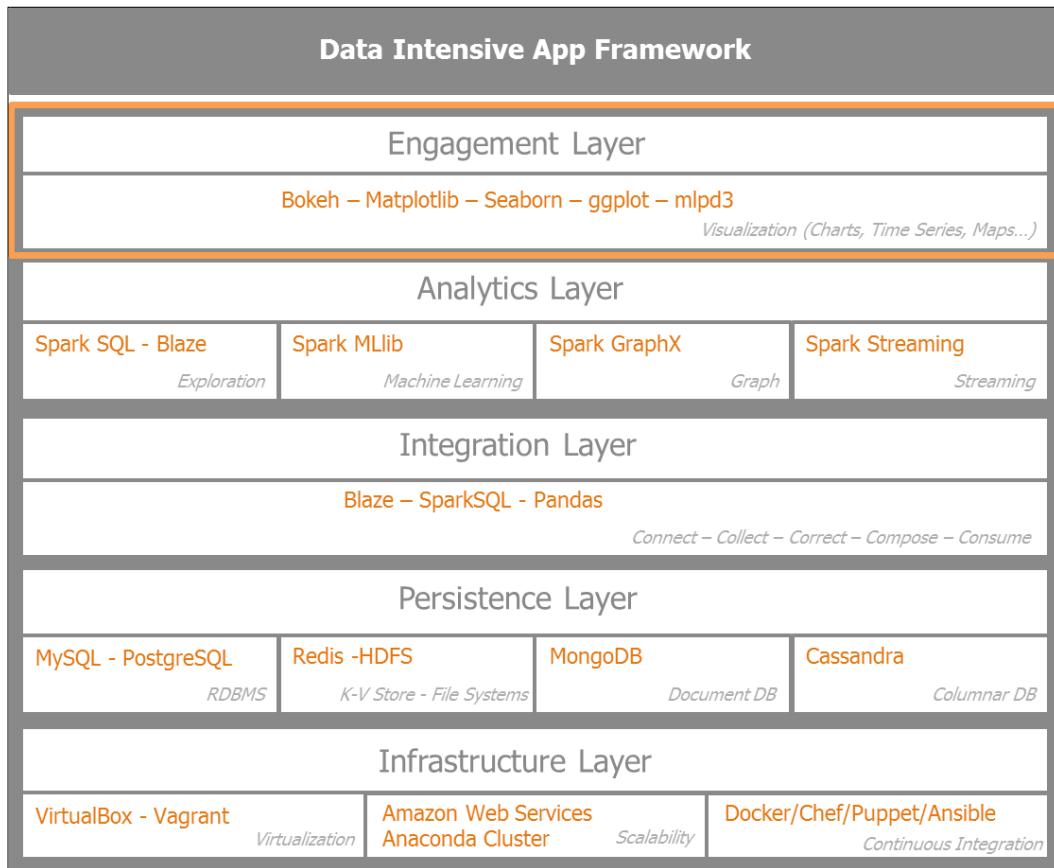
In this chapter, we will cover the following points:

- Gauging the key words and memes within a social network community using charts and wordcloud
- Mapping the most active location where communities are growing around certain themes or topics

### Revisiting the data-intensive apps architecture

We have reached the final layer of the data-intensive apps architecture: the engagement layer. This layer focuses on how to synthesize, emphasize, and visualize the key context relevant information for the data consumers. A bunch of numbers in a console will not suffice to engage with end-users. It is critical to present the mass of information in a rapid, digestible, and attractive fashion.

The following diagram sets the context of the chapter's focus highlighting the engagement layer.



For Python plotting and visualizations, we have quite a few tools and libraries. The most interesting and relevant ones for our purpose are the following:

- **Matplotlib** is the grandfather of the Python plotting libraries. Matplotlib was originally the brainchild of *John Hunter* who was an open source software proponent and established Matplotlib as one of the most prevalent plotting libraries both in the academic and the data scientific communities. Matplotlib allows the generation of plots, histograms, power spectra, bar charts, error charts, scatterplots, and so on. Examples can be found on the Matplotlib dedicated website at <http://matplotlib.org/examples/index.html>.

- **Seaborn**, developed by *Michael Waskom*, is a great library to quickly visualize statistical information. It is built on top of Matplotlib and integrates seamlessly with Pandas and the Python data stack, including Numpy. A gallery of graphs from Seaborn at <http://stanford.edu/~mwaskom/software/seaborn/examples/index.html> shows the potential of the library.
- **ggplot** is relatively new and aims to offer the equivalent of the famous ggplot2 from the R ecosystem for the Python data wranglers. It has the same look and feel of ggplot2 and uses the same grammar of graphics as expounded by Hadley Wickham. The ggplot the Python port is developed by the team at yhat. More information can be found at <http://ggplot.yhat.com>.
- **D3.js** is a very popular, JavaScript library developed by *Mike Bostock*. D3 stands for **Data Driven Documents** and brings data to life on any modern browser leveraging HTML, SVG, and CSS. It delivers dynamic, powerful, interactive visualizations by manipulating the DOM, the Document Object Model. The Python community could not wait to integrate D3 with Matplotlib. Under the impulse of Jake Vanderplas, mpld3 was created with the aim of bringing matplotlib to the browser. Examples graphics are hosted at the following address: <http://mpld3.github.io/index.html>.
- **Bokeh** aims to deliver high-performance interactivity over very large or streaming datasets whilst leveraging lot of the concepts of D3.js without the burden of writing some intimidating javascript and css code. Bokeh delivers dynamic visualizations on the browser with or without a server. It integrates seamlessly with Matplotlib, Seaborn and ggplot and renders beautifully in IPython notebooks or Jupyter notebooks. Bokeh is actively developed by the team at Continuum.io and is an integral part of the Anaconda Python data stack.

Bokeh server provides a full-fledged, dynamic plotting engine that materializes a reactive scene graph from JSON. It uses web sockets to keep state and update the HTML5 canvas using Backbone.js and Coffee-script under the hoods. Bokeh, as it is fueled by data in JSON, creates easy bindings for other languages such as R, Scala, and Julia.

This gives a high-level overview of the main plotting and visualization library. It is not exhaustive. Let's move to concrete examples of visualizations.

## Preprocessing the data for visualization

Before jumping into the visualizations, we will do some preparatory work on the data harvested:

```
In [16]:  
# Read harvested data stored in csv in a Panda DF  
import pandas as pd  
csv_in = '/home/an/spark/spark-1.5.0-bin-hadoop2.6/examples/AN_Spark/  
data/unq_tweetstxt.csv'  
pddf_in = pd.read_csv(csv_in, index_col=None, header=0, sep=';',  
encoding='utf-8')  
In [20]:  
print('tweets pandas dataframe - count:', pddf_in.count())  
print('tweets pandas dataframe - shape:', pddf_in.shape)  
print('tweets pandas dataframe - cols:', pddf_in.columns)  
('tweets pandas dataframe - count:', Unnamed: 0      7540  
id          7540  
created_at  7540  
user_id     7540  
user_name   7538  
tweet_text   7540  
dtype: int64)  
('tweets pandas dataframe - shape:', (7540, 6))  
('tweets pandas dataframe - cols:', Index([u'Unnamed: 0',  
u'id', u'created_at', u'user_id', u'user_name', u'tweet_text'],  
dtype='object'))
```

For the purpose of our visualization activity, we will use a dataset of 7,540 tweets. The key information is stored in the `tweet_text` column. We preview the data stored in the dataframe calling the `head()` function on the dataframe:

```
In [21]:  
pddf_in.head()  
Out[21]:  
    Unnamed: 0   id   created_at   user_id   user_name   tweet_text  
0      0  638830426971181057  Tue Sep 01 21:46:57 +0000 2015  
3276255125  True Equality  ernestsgantt: BeyHiveInFrance: 9_A_6:  
dreamint...  
1      1  638830426727911424  Tue Sep 01 21:46:57 +0000 2015  
3276255125  True Equality  ernestsgantt: BeyHiveInFrance:  
PhuketDailyNews...  
2      2  638830425402556417  Tue Sep 01 21:46:56 +0000 2015  
3276255125  True Equality  ernestsgantt: BeyHiveInFrance: 9_A_6:  
ernestsg...
```

---

```

3   3   638830424563716097 Tue Sep 01 21:46:56 +0000 2015
3276255125 True Equality ernestsgantt: BeyHiveInFrance:
PhuketDailyNews...
4   4   638830422256816132 Tue Sep 01 21:46:56 +0000 2015
3276255125 True Equality ernestsgantt: elsahe12: 9_A_6:
dreamintention...

