HIGH PERFORMANCE IN-MEMORY COMPUTING WITH APACHE IGNITE

BUILDING LOW LATENCY, NEAR REAL-TIME APPLICATION

SHAMIM BHUIYAN, MICHAEL ZHELUDKOV
AND TIMUR ISACHENKO

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Shamim Ahmed Bhuiyan, Michael Zheludkov and Timur Isachenko

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In memory of my Father. - Shamim Ahmed Bhuiyan

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Preface

My first acquaintance with High load system was at the beginning of 2007 and I started working on a real world project since 2009. From that moment, I spent most of my office time with Cassandra, Hadoop, and numerous CEP tools. Our first Hadoop project (the year 2011-2012) with a cluster of 54 nodes often disappoint me with its long startup time. I have never been satisfied with the performance of our applications and always looking for something new to boost the performance of our information system. During this time, I have tried HazelCast, Ehcache, Oracle Coherence as an In-memory cache to gain the performance of the application, and most of all time disappointed for the complexity of using this library or for functional limitations.

When I have first encountered with Apache Ignite, I was wondered, it was that platform that I was waiting for a long time. A simple spring based framework with a lot of awesome features such as DataBase caching, Big data acceleration, Streaming and compute grid.

In 2015, I have participated in Russian HighLoad++ conference[1] with my presentation and started blogging in Dzone/JavaCodeGeeks and in my personal blog[2] about developing High load systems. They become popular and I received a lot of feedback from readers. Through them, I clarified the idea behind the book. The goal was to provide a guide for those who really need to implement the In-memory platform in their projects. At the same time, the idea behind the book is not writing a manual. Although Apache Ignite platform is very big and growing smoothly day by day, we concentrated only on that features of the platform (from our point of the view) that can really help to improve the performance of the applications.

We hope that, *High performance in-memory computing with Apache Ignite* will be the go-to-guide for architects and developers: both new and at an intermediate level, to get up and developing with as liitle friction as possible.

Shamim Ahmed

What this book covers

Chapter one - Installation and the first ignite application introduces the Ignite platform and shows you how to setup the Ignite in your environment. At the end of the chapter, you will implement your first simple Ignite application to read and write from the Cache. You will also learn how to install and configure SQL IDE to run SQL queries against Ignite cache.

Chapter two - Architecture overview covers the functional and architecture overview of the Ignite data fabrics. Here you will learn the concepts and the terminology of Ignite. The chapter introduces

[1] http://www.highload.ru/2015/abstracts/1875.html

[2] http://frommyworkshop.blogspot.ru

the main features of Apache Ignite such as cluster topology, caching topology, caching strategies, transactions, Ignite data model, data collocation and how SQL queries works in Ignite. You will become familiar with some other concepts like multi-datacenter replication, Ignite asynchronous support and resilience ability.

Chapter three - In-memory caching presents some of the popular Ignite data grid features, such as 2nd level cache, java method caching, web session clustering and off-heap memory. This chapter covers developments and technics to improve the performance of your existing web applications.

Chapter four - Persistence guides you to implements transactions and persistence of the Ignite cache. This chapter explores in depth the features of SQL in Apache Ignite, developing HTAP application and provides several real-world examples of how to use it.

Chapter five - Accelerating Big Data computing, we focus on more advanced features and extensions to the Ignite platform. We discuss the main problems of the Hadoop ecosystems and how Ignite can help to improve the performance of the exists Hadoop jobs. We detail the three main features of the Ignite *Hadoop accelerator*: in-memory Map/Reduce, IGFS, and Hadoop file system cache. We also provide brief examples of uses Apache Pig and Hive to run Map/Reduce jobs on top of the Ignite. At the end of the chapter we shows how to easily share states in-memory across different Spark applications.

Chapter six - Streaming and complex event processing takes the next step and goes beyond using Ignite to solve the real time complex event processing problem. This chapter covers how Ignite can be used easily with other BigData technologies such as flume, storm and camel to solve various business problems. You will guide through with a few complete examples to developing real-time data processing in Ignite.

Chapter seven - Distributive computing answers the Ignite implements of distributed computing. This chapter covers, how Ignite can help you to easily develop Microservice like application, which will be performed in parallel fashion to gain high performance, low latency, and liner scalability. You will learn about Ignite MapReduce & ForkJoin Processing, Distributed closure execution, continuous mapping etc. to distribute computations and data processing across multiple computers in the cluster.

Code Samples

All code samples, scripts and more in-depth examples can be found on GitHub at GitHub repo[3]

[3] https://github.com/srecon/ignite-book-code-samples

About the authors

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Timur spends his time learning cutting edge technologies every day to make a best developer out himself.

[4] http://frommyworkshop.blogspot.ru/

Introduction

The last couple of years, word high-performance computing is getting popular in IT word. What does the term *High performance computing* with those additional words above means? In IT world *High performance computing* generally refers to the practice of aggregating computing power in such way that delivers much higher performance than one could get out of a typical desktop computer or workstation in order to solve large problems in science, engineering, or business.

Now High performance computing is not only used in modeling complex physical phenomena such as weather, astronomical calculation but also used in industry to improve the product, reduce production costs and decrease the time it takes to develop products. As our ability to collect Big Data increases, the need to be able to analyses the data also increase. Even more with high-speed internet connection, end users or clients of any application also want to get informationы quickly as possible. All of this above area, high-performance computing can be a most useful tool.

However, while we are aggregating a few computers together in one grid, we can't achieve the performance not more than 2-3x times than usual workstation. If someone wants a 4-5x performance, flash storage (SSD, Flash on PCI-E) can do the job easily, this device is definitely cheap and can provide such type of modest performance boost. However, when we have to achieve more than 10-20x performance, we have to find another paradigm or solution. Here, where comes the new term in-memory computing.