```

We will now create some utility functions to clean up the tweet text and parse the twitter date. First, we import the Python regular expression regex library `re` and the time library to parse dates and time:

```
In [72]:
import re
import time
```

We create a dictionary of regex that will be compiled and then passed as function:

- **RT**: The first regex with key `RT` looks for the keyword `RT` at the beginning of the tweet text:

```
re.compile(r'^RT'),
```

- **ALNUM**: The second regex with key `ALNUM` looks for words including alphanumeric characters and underscore sign preceded by the @ symbol in the tweet text:

```
re.compile(r'(@[a-zA-Z0-9_]+)'),
```

- **HASHTAG**: The third regex with key `HASHTAG` looks for words including alphanumeric characters preceded by the # symbol in the tweet text:

```
re.compile(r'(#[\w\d]+)'),
```

- **SPACES**: The fourth regex with key `SPACES` looks for blank or line space characters in the tweet text:

```
re.compile(r'\s+'),
```

- **URL**: The fifth regex with key `URL` looks for url addresses including alphanumeric characters preceded with `https://` or `http://` markers in the tweet text:

```
re.compile(r'([https://|http://]?[a-zA-Z\d\//]+\[\.\]+\[a-zA-Z\d\//\.\]+)')
```

```
In [24]:
```

```
regexp = {"RT": r'^RT', "ALNUM": r'(@[a-zA-Z0-9_]+)', "HASHTAG": r'(#[\w\d]+)', "URL": r'([https://|http://]?[a-zA-Z\d\//]+\[\.\]+\[a-zA-Z\d\//\.\]+)', "SPACES": r'\s+'}
```

```
regexp = dict((key, re.compile(value)) for key, value in regexp.  
items())  
In [25]:  
regexp  
Out[25]:  
{'ALNUM': re.compile(r'(@[a-zA-Z0-9_]+)'),  
'HASHTAG': re.compile(r'(#[\w\d]+)'),  
'RT': re.compile(r'^RT'),  
'SPACES': re.compile(r'\s+'),  
'URL': re.compile(r'([https://|http://]?[a-zA-Z\d/] +[\.\.]+[a-zA-  
Z\d\.\.]+)')}
```

We create a utility function to identify whether a tweet is a retweet or an original tweet:

```
In [77]:  
def getAttributeRT(tweet):  
    """ see if tweet is a RT """  
    return re.search(regexp["RT"], tweet.strip()) != None
```

Then, we extract all user handles in a tweet:

```
def getUserHandles(tweet):  
    """ given a tweet we try and extract all user handles"""  
    return re.findall(regexp["ALNUM"], tweet)
```

We also extract all hashtags in a tweet:

```
def getHashtags(tweet):  
    """ return all hashtags"""  
    return re.findall(regexp["HASHTAG"], tweet)
```

Extract all URL links in a tweet as follows:

```
def getURLs(tweet):  
    """ URL : [http://] ? [\w\.\?/]+ """  
    return re.findall(regexp["URL"], tweet)
```

We strip all URL links and user handles preceded by @ sign in a tweet text. This function will be the basis of the wordcloud we will build soon:

```
def getTextNoURLsUsers(tweet):  
    """ return parsed text terms stripped of URLs and User Names in  
    tweet text  
        ' '.join(re.sub("(@[A-Za-z0-9]+) | ([^0-9A-Za-z \t]) | (\w+:\/\//\S+)", " ",x).split()) """  
    return ' '.join(re.sub("(@[A-Za-z0-9]+) | ([^0-9A-Za-z \t]) | (\w+:\/\//\S+)| (RT)", " ", tweet).lower().split())
```

We label the data so we can create groups of datasets for the wordcloud:

```
def setTag(tweet):
    """ set tags to tweet_text based on search terms from tags_list"""
    tags_list = ['spark', 'python', 'clinton', 'trump', 'gaga',
    'bieber']
    lower_text = tweet.lower()
    return filter(lambda x:x.lower() in lower_text,tags_list)
```

We parse the twitter date in the yyyy-mm-dd hh:mm:ss format:

```
def decode_date(s):
    """ parse Twitter date into format yyyy-mm-dd hh:mm:ss"""
    return time.strptime('%Y-%m-%d %H:%M:%S', time.strptime(s,'%a %b
    %d %H:%M:%S +0000 %Y'))
```

We preview the data prior to processing:

```
In [43]:
pddf_in.columns
Out[43]:
Index([u'Unnamed: 0', u'id', u'created_at', u'user_id', u'user_name',
u'tweet_text'], dtype='object')
In [45]:
# df.drop([Column Name or list],inplace=True,axis=1)
pddf_in.drop(['Unnamed: 0'], inplace=True, axis=1)
In [46]:
pddf_in.head()
Out[46]:
   id  created_at  user_id  user_name  tweet_text
0  638830426971181057  Tue Sep 01 21:46:57 +0000 2015  3276255125
True Equality  ernestsgantt: BeyHiveInFrance: 9_A_6: dreamint...
1  638830426727911424  Tue Sep 01 21:46:57 +0000 2015  3276255125
True Equality  ernestsgantt: BeyHiveInFrance: PhuketDailyNews...
2  638830425402556417  Tue Sep 01 21:46:56 +0000 2015  3276255125
True Equality  ernestsgantt: BeyHiveInFrance: 9_A_6: ernestsg...
3  638830424563716097  Tue Sep 01 21:46:56 +0000 2015  3276255125
True Equality  ernestsgantt: BeyHiveInFrance: PhuketDailyNews...
4  638830422256816132  Tue Sep 01 21:46:56 +0000 2015  3276255125
True Equality  ernestsgantt: elsahel12: 9_A_6: dreamintention...
```

We create new dataframe columns by applying the utility functions described. We create a new column for htag, user handles, URLs, the text terms stripped from URLs, and unwanted characters and the labels. We finally parse the date:

```
In [82] :  
pddf_in['htag'] = pddf_in.tweet_text.apply(getHashtags)  
pddf_in['user_handles'] = pddf_in.tweet_text.apply(getUserHandles)  
pddf_in['urls'] = pddf_in.tweet_text.apply(getURLs)  
pddf_in['txt_terms'] = pddf_in.tweet_text.apply(getTextNoURLsUsers)  
pddf_in['search_grp'] = pddf_in.tweet_text.apply(setTag)  
pddf_in['date'] = pddf_in.created_at.apply(decode_date)
```

The following code gives a quick snapshot of the newly generated dataframe:

```
In [83] :  
pddf_in[2200:2210]  
Out[83] :  
    id      created_at    user_id    user_name    tweet_text    htag    urls  
ptxt    tgrp    date    user_handles    txt_terms    search_grp  
2200    638242693374681088    Mon Aug 31 06:51:30 +0000 2015    19525954  
CENATIC    El impacto de @ApacheSpark en el procesamiento...  
[#sparkSpecial]    [://t.co/4PQmJNuEJB]    el impacto de en el  
procesamiento de datos y e...    [spark]    2015-08-31 06:51:30    [@  
ApacheSpark]    el impacto de en el procesamiento de datos y e...  
[spark]  
2201    638238014695575552    Mon Aug 31 06:32:55 +0000 2015    51115854  
Nawfal    Real Time Streaming with Apache Spark\nhttp://...    [#IoT,  
#SmartMelbourne, #BigData, #Apachespark]    [://t.co/GW5PaqwVab]    real  
time streaming with apache spark iot smar...    [spark]    2015-08-  
31 06:32:55    []    real time streaming with apache spark iot smar...  
[spark]  
2202    638236084124516352    Mon Aug 31 06:25:14 +0000 2015    62885987  
Mithun Katti    RT @differentsachin: Spark the flame of digita...  
[#IBMHackathon, #SparkHackathon, #ISLconnectIN...    []    spark  
the flame of digital india ibmhackathon ...    [spark]    2015-08-  
31 06:25:14    [@differentsachin, @ApacheSpark]    spark the flame of  
digital india ibmhackathon ...    [spark]  
2203    638234734649176064    Mon Aug 31 06:19:53 +0000 2015    140462395  
solaimurugan v    Installing @ApacheMahout with @ApacheSpark 1.4...  
[]    [1.4.1, ://t.co/3c5dGbfaZe.]    installing with 1 4 1 got many  
more issue whil...    [spark]    2015-08-31 06:19:53    [@ApacheMahout,  
@ApacheSpark]    installing with 1 4 1 got many more issue whil...  
[spark]
```

---

```

2204 638233517307072512 Mon Aug 31 06:15:02 +0000 2015
2428473836 Ralf Heineke RT @RomeoKienzler: Join me @velocityconf
on #m... [#machinelearning, #devOps, #Bl] [://t.co/U5xL7pYEmF]
join me on machinelearning based devops operat... [spark] 2015-08-
31 06:15:02 [@RomeoKienzler, @velocityconf, @ApacheSpark] join me
on machinelearning based devops operat... [spark]
2205 638230184848687106 Mon Aug 31 06:01:48 +0000 2015 289355748
Akim Boyko RT @databricks: Watch live today at 10am PT is...
[] [1.5, ://t.co/16cix6Asti] watch live today at 10am pt is 1
5 presented b... [spark] 2015-08-31 06:01:48 [@databricks, @
ApacheSpark, @databricks, @pwen...] watch live today at 10am pt is 1
5 presented b... [spark]
2206 638227830443110400 Mon Aug 31 05:52:27 +0000 2015 145001241
sachin aggarwal Spark the flame of digital India @ #IBMHackath...
[#IBMHackathon, #SparkHackathon, #ISLconnectIN... [://t.co/
C1AO3uNexe] spark the flame of digital india ibmhackathon ...
[spark] 2015-08-31 05:52:27 [@ApacheSpark] spark the flame of
digital india ibmhackathon ... [spark]
2207 638227031268810752 Mon Aug 31 05:49:16 +0000 2015 145001241
sachin aggarwal RT @pravin_gadakh: Imagine, innovate and Igni...
[#IBMHackathon, #ISLconnectIN2015] [] gadakh imagine innovate
and ignite digital ind... [spark] 2015-08-31 05:49:16 [@pravin_
gadakh, @ApacheSpark] gadakh imagine innovate and ignite digital
ind... [spark]
2208 638224591920336896 Mon Aug 31 05:39:35 +0000 2015 494725634
IBM Asia Pacific RT @sachinparmar: Passionate about Spark?? Hav...
[#IBMHackathon, #ISLconnectIN] [India..] passionate about spark
have dreams of clean sa... [spark] 2015-08-31 05:39:35 [@
sachinparmar] passionate about spark have dreams of clean sa...
[spark]
2209 638223327467692032 Mon Aug 31 05:34:33 +0000 2015
3158070968 Open Source India "Game Changer" #ApacheSpark speeds up
#bigdata... [#ApacheSpark, #bigdata] [://t.co/ieTQ9ocMim] game
changer apachespark speeds up bigdata pro... [spark] 2015-08-
31 05:34:33 [] game changer apachespark speeds up bigdata pro...
[spark]

```

We save the processed information in a CSV format. We have 7,540 records and 13 columns. In your case, the output will vary according to the dataset you chose:

```

In [84]:
f_name = '/home/an/spark/spark-1.5.0-bin-hadoop2.6/examples/AN_Spark/
data/unq_tweets_processed.csv'
pddf_in.to_csv(f_name, sep=';', encoding='utf-8', index=False)
In [85]:
pddf_in.shape
Out[85]:
(7540, 13)

```

## Gauging words, moods, and memes at a glance

We are now ready to proceed with building the wordclouds which will give us a sense of the important words carried in those tweets. We will create wordclouds for the datasets harvested. Wordclouds extract the top words in a list of words and create a scatterplot of the words where the size of the word is correlated to its frequency. The more frequent the word in the dataset, the bigger will be the font size in the wordcloud rendering. They include three very different themes and two competing or analogous entities. Our first theme is obviously data processing and analytics, with Apache Spark and Python as our entities. Our second theme is the 2016 presidential election campaign, with the two contenders: Hilary Clinton and Donald Trump. Our last theme is the world of pop music with Justin Bieber and Lady Gaga as the two exponents.

## Setting up wordcloud

We will illustrate the programming steps by analyzing the spark related tweets. We load the data and preview the dataframe:

```
In [21]:  
import pandas as pd  
csv_in = '/home/an/spark/spark-1.5.0-bin-hadoop2.6/examples/AN_Spark/  
data/spark_tweets.csv'  
tspark_df = pd.read_csv(csv_in, index_col=None, header=0, sep=',',  
encoding='utf-8')  
In [3]:  
tspark_df.head(3)  
Out[3]:  
    id      created_at    user_id    user_name    tweet_text    htag    urls  
    ptxt    tgrp      date    user_handles    txt_terms    search_grp  
0   638818911773856000    Tue Sep 01 21:01:11 +0000 2015    2511247075  
Noor Din    RT @kdnuggets: R leads RapidMiner, Python catc...  [#KDN]  
[://t.co/3bsaTT7eUs]    r leads rapidminer python catches up big data  
...  [spark, python]    2015-09-01 21:01:11  [@kdnuggets]    r leads  
rapidminer python catches up big data ...  [spark, python]  
1   622142176768737000    Fri Jul 17 20:33:48 +0000 2015    24537879  
IBM Cloudant  Be one of the first to sign-up for IBM Analyti...  
[#ApacheSpark, #SparkInsight]  [://t.co/C5TZpetVA6, ://t.co/  
R1L29DePaQ]  be one of the first to sign up for ibm analyti...  
[spark]    2015-07-17 20:33:48  []  be one of the first to sign up  
for ibm analyti...  [spark]
```

```
2 622140453069169000 Fri Jul 17 20:26:57 +0000 2015 515145898
Arno Candel Nice article on #apachespark, #hadoop and #dat...
[#apachespark, #hadoop, #datascience] [://t.co/IyF44pV0f3] nice
article on apachespark hadoop and datasci... [spark] 2015-07-
17 20:26:57 [@h2oai] nice article on apachespark hadoop and
datasci... [spark]
```



The wordcloud library we will use is the one developed by Andreas Mueller and hosted on his GitHub account at [https://github.com/amueller/word\\_cloud](https://github.com/amueller/word_cloud).



The library requires **PIL** (short for **Python Imaging Library**). PIL is easily installable by invoking `conda install pil`. PIL is a complex library to install and is not yet ported on Python 3.4, so we need to run a Python 2.7+ environment to be able to see our wordcloud:

```
#
# Install PIL (does not work with Python 3.4)
#
an@an-VB:~$ conda install pil

Fetching package metadata: ....
Solving package specifications: .....
Package plan for installation in environment /home/an/anaconda:

The following packages will be downloaded:
```

package	build
libpng-1.6.17	0 214 KB
freetype-2.5.5	0 2.2 MB
conda-env-2.4.4	py27_0 24 KB
pil-1.1.7	py27_2 650 KB
<hr/>	
Total:	3.0 MB

The following packages will be UPDATED:

```
conda-env: 2.4.2-py27_0 --> 2.4.4-py27_0
freetype: 2.5.2-0 --> 2.5.5-0
libpng: 1.5.13-1 --> 1.6.17-0
pil: 1.1.7-py27_1 --> 1.1.7-py27_2
```

```
Proceed ([y]/n)? y
```

Next, we install the wordcloud library:

```
#  
# Install wordcloud  
# Andreas Mueller  
# https://github.com/amueller/word_cloud/blob/master/wordcloud/  
wordcloud.py  
  
#  
  
an@an-VB:~$ pip install wordcloud  
Collecting wordcloud  
  Downloading wordcloud-1.1.3.tar.gz (163kB)  
    100% |██████████| 163kB 548kB/s  
Building wheels for collected packages: wordcloud  
  Running setup.py bdist_wheel for wordcloud  
    Stored in directory: /home/an/.cache/pip/wheels/32/a9/74/58e379e5dc6  
14bfd9dd9832d67608faac9b2bc6c194d6f6df5  
Successfully built wordcloud  
Installing collected packages: wordcloud  
Successfully installed wordcloud-1.1.3
```

## Creating wordclouds

At this stage, we are ready to invoke the wordcloud program with the generated list of terms from the tweet text.