In plain English, in-memory computing primarily relies on keeping data in a server's RAM as a means of processing at faster speeds.

Why is it so popular? Because memory prices are drop to minimal, now RAM is has come down in cost, in-memory computing is used to speed access to result from data intensive processing problem. Imagine, you want to provide 16000 RPS for your customer internet banking portal or million transactions per second for online transaction processing system such as OW4, with traditional disk-based computing, it will very worth to achieve this performance. Best use cases for in-memory computing is as follows:

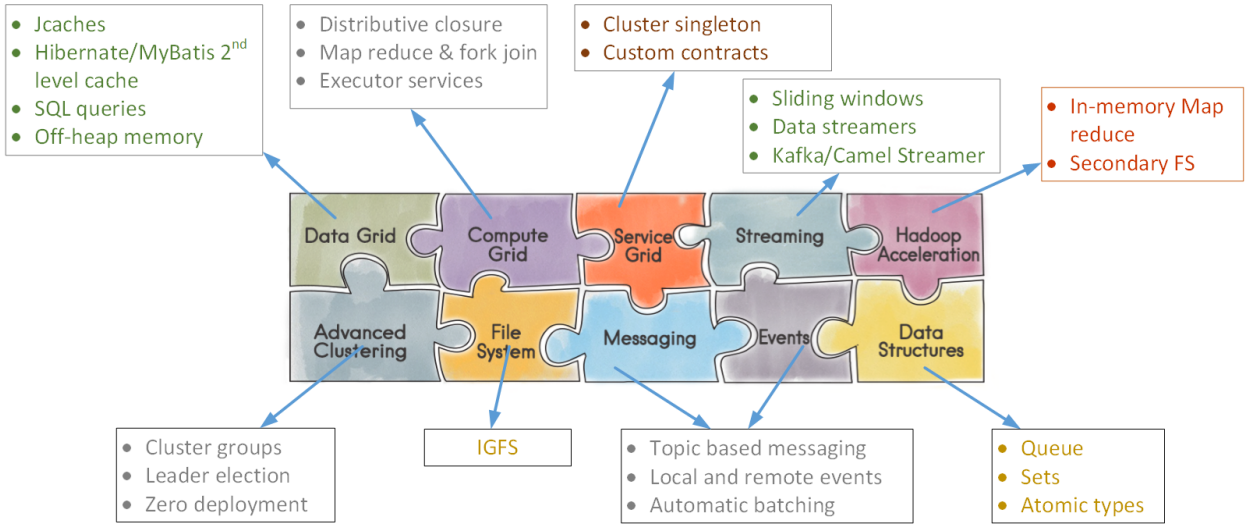
- High volume of ACID transactions processing.
- Cache as a Service (CaaS).
- Database caching.
- Complex event processing for IoT projects.
- Real-time analytics.
- HTAP busniess applications.

What is Apache Ignite?

Apache Ignite provides a convenient and easy to use interface for developers to work with large-scale data sets in real time and other aspects of in-memory computing. Apache Ignite has the following features:

1. Data grid.
2. Compute grid.
3. Service grid.
4. Bigdata accelerator;
5. and Streaming grid.

The following figure illustrate the basic features of apache Ignite.



Ignite features

The core apache Ignite technologies:

1. Open source.
2. Written in pure Java.
3. Supports java 7 and 8.
4. Based on Spring.
5. Supports .Net, C++ and PHP.

The primary capabilities that apache Ignite provides is as follows

- Elasticity: Apache Ignite cluster can grow horizontally by adding new nodes.

- Persistence: Apache Ignite data grid can persist cache entries in RDBMS, even in NoSQL like MongoDB or Cassandra.
- Cache as a Service (CaaS): Apache Ignite allows to implements Cache-as-a-Service across the organization which allows multiple application from different departments to access managed in-memory cache instead of slow disk base database.
- 2nd Level Cache: Apache Ignite is the perfect caching tier to use as a 2nd level cache in Hibernate and MyBatis.
- High-performance Hadoop accelerator: Apache Ignite can replace Hadoop task tracker and job tracker and HDFS to increase the performance of big data analysis.
- Share state in-memory across Spark applications: Ignite RDD allows easily share state in-memory between different Spark jobs or applications. With Ignite in-memory shared RDD's, any Spark application can put data into Ignite cache which will be accessible by another Spark application later.
- Distributed computing: Apache Ignite provides a set of simple APIs that allows a user to distribute computation and data processing across multiple nodes in the cluster to gain high performance. Apache Ignite distributed services is very useful to develop and execute *microservice* like architecture.
- Streaming: Apache Ignite allows processing continuous never-ending streams of data in scalable and fault- tolerant fashion in in-memory, rather than analyzing data after it's reached the database.

Who uses Apache Ignite?

Apache Ignite is in wide use around the world, and usages are growing all the time. Companies like Barclays, Misys, Sberbank (3rd largest bank in the Europe) all use Ignite to power pieces of their architecture and it is critical to the day-to-day operations of those organizations.

Why Ignite instead of others?

There are a few others alternatives of Apache Ignite exists from other vendors such as HazelCast, Oracle, Ehcache, GemFire etc. The main difference of apache Ignite with others is its quantity of functionality and simplicity of use. Apache Ignite provides a verity of functionalities, which you can use for different use cases. Unlike other competitors, Ignite provides a set of components called *Hadoop accelerator*, Spark shared RDD, that can deliver real-time performance to Hadoop & Spark users.

Our Hope

It is true that, you have a lot to learn when diving into Apache Ignite. Just like any other distributed system, it can be complex. But by the end of this book, we hope to have simplified it enough for you

to not only build an application based on in-memory computing but also to be able to administer the cluster supporting your application.

For every topic, a *complete sample running* application will be presented, which will help you to a quick start with the topic. The book will be a *project-based* guide, where each chapter focuses on the complete implementation of a real-world scenario, the commonly occurring challenges in each scenario will be also discussed, along with tips and tricks and best practices on how to overcome them.

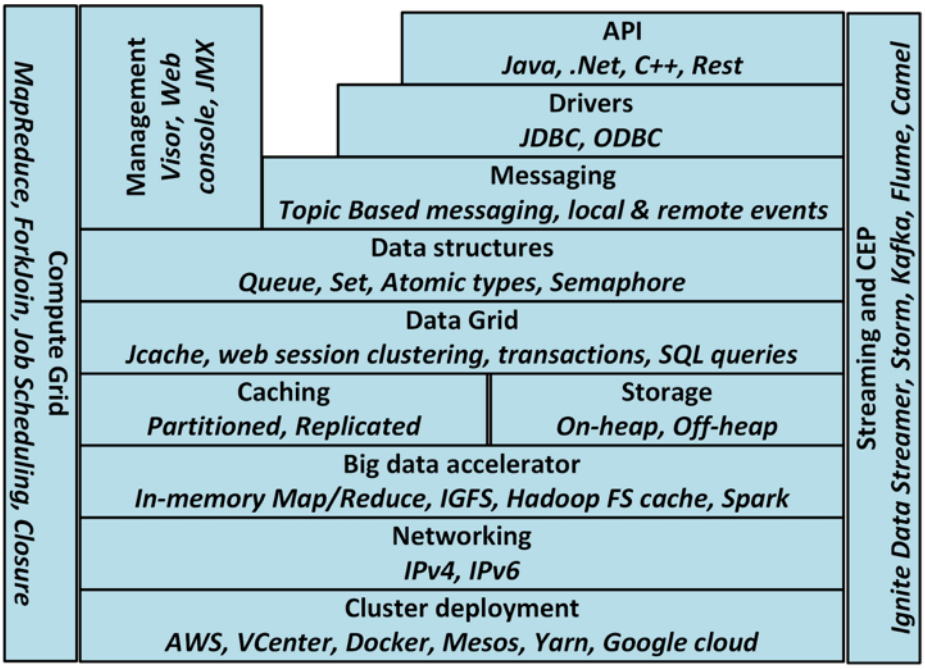
Chapter two: Architecture overview

To better understand the functionality of the Apache Ignite and use cases, it's very important to understand its architecture and the topology. Getting a better understanding of Ignite architecture, you can decide which topology or caching mode to use to solve different problems in your enterprise architecture landscape and gets maximum benefits from the in-memory computing. Unlike master-slave designs, Ignite makes use of an entirely peer-to-peer architecture. Every node in entire Ignite cluster can accept read and write, no matter where the data being written. Therefore, in this chapter we are going to cover the following topics:

- Apache Ignite functional overview.
- Different cluster topology.
- Caching topology.
- Caching strategy.
- Clustering.
- Data model.
- Multi-datacenter replication.
- Asynchronous support.
- How SQL query works in Ignite.
- Resilience.

Functional overview

The Ignite architecture has sufficient flexibilities and advanced features that can be used in a large number of different architecture patterns and styles. You can view Ignite as a collection of independent, well-integrated, in-memory components geared to improve performance and scalability of your application. The following schematic represents the basic functionalities of Apache Ignite.



Functional architecture

Note that, Apache Ignite contains a lot of features that are not represented in the above figure for lack of space. Ignite is organized in a modular fashion, provides single jar (library) for each of the functionality. You only have to apply the desired library into your project to use the Ignite.

Cluster Topology

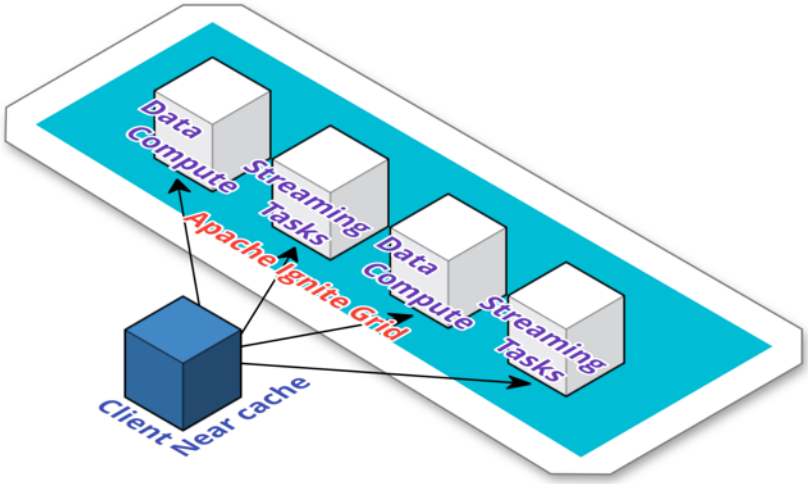
Ignite design implies that the entire system itself is both inherently available and massively scalable. Ignite internode communication allows all nodes to quickly receive updates without the need for a **master coordinator**. Nodes can be added or removed non-disruptively to increase the amount of *RAM* available. Ignite data fabrics are fully resilient, allowing non-disruptive automated detection and recovery of a single server or multiple servers.

> ## Note:
>
> In contrast to the monolithic and master-slave architectures, there are no special nodes in Ignite. All nodes are identical in the Ignite cluster.

Client and Server

However, Apache Ignite has an optional notion of servers and provides two types of nodes: Client and Server nodes.