Let's get started with the wordcloud program by first calling %matplotlib inline to display the wordcloud in our notebook:

```
In [4]:  
%matplotlib inline  
In [11]:
```

We convert the dataframe txt\_terms column into a list of words. We make sure it is all converted into the str type to avoid any bad surprises and check the list's first four records:

```
len(tspark_df['txt_terms'].tolist())  
Out[11]:  
2024  
In [22]:  
tspark_ls_str = [str(t) for t in tspark_df['txt_terms'].tolist()]  
In [14]:  
len(tspark_ls_str)  
Out[14]:
```

```
2024
In [15]:
tspark_ls_str[:4]
Out[15]:
['r leads rapidminer python catches up big data tools grow spark
ignites kdn',
 'be one of the first to sign up for ibm analytics for apachespark
today sparkinsight',
 'nice article on apachespark hadoop and datascience',
 'spark 101 running spark and mapreduce together in production
hadoopsummit2015 apachespark altiscale']
```

We first call the Matplotlib and the wordcloud libraries:

```
import matplotlib.pyplot as plt
from wordcloud import WordCloud, STOPWORDS
```

From the input list of terms, we create a unified string of terms separated by a whitespace as the input to the wordcloud program. The wordcloud program removes stopwords:

```
# join tweets to a single string
words = ' '.join(tspark_ls_str)

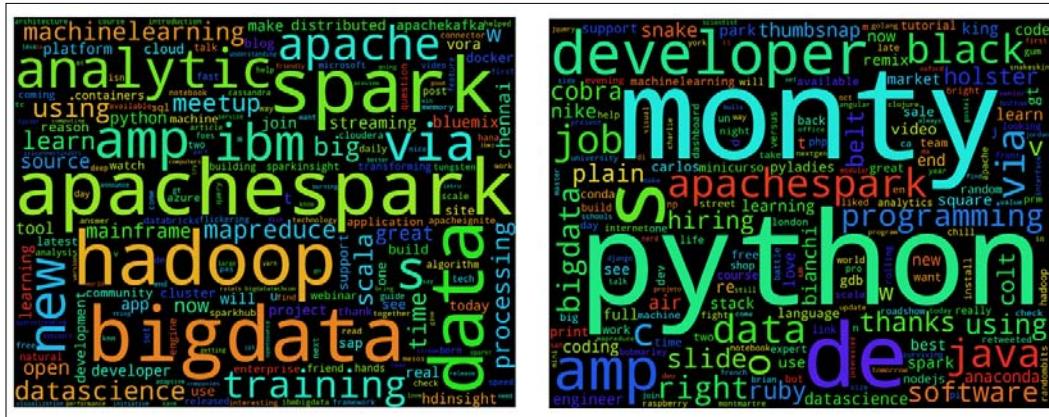
# create wordcloud
wordcloud = WordCloud(
    # remove stopwords
    stopwords=STOPWORDS,
    background_color='black',
    width=1800,
    height=1400
) .generate(words)

# render wordcloud image
plt.imshow(wordcloud)
plt.axis('off')

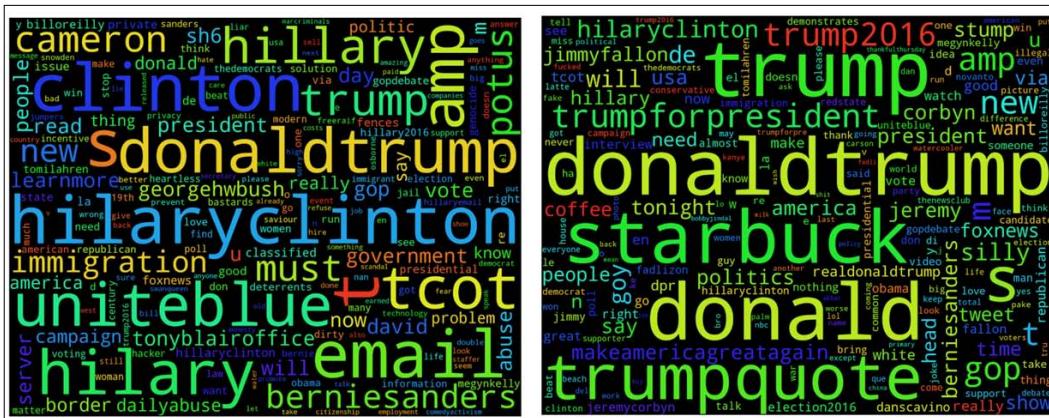
# save wordcloud image on disk
plt.savefig('./spark_tweets_wordcloud_1.png', dpi=300)

# display image in Jupyter notebook
plt.show()
```

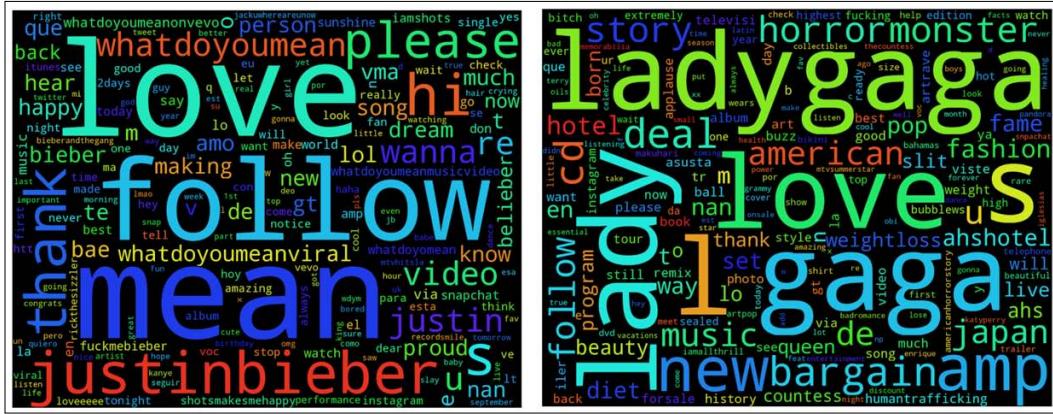
Here, we can visualize the wordclouds for Apache Spark and Python. Clearly, in the case of Spark, *Hadoop*, *big data*, and *analytics* are the memes, while Python recalls the root of its name Monty Python with a strong focus on *developer*, *apache spark*, and programming with some hints to java and ruby.



We can also get a glimpse in the following wordclouds of the words preoccupying the North American 2016 presidential election candidates: Hilary Clinton and Donald Trump. Seemingly Hilary Clinton is overshadowed by the presence of her opponents Donald Trump and Bernie Sanders, while Trump is heavily centered only on himself:



Interestingly, in the case of Justin Bieber and Lady Gaga, the word *love* appears. In the case of Bieber, *follow* and *belieber* are key words, while *diet*, *weight loss*, and *fashion* are the preoccupations for the Lady Gaga crowd.



# Geo-locating tweets and mapping meetups

Now, we will dive into the creation of interactive maps with Bokeh. First, we create a world map where we geo-locate sample tweets and, on moving our mouse over these locations, we can see the users and their respective tweets in a hover box.

The second map is focused on mapping upcoming meetups in London. It could be an interactive map that would act as a reminder of date, time, and location for upcoming meetups in a specific city.

# Geo-locating tweets

The objective is to create a world map scatter plot of the locations of important tweets on the map, and the tweets and authors are revealed on hovering over these points. We will go through three steps to build this interactive visualization:

1. Create the background world map by first loading a dictionary of all the world country boundaries defined by their respective longitude and latitudes.
  2. Load the important tweets we wish to geo-locate with their respective coordinates and authors.
  3. Finally, scatter plot on the world map the tweets coordinates and activate the hover tool to visualize interactively the tweets and author on the highlighted dots on the map.