Node	Description
Server	Contains Data, participates in caching, computations, streaming and can be part of the in-memory Map-Reduce tasks.
Client	Provides the ability to connect to the servers remotely for put/get elements into the cache. It can also store a portions of data (near cache), which is a smaller local cache that stores most recently and most frequently accessed data.



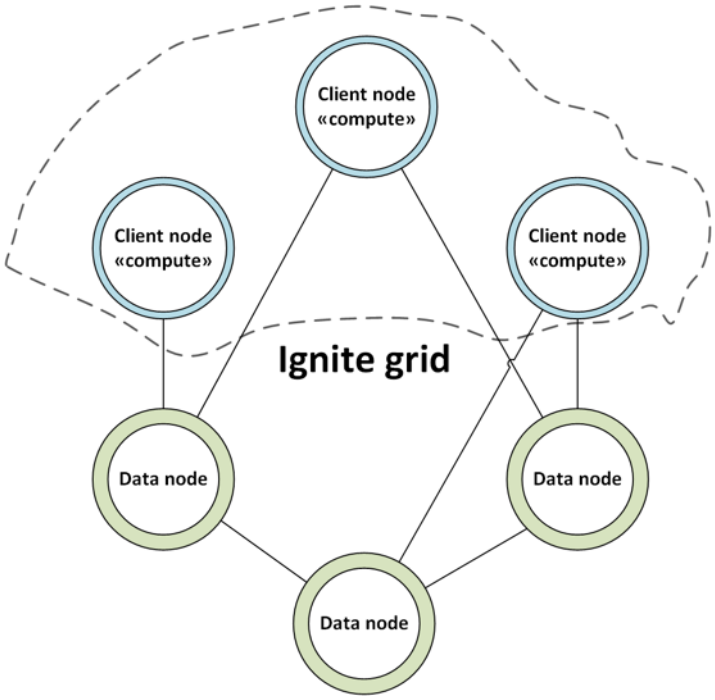
Ignite client and servers

The server node also can be grouped together in a cluster to perform some work. Within a cluster, you can limit job execution, service deployment, streaming and other tasks to run only within cluster group. You can create cluster group based on any predicate. For instance, you can create cluster group from a group of nodes, where all the nodes are responsible for caching data for **testCache**. We shall discuss the clustering in more detail in the subsequent section of this chapter. By default, all nodes are started as a server node, and client mode needs to be explicitly enabled. Note that, you can't physically separate data nodes from compute nodes. In Apache Ignite, servers that contain data, are also using to executing computation.

In Apache Ignite, client node also can be participated in job execution. The concept looked complicated at first glance, let's try to clear the concept.

Server node always stores data and **by default** can participate in any computation task. On the other hand, the *Client* node is using to manipulates with caches into the server, can store **local** data and can be participated in **computation task**. Usually, client nodes are using to put or retrieve data from the caches. But this types of hybrid client nodes gives some flexibility when considering to develop a massive Ignite grid with a lot of nodes. Both clients and server nodes are located in one grid, in some cases (as for example, high volume of acid transactions in data node) you just do not want to execute any computation on data node. In this case, you can choose to execute jobs only on client nodes by creating a corresponding cluster group. In this way, you can separate data node from the compute node in one grid. Compute on clients can be performed with the following pseudo code.

```
ClusterGroup clientGroup = ignite.cluster().forClients();
IgniteCompute clientCompute = ignite.compute(clientGroup);
// Execute computation on the client nodes.
clientCompute.broadcast(() -> System.out.println("sum of: " + (2+2)));
```



Client cluster group

There is one downside of this approach. With this approach, data will be allocated to separate nodes and for the computing of this data, all the client nodes should retrieve the data from the server nodes. It can produce a lot of network connections and create latency. However, you can always run client and server node in separate JVM on one single host to decrease the network latency. We will discuss the different deployment approaches in more details later in this chapter.

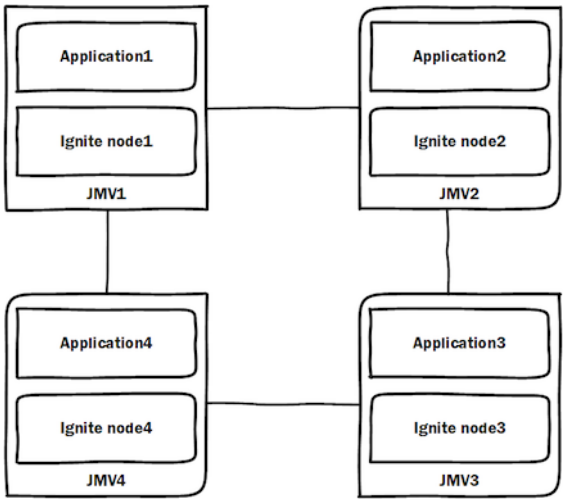
From the deployment point of view, Apache Ignite servers also can be divided into the following groups.

- Embedded with application.
- Server in separate JVM.

Embedded with the application

With this approach, Apache Ignite node runs on the same JVM with the application. It can be any web application running on an application server or with standalone Java application. For example, our standalone **HelloIgnite** application from the chapter one – is an embedded Ignite server. Ignite

server run along with the application in the same JVM and joins with other nodes of the grid. If the application dies or takes down, Ignite server also shutting down. This approach of the topology shown in the following diagram:



Embedded with the application

If you run the HelloIgnite application again and examine the logs of the server, you should find the following:

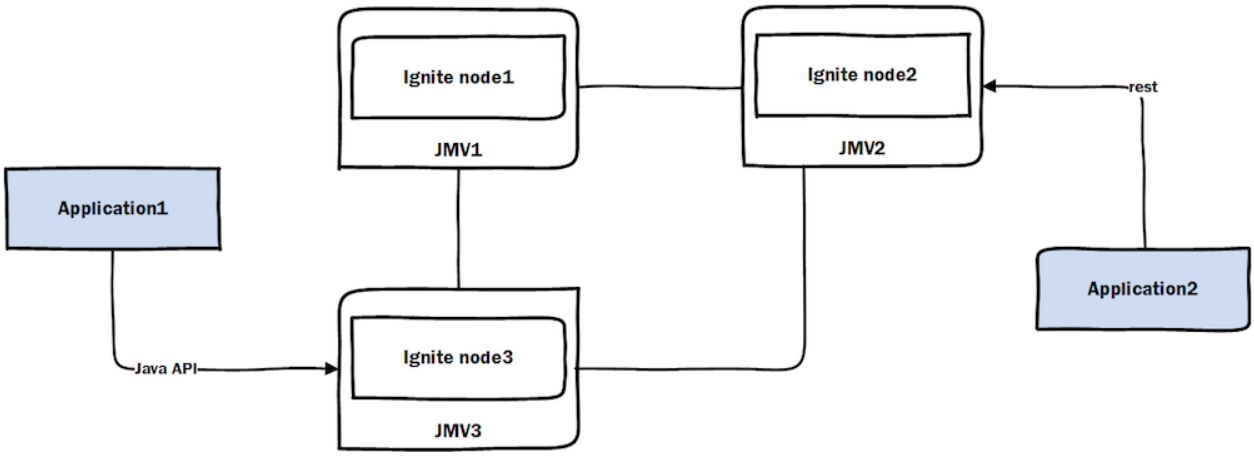
```
[18:36:05] Ignite node started OK (id=3113ed1e)
[18:36:05] Topology snapshot [ver=8, servers=1, clients=0, CPUs=8, heap=1.0GB]
[21:26:12] Topology snapshot [ver=9, servers=2, clients=0, CPUs=8, heap=4.5GB]
[21:26:13] Topology snapshot [ver=10, servers=1, clients=0, CPUs=8, heap=1.0GB]
```

Ignite log

HelloIgnite application run and joins to the cluster as a server, after completing the task, application exits with the Ignite server from the Ignite grid.

Server in separate JVM (real cluster topology)

In this approach, server nodes will run in separate JVM and the client remotely connects to the server for working with the cache. Server nodes participate in caching, compute executions, streaming and much more. The client can also use REST API to connect to any individual node. By default, all Ignite nodes are started as server nodes, client node needs to be explicitly enabled.

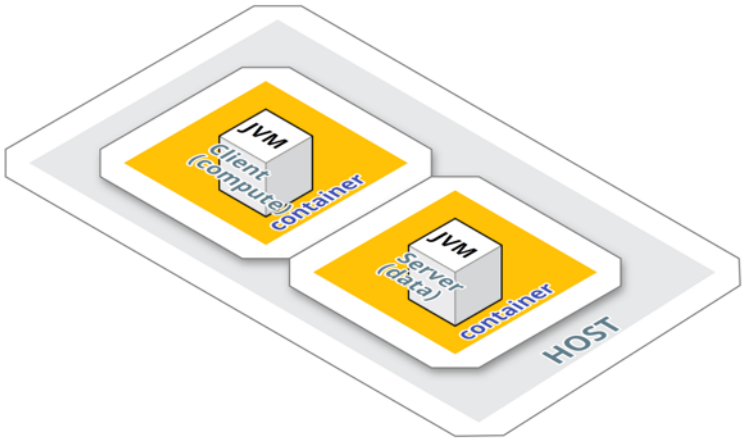


Real cluster topology

Under most circumstances, this approach is the first choose, as it provides greater flexibility in terms of cluster mechanics. Ignite server can be taken down and restarted without any impact to the overall application or cluster.

Client and Server in separate JVM on single host

You can consider this given approach, whenever you have a high volume transactions on your data nodes and also planning perform some computations on this node. You can execute client and server in separate JVM within a container such as Docker or openVZ. Containers can be located in the single host machine. The container will isolate the resources (cpu, ram, network interface etc.) and the JVM will only use isolated resources assigned to this container.



Client and server in seperate JVM

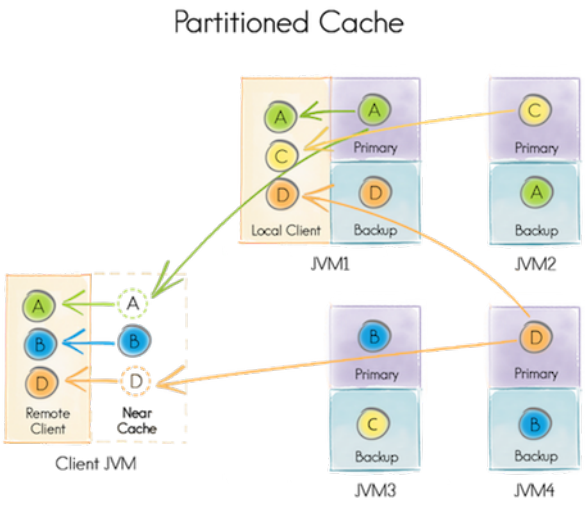
This above approach also has its own downside. During executions, the client (compute) node can retrieve data from any other data node that reside on other hosts and it can increase the network latency.

Caching Topology

Ignite provides three different approaches of caching topology: *Partitioned*, *Replicated* and *Local*. A *cache mode* is configured for each cache individually. Every caching topology has its own goal with pros and cons. Default cache topology is *partitioned*, without any backup option.

Partitioned caching topology

The goal of this topology is to get extreme *scalability*. In this mode, Ignite cluster transparently **partition** the cached data to distribute the load to an entire cluster evenly. By partitioning the data evenly, the size of the cache and the processing power grows linearly with the size of the cluster. The responsibility for managing the data is automatically load-balancing across the cluster. Every node or server of the cluster contains its primary data with the backup copy if defined.