In step one, we create a Python list called data that will contain all the world countries boundaries with their respective latitude and longitude:

```
In [4]:  
#  
# This module exposes geometry data for World Country Boundaries.  
#  
import csv  
import codecs  
import gzip  
import xml.etree.cElementTree as et  
import os  
from os.path import dirname, join  
  
nan = float('NaN')  
__file__ = os.getcwd()  
  
data = {}  
with gzip.open(join(dirname(__file__), 'AN_Spark/data/World_Country_  
Boundaries.csv.gz')) as f:  
    decoded = codecs.iterdecode(f, "utf-8")  
    next(decoded)  
    reader = csv.reader(decoded, delimiter=',', quotechar='''')  
    for row in reader:  
        geometry, code, name = row  
        xml = et.fromstring(geometry)  
        lats = []  
        lons = []  
        for i, poly in enumerate(xml.findall('.//outerBoundaryIs/  
LinearRing/coordinates')):  
            if i > 0:  
                lats.append(nan)  
                lons.append(nan)  
            coords = (c.split(',')[:2] for c in poly.text.split())  
            lat, lon = list(zip(*[(float(lat), float(lon)) for lon,  
lat in  
                    coords]))  
            lats.extend(lat)  
            lons.extend(lon)  
        data[code] = {  
            'name' : name,  
            'lats' : lats,  
            'lons' : lons,  
        }  
    }
```

```
In [5]:  
len(data)  
Out[5]:  
235
```

In step two, we load a sample set of important tweets that we wish to visualize with their respective geo-location information:

```
In [69]:  
# data  
#  
#  
In [8]:  
import pandas as pd  
csv_in = '/home/an/spark/spark-1.5.0-bin-hadoop2.6/examples/AN_Spark/  
data/spark_tweets_20.csv'  
t20_df = pd.read_csv(csv_in, index_col=None, header=0, sep=',',  
encoding='utf-8')  
In [9]:  
t20_df.head(3)  
Out[9]:  
   id created_at user_id      user_name tweet_text htag      urls  
ptxt    tgrp      date     user_handles  txt_terms search_grp  lat  
lon  
0  638818911773856000 Tue Sep 01 21:01:11 +0000 2015 2511247075  
Noor Din      RT @kdnuggets: R leads RapidMiner, Python catc... [#KDN]  
[://t.co/3bsaTT7eUs]      r leads rapidminer python catches up big data  
... [spark, python]      2015-09-01 21:01:11      [@kdnuggets]      r  
leads rapidminer python catches up big data ...      [spark, python]  
37.279518      -121.867905  
1  622142176768737000 Fri Jul 17 20:33:48 +0000 2015 24537879  
IBM Cloudant      Be one of the first to sign-up for IBM Analyti...  
[#ApacheSpark, #SparkInsight]      [://t.co/C5TZpetVA6, ://t.co/  
R1L29DePaQ]      be one of the first to sign up for ibm analyti...  
[spark]      2015-07-17 20:33:48      [] be one of the first to sign up  
for ibm analyti...      [spark]      37.774930      -122.419420  
2  622140453069169000 Fri Jul 17 20:26:57 +0000 2015 515145898  
Arno Candel      Nice article on #apachespark, #hadoop and #dat...  
[#apachespark, #hadoop, #datascience]      [://t.co/IyF44pV0f3]      nice  
article on apachespark hadoop and datasci...      [spark]      2015-07-  
17 20:26:57      [@h2oai]      nice article on apachespark hadoop and  
datasci...      [spark]      51.500130      -0.126305  
In [98]:  
len(t20_df.user_id.unique())  
Out[98]:  
19  
In [17]:
```

## *Visualizing Insights and Trends*

---

```
t20_geo = t20_df[['date', 'lat', 'lon', 'user_name', 'tweet_text']]  
In [24]:  
#  
t20_geo.rename(columns={'user_name':'user', 'tweet_text':'text' },  
inplace=True)  
In [25]:  
t20_geo.head(4)  
Out[25]:  
    date      lat      lon     user      text  
0  2015-09-01  21:01:11   37.279518 -121.867905    Noor Din      RT  
@kdnuggets: R leads RapidMiner, Python catc...  
1  2015-07-17  20:33:48   37.774930 -122.419420    IBM Cloudant  
Be one of the first to sign-up for IBM Analyti...  
2  2015-07-17  20:26:57   51.500130 -0.126305    Arno Candel  
Nice article on #apachespark, #hadoop and #dat...  
3  2015-07-17  19:35:31   51.500130 -0.126305    Ira Michael  
Blonder      Spark 101: Running Spark and #MapReduce togeth...  
In [22]:  
df = t20_geo  
#
```

In step three, we first imported all the necessary Bokeh libraries. We will instantiate the output in the Jupyter Notebook. We get the world countries boundary information loaded. We get the geo-located tweet data. We instantiate the Bokeh interactive tools such as wheel and box zoom as well as the hover tool.

```
In [29]:  
#  
# Bokeh Visualization of tweets on world map  
#  
from bokeh.plotting import *  
from bokeh.models import HoverTool, ColumnDataSource  
from collections import OrderedDict  
  
# Output in Jupiter Notebook  
output_notebook()  
  
# Get the world map  
world_countries = data.copy()  
  
# Get the tweet data  
tweets_source = ColumnDataSource(df)  
  
# Create world map
```

```
countries_source = ColumnDataSource(data= dict(
    countries_xs=[world_countries[code]['lons'] for code in world_
countries],
    countries_ys=[world_countries[code]['lats'] for code in world_
countries],
    country = [world_countries[code]['name'] for code in world_
countries],
))

# Instantiate the bokeh interactive tools
TOOLS="pan,wheel_zoom,box_zoom,reset,resize,hover,save"
```

We are now ready to layer the various elements gathered into an object figure called **p**. Define the title, width, and height of **p**. Attach the tools. Create the world map background by patches with a light background color and borders. Scatter plot the tweets according to their respective geo-coordinates. Then, activate the hover tool with the users and their respective tweet. Finally, render the picture on the browser. The code is as follows:

```
# Instantiate the figure object
p = figure(
    title="%s tweets " %(str(len(df.index))),
    title_text_font_size="20pt",
    plot_width=1000,
    plot_height=600,
    tools=TOOLS)

# Create world patches background
p.patches(xs="countries_xs", ys="countries_ys", source = countries_
source, fill_color="#F1EEF6", fill_alpha=0.3,
          line_color="#999999", line_width=0.5)

# Scatter plots by longitude and latitude
p.scatter(x="lon", y="lat", source=tweets_source, fill_
color="#FF0000", line_color="#FF0000")
#

# Activate hover tool with user and corresponding tweet information
hover = p.select(dict(type=HoverTool))
hover.point_policy = "follow_mouse"
hover.tooltips = OrderedDict([
    ("user", "@user"),
    ("tweet", "@text"),
])
]

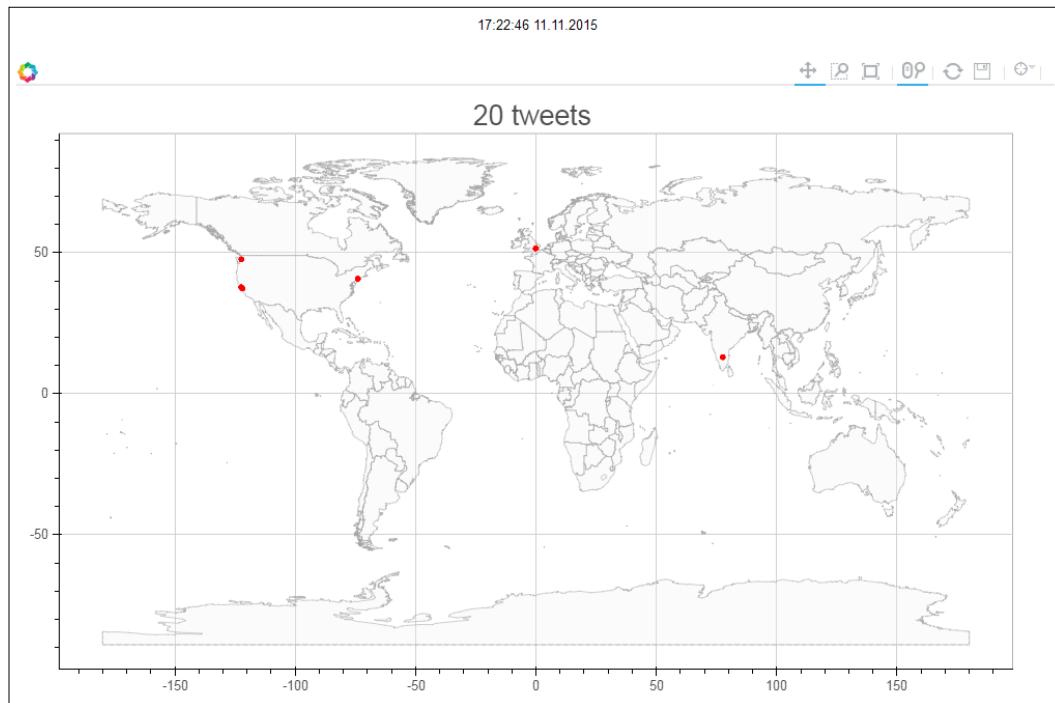
# Render the figure on the browser
```

```
show(p)
BokehJS successfully loaded.

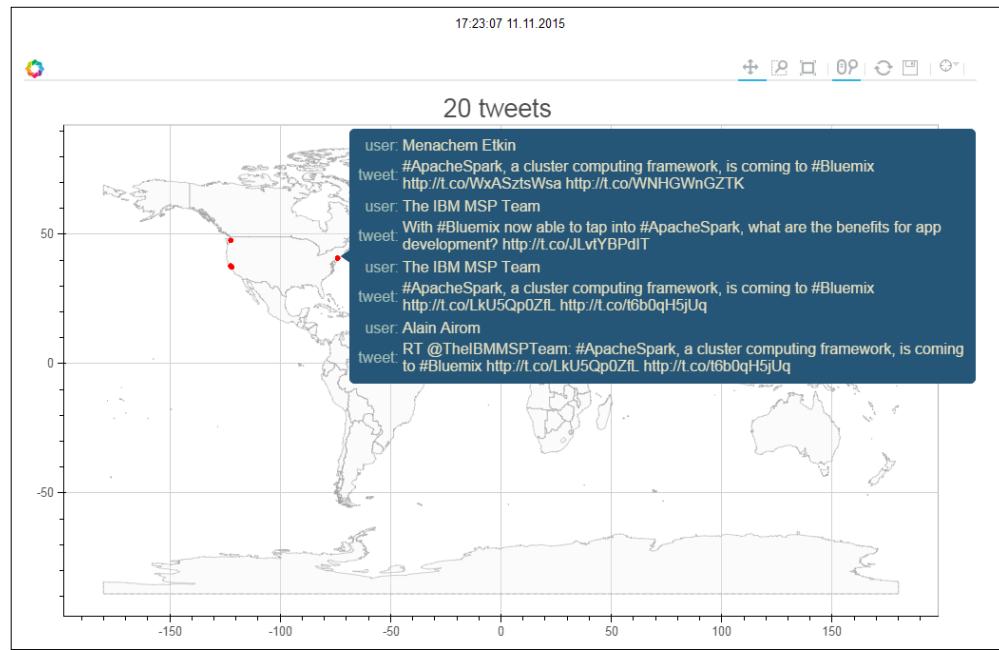
inspect

#
```

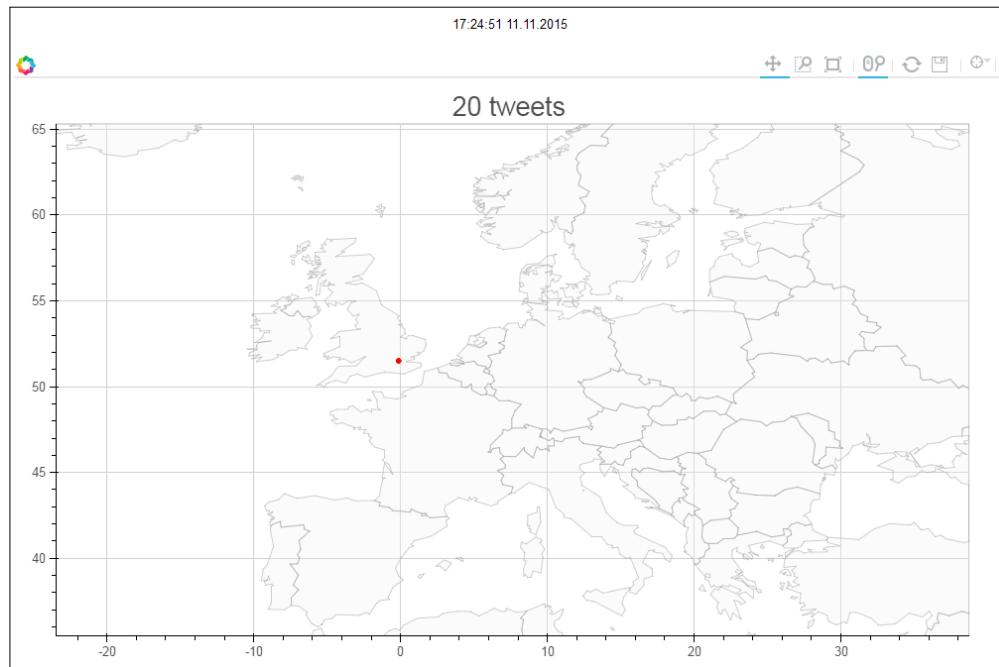
The following code gives an overview of the world map with the red dots representing the locations of the tweets' origins:



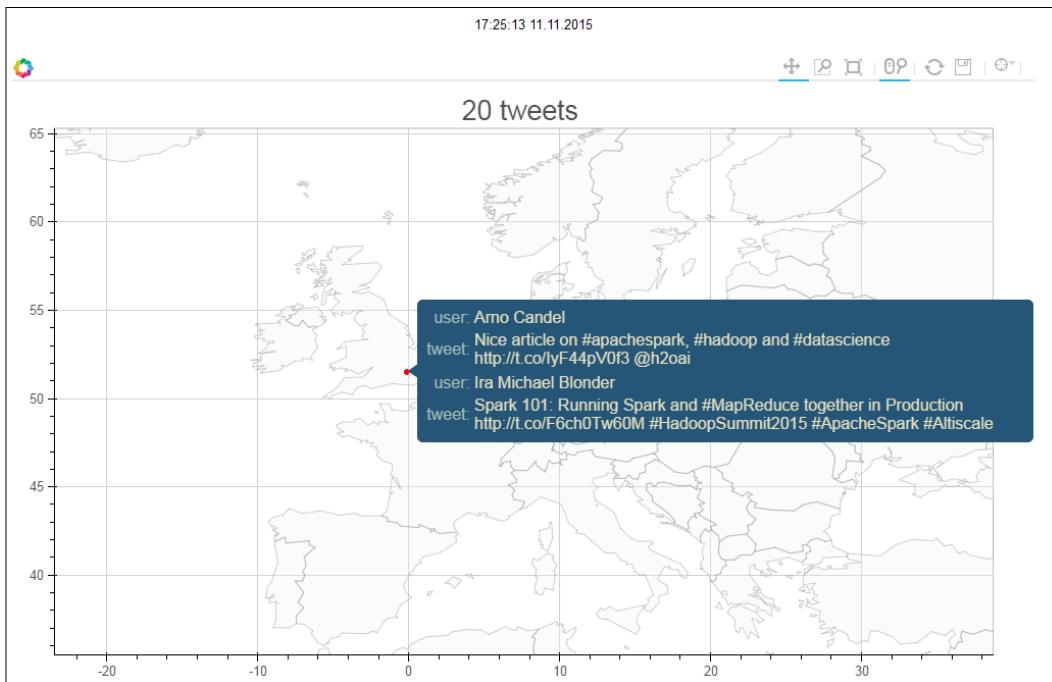
We can hover on a specific dot to reveal the tweets in that location:



We can zoom into a specific location:



Finally, we can reveal the tweets in the given zoomed-in location:



## Displaying upcoming meetups on Google Maps

Now, our objective is to focus on upcoming meetups in London. We are mapping three meetups **Data Science London**, **Apache Spark**, and **Machine Learning**. We embed a Google Map within a Bokeh visualization and geo-locate the three meetups according to their coordinates and get information such as the name of the upcoming event for each meetup with a hover tool.