Partitioned caching topology

With partitioned cache topology, DML operations on the cache are extremely fast, because only one primary node (optionally 1 or more backup node) needs to be updated for every key. For high availability, a backup copy of the cache entry should be configured. The backup copy is the redundant copy of one or more primary copy, which will live in another node. There is a simple formula to calculate, how many backups copy you need for the high availability of your cluster.

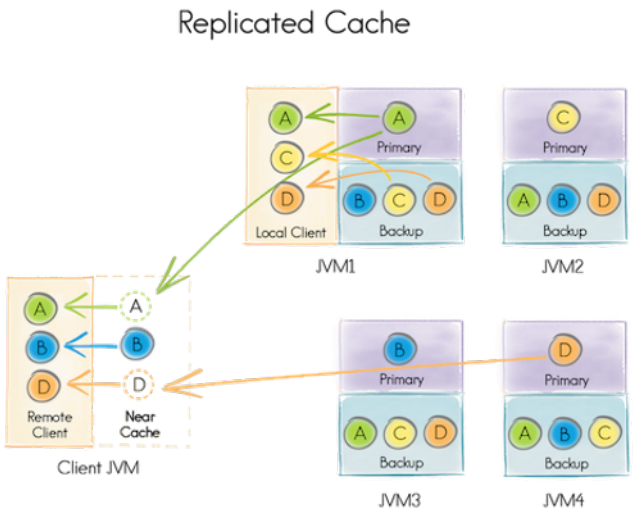
The number of backup copy = N-1, where N is the total number of the nodes in the cluster.

Assume, you have a total number of 3 nodes in the cluster. If you always want to get a response from your cluster (when some of your nodes will be unavailable), your backup copy should be not less than 2. In this case, 3 copies of the cache entry will be written, 2 for backup copies and 1 for the primary cache entry. Partitioned caches are ideal when working with large datasets and updates are

very frequent. The backup process can be synchronous and asynchronous. In synchronous mode, the client should wait for the responses from the remote nodes, before completing the commit or write.

Replicated caching topology

The goal of this approach to get extreme *performance*. With this approach cache data is *replicated* to all members of the cluster. Since the data is replicated to each cluster node, it is available for use without any waiting. This provides highest possible speed for read access, each member accesses the data from its own memory. There is also a downside of this approach, frequent writes are very expensive for this topology. Updating a replicated cache requires pushing the new version of the data to all other cluster members. This will limit the scalability if there are a high frequency of updates on members.



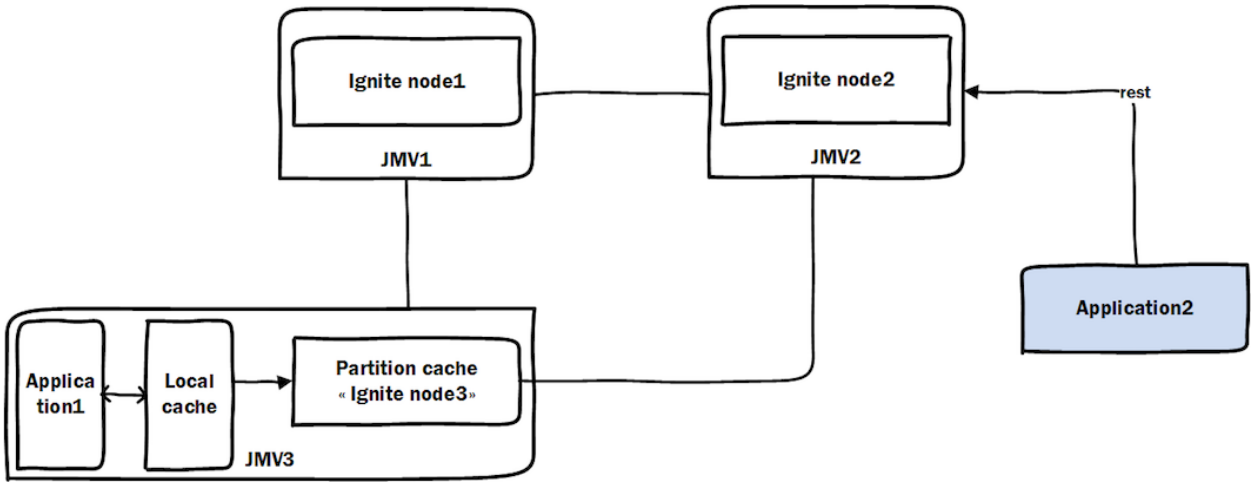
Replicated caching topology

In the above diagram, the same data is stored in all cluster nodes; the size of a replicated cache is limited by the amount of memory available on each node with the smallest amount of RAM. This mode is ideal for scenarios where cache reads are a lot more frequent than cache writes, and the data sets are small. The scalability of replication is inversely proportional to the number of members, the frequency of updates per member, and the size of the updates.

Local mode

This is a very primitive version of cache mode; with this approach, no data are distributed to other nodes of the cluster. As far as, the Local cache does not have any replication or partitioning process, data fetching is very inexpensive and very fast. It provides zero latency access to recently-used and frequently-used data. Local cache mostly used in read-only operations, it also works very well

to read/write-through behavior, where data is loaded from the data sources on misses. Unlike a distributed cache, local cache still has all the features of distributed cache, it provides query caching, automatic data eviction and much more.