First, import all the necessary Bokeh libraries:

```
In [ ]:  
#  
# Bokeh Google Map Visualization of London with hover on specific  
# points  
#  
#  
from __future__ import print_function
```

```
from bokeh.browserlib import view
from bokeh.document import Document
from bokeh.embed import file_html
from bokeh.models.glyphs import Circle
from bokeh.models import (
    GMapPlot, Range1d, ColumnDataSource,
    PanTool, WheelZoomTool, BoxSelectTool,
    HoverTool, ResetTool,
    BoxSelectionOverlay, GMapOptions)
from bokeh.resources import INLINE

x_range = Range1d()
y_range = Range1d()
```

We will instantiate the Google Map that will act as the substrate upon which our Bokeh visualization will be layered:

```
# JSON style string taken from: https://snazzymaps.com/style/1/pale-
dawn
map_options = GMapOptions(lat=51.50013, lng=-0.126305, map_
type="roadmap", zoom=13, styles=""""
[{"featureType": "administrative", "elementType": "all", "stylers": [{"visi
bility": "on"}, {"lightness": 33}]},
 {"featureType": "landscape", "elementType": "all", "stylers": [{"color": "#f2e5d4"}]},
 {"featureType": "poi.park", "elementType": "geometry", "stylers": [{"color
": "#c5dac6"}]},
 {"featureType": "poi.park", "elementType": "labels", "stylers": [{"visibil
ity": "on"}, {"lightness": 20}]},
 {"featureType": "road", "elementType": "all", "stylers": [{"lightne
ss": 20}]},
 {"featureType": "road.highway", "elementType": "geometry", "stylers": [{"c
olor": "#c5c6c6"}]},
 {"featureType": "road.arterial", "elementType": "geometry", "stylers": [{"c
olor": "#e4d7c6"}]},
 {"featureType": "road.local", "elementType": "geometry", "stylers": [{"col
or": "#fbfaf7"}]},
 {"featureType": "water", "elementType": "all", "stylers": [{"visibility": "o
n"}, {"color": "#acbcc9"}]}]
""")
```

Instantiate the Bokeh object plot from the class `GMapPlot` with the dimensions and map options from the previous step:

```
# Instantiate Google Map Plot
plot = GMapPlot(
    x_range=x_range, y_range=y_range,
    map_options=map_options,
    title="London Meetups"
)
```

Bring in the information from our three meetups we wish to plot and get the information by hovering above the respective coordinates:

```
source = ColumnDataSource(
    data=dict(
        lat=[51.49013, 51.50013, 51.51013],
        lon=[-0.130305, -0.126305, -0.120305],
        fill=['orange', 'blue', 'green'],
        name=['LondonDataScience', 'Spark', 'MachineLearning'],
        text=['Graph Data & Algorithms', 'Spark Internals', 'Deep
Learning on Spark']
    )
)
```

Define the dots to be drawn on the Google Map:

```
circle = Circle(x="lon", y="lat", size=15, fill_color="fill", line_
color=None)
plot.add_glyph(source, circle)
```

Define the strings for the Bokeh tools to be used in this visualization:

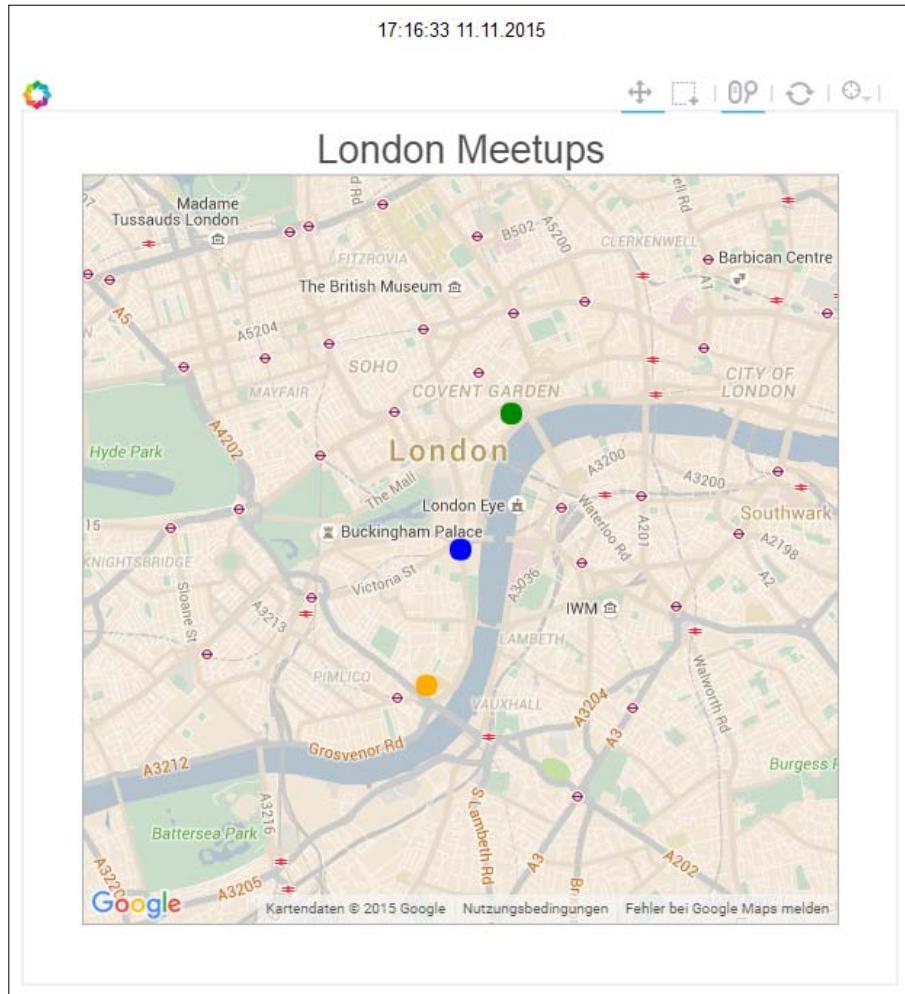
```
# TOOLS="pan,wheel_zoom,box_zoom,reset,hover,save"
pan = PanTool()
wheel_zoom = WheelZoomTool()
box_select = BoxSelectTool()
reset = ResetTool()
hover = HoverTool()
# save = SaveTool()

plot.add_tools(pan, wheel_zoom, box_select, reset, hover)
overlay = BoxSelectionOverlay(tool=box_select)
plot.add_layout(overlay)
```

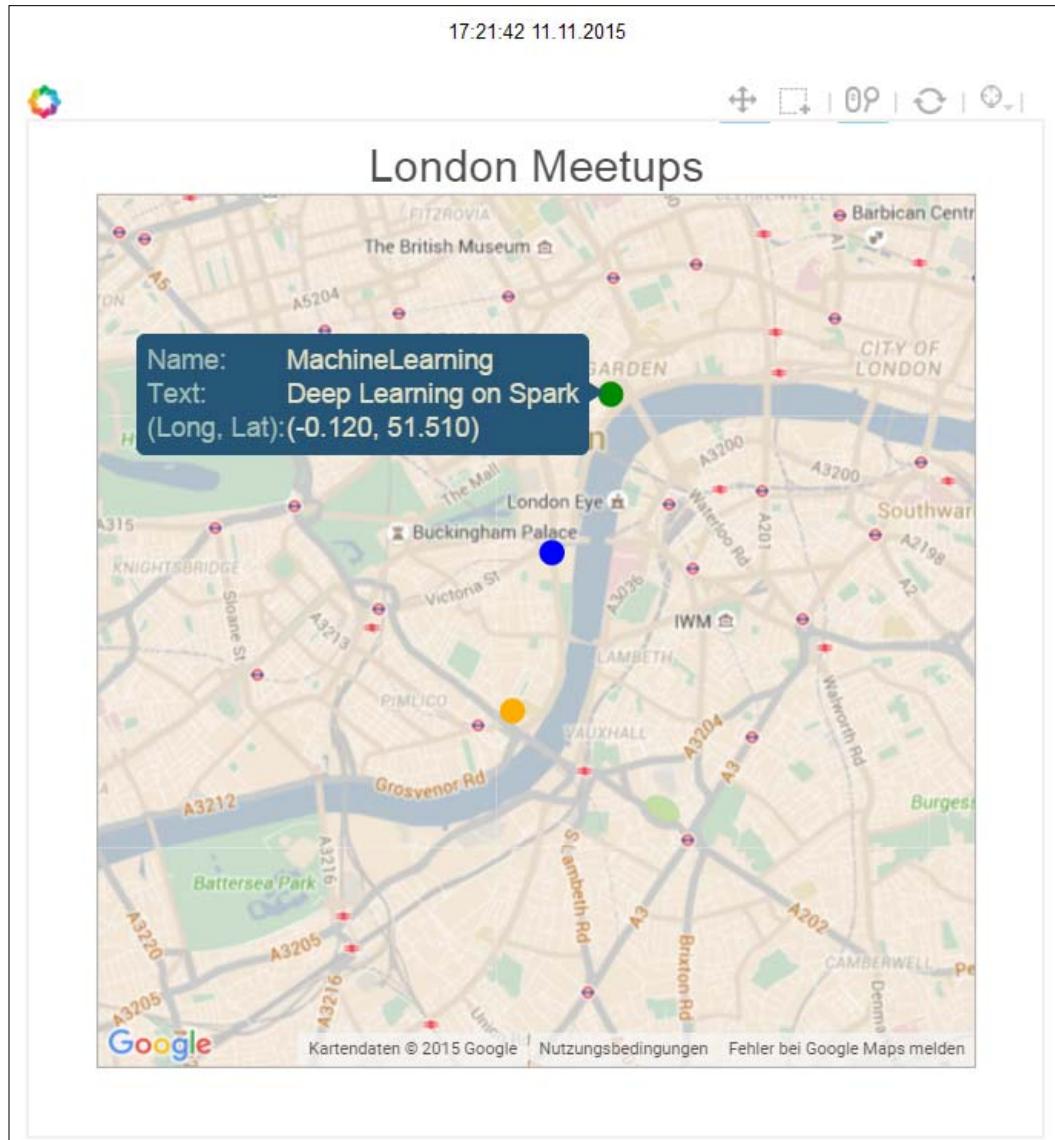
Activate the hover tool with the information that will be carried:

```
hover = plot.select(dict(type=HoverTool))
hover.point_policy = "follow_mouse"
hover.tooltips = OrderedDict([
    ("Name", "@name"),
    ("Text", "@text"),
    ("(Long, Lat)", "(@lon, @lat)"),
])
show(plot)
```