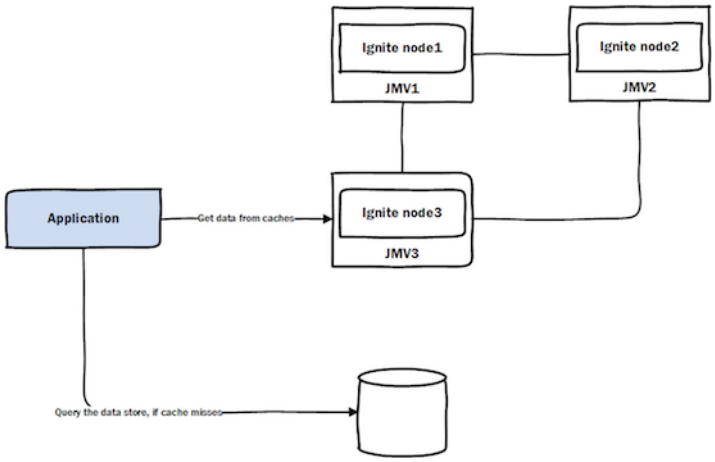
Local mode

Caching strategy

With the explosion of high transactions web applications and mobile apps, data storage became the main bottleneck of performance. In most cases, persistence stores such as a relational database cannot scale out perfectly by adding more servers. In this circumstance, in-memory distributed cache offers an excellent solution to data storage bottleneck. It extends on multiple servers (called a grid) to pool their memory together and keep all cache synchronized across servers. There are two main strategies to use such a distributed in-memory cache:

Cache-aside

In this approach, an application is responsible for reading and writing from the persistence store. The cache doesn't interact with the database at all, which it's call cache-aside. The cache is staying aside as a fast scaling in-memory data store. The application checks the cache for data before query the data store. Also, the application updates the cache after making any changes to the persistence store.

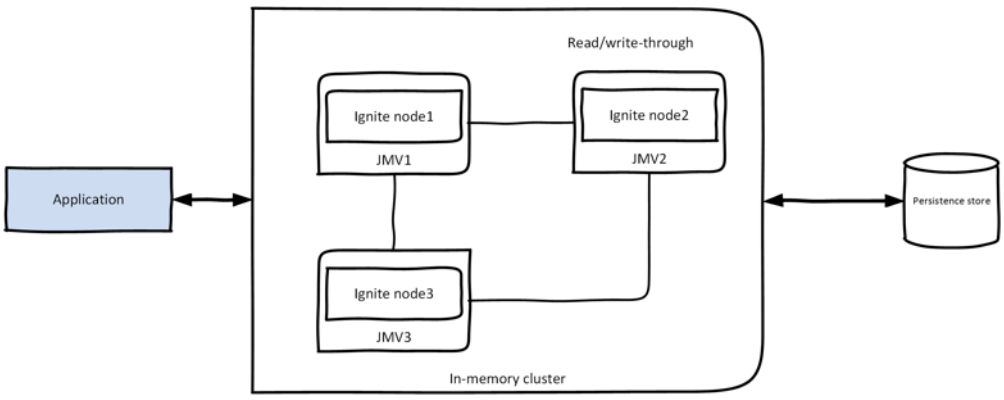


Cache-aside

However, the cache-aside is very fast, there are a few disadvantages with this given strategy. Application code can be complex and also may code duplication if multiple application is dealing with the same data store. Even, when cache data misses, application querying the data store, update the caches and continue processing. This can result in multiple database visits if different application threads perform this processing at the same time.

Read-through and Write-through

This is where application treats in-memory cache as the main data store, and reads data from it and writes data to it. In-memory cache is responsible for propagating the query to the data store if cache misses. Also, the data will be persisted automatically whenever it is updated in the cache. All read-through and write-through operations will participate in the overall cache transaction and will be committed or rolled back as a whole.



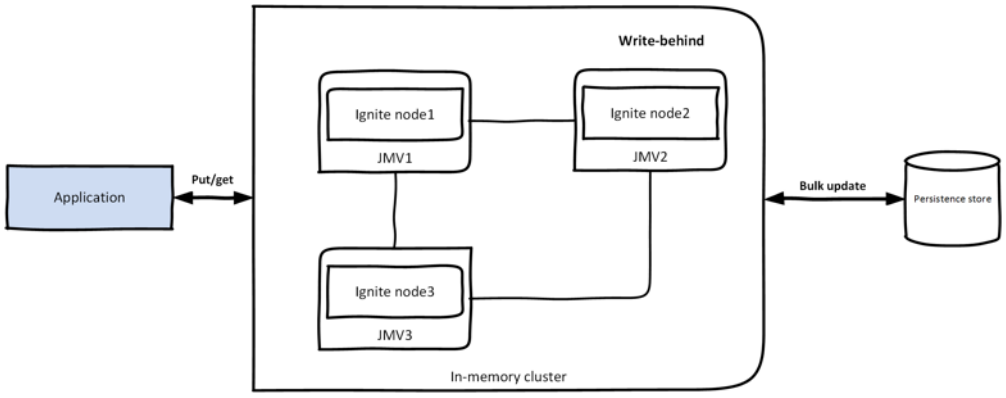
Read/Write-through

Read-through and write-through has numerous advantages over cache-aside. First of all, this given approach simplifies application code. Read-through allows the cache to automatically reload objects

from the database when it expires. This means that your application does not have to hit the database in peak hours because the latest data is always in the cache.

Write behind

It is also possible to use write-behind to get better write performance. Write-behind lets your application quickly update the cache and return. It then aggregates the updates and asynchronously flushes them to persistence store as a bulk operation. Also with Write-behind, you can specify throttling limits, so the database writes are not performed as fast as the cache updates and therefore the pressure on the database is not so much. Additionally, you can schedule the database writes to occur during off-peak hours, which can minimize the pressure on the Database.