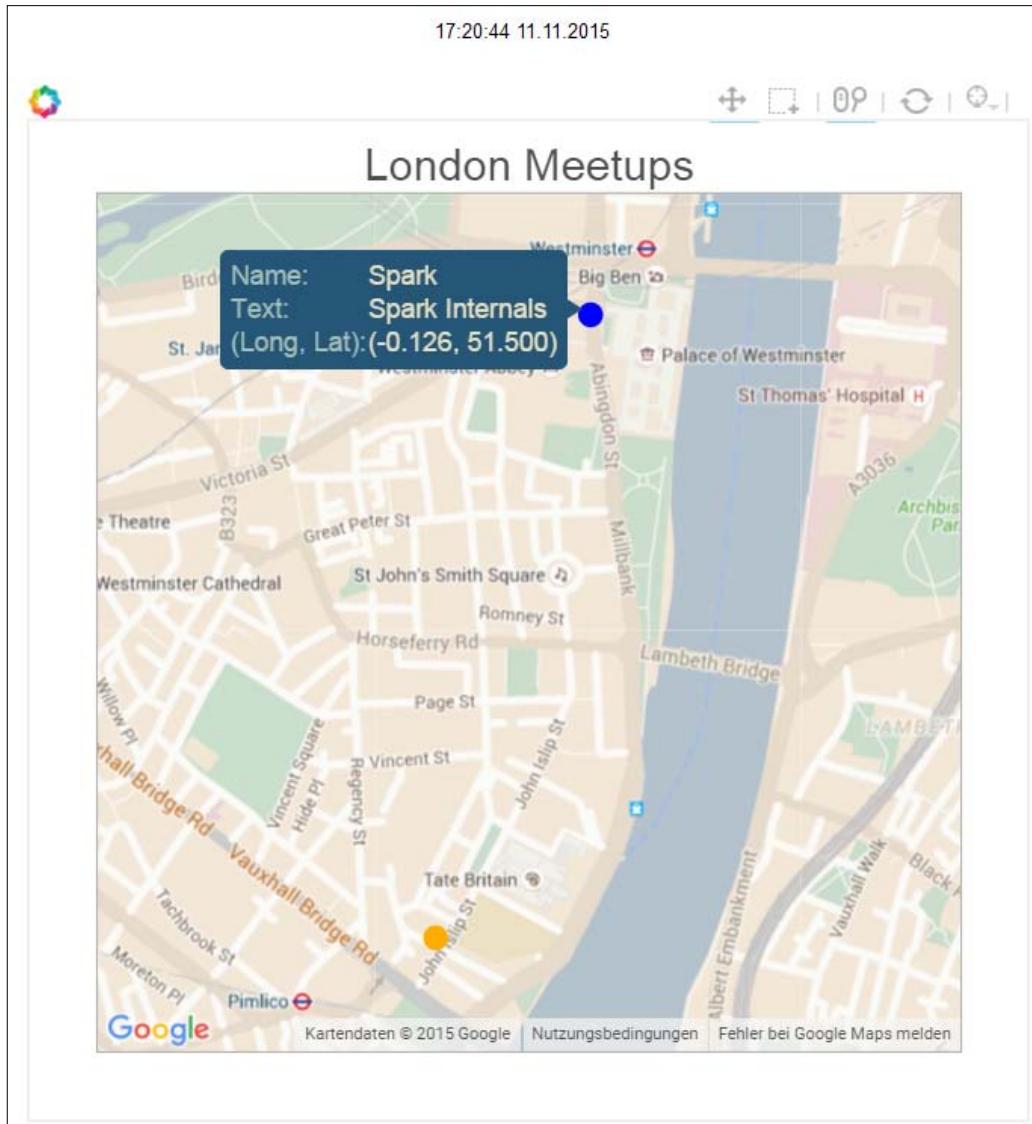
Render the plot that gives a pretty good view of London:



Once we hover on a highlighted dot, we can get the information of the given meetup:



Full smooth zooming capability is preserved, as the following screenshot shows:



## Summary

In this chapter, we focused on few visualization techniques. We saw how to build wordclouds and their intuitive power to reveal, at a glance, lots of the key words, moods, and memes carried through thousands of tweets.

We then discussed interactive mapping visualizations using Bokeh. We built a world map from the ground up and created a scatter plot of critical tweets. Once the map was rendered on the browser, we could interactively hover from dot to dot and reveal the tweets originating from different parts of the world.

Our final visualization was focused on mapping upcoming meetups in London on Spark, data science, and machine learning and their respective topics, making a beautiful interactive visualization with an actual Google Map.

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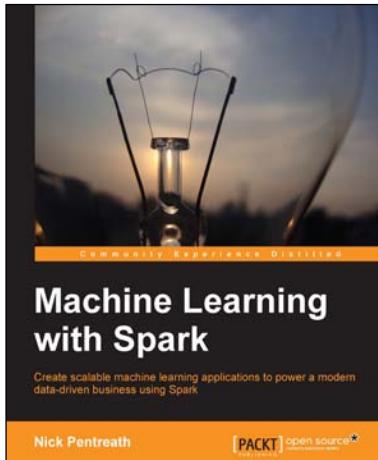
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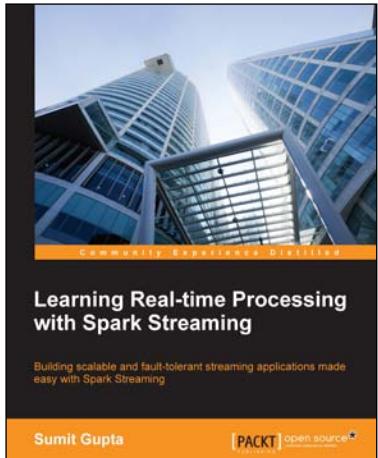
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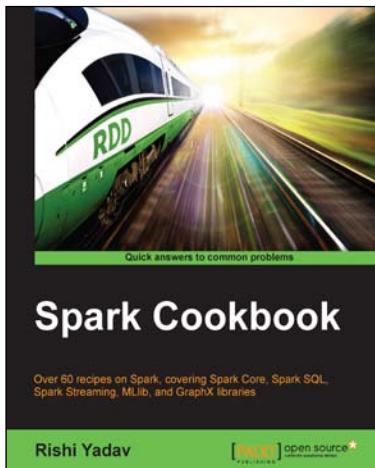
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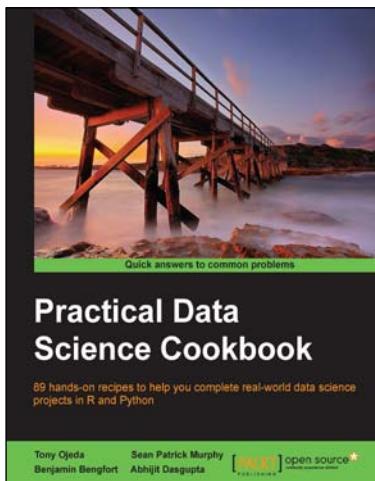
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