Write behind

Apache Ignite provides all of this above caching strategies. Apache Ignite implements JCache specification, which is used to write-through and read-through to and from the persistence store. In addition, Ignite provides *Ignite Cassandra* module, which implements persistent store for Ignite caches by utilizing Cassandra as a persistent storage for expired cache entries.

Data model

Apache Ignite implements a Key-Value data model, specially JCache (JSR 107) specification. JCache, being specified in JSR107, provides a common way for Java application to interact with Cache. Terracotta has played the leading role in JSR107 development, acting as a specification lead. Finally, on 18th March 2014, the JCache final specification has been released. In September this year, Spring 4.1 has been released with the implementations of the JSR107. Why did we need another specification of Java? Because open sources caching projects and the commercial vendor like Terracotta and Oracle have been out there over a decade. Each project and vendors use a very similar hash table like API for basic storage. With the JSR107 specification, at last developers can program to a standard API instead of being tied to a single vendor.

From a design point of view, JCache provides a very simple key-value store. A key-value store is a simple Hashtable or Map, primarily used when you access the database table via primary key. You

can think key-value is a simple table in a traditional RDBMS with two columns such as key and value. Data type of the value column can be any primitive data type such as String, Integer or any complex Java object (or Blob – in Oracle Terms). The application can provide a Key and Value and persist the pair, if the Key already exists, the value will be overwritten, otherwise, a new Value will be created. For clarity, we can compare the key-value store with Oracle terminology.

Oracle	Apache Ignite
Database Instance	Apache Ignite server
Table	Cache
Row	Key-value
RowID	Key

Key-value stores are the simplest data store in NoSQL world. It has very primitive operations like *put*, *get* or *delete* the value from the store. Since it always uses primary key access, they generally have a great performance and scalability.

Since 2014, JCache supports the following platforms:

JCache Delivery	Target Platform
Specification	Java 6+ (SE or EE)
Reference Implementation	Java 7+ (SE or EE)
Technology Compatibility kit	Java 7+ (SE or EE)
Demos and Samples	Java 7+ (SE or EE), Java 8+ (SE or EE)

At this moment most of all caching projects and the vendors implements the JCache specification as follows:

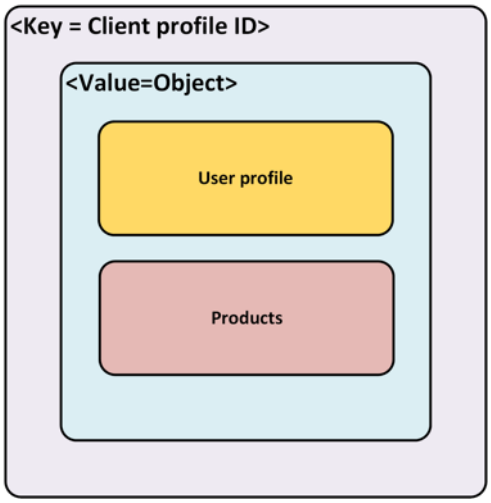
- Oracle Coherence
- Hazelcast
- Terracotta Ehcache
- Apache Ignite
- Infinispan

The Java caching API defines five core interfaces: CachingProvider, CacheManager, Cache, Entry and Expiry.

- A CachingProvider defines the mechanism to establish, configure, acquire, manage and control zero or more CacheManagers.
- A CacheManager defines the mechanism to establish, configure, acquire, manage and control zero or more uniquely named Caches all within the context of the said CacheManager
- A Cache is a hash table like data structure that permits the temporary storage of key-based values. A Cache is owned by a single CacheManager.

- An entry is a single key-value pair stored in a Cache.

A Key-value pair can be easily illustrated in a diagram. Consider the following figure of an entry in Cache.



Key-value entry

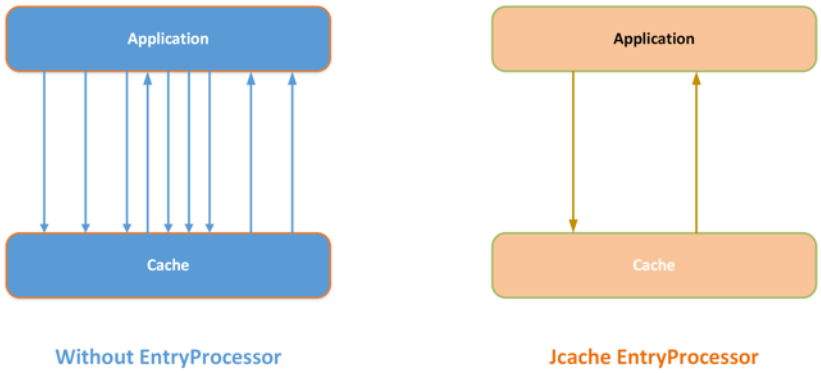
With the key-value store, Java caching API also provides the following additional features:

- Basic Cache operations
- atomic operations, similar to java.util.ConcurrentMap
- read-through caching
- write-through caching
- Entry processor
- cache event listeners
- statistics
- caching annotations
- full generics API for compile time safety
- storage by reference (applicable to on heap caches only) and storage by value

In addition to JCache, Apache Ignite provides ACID transaction, SQL query capability, data loading, Asynchronous mode and various memory models. Apache Ignite provides the **IgniteCache** interface, which extends the Java Cache interface to working with the Cache. In the previous chapter, we already saw some basic operations of IgniteCache. Here is the pseudo code of the HelloWorld application from the previous chapter.

```
IgniteCache<Integer, String> cache = ignite.getOrCreateCache("testCache");
// put some cache elements
for(int i = 1; i <= 100; i++){
    cache.put(i, Integer.toString(i));
}
// get them from the cache and write to the console
for(int i =1; i<= 100; i++){
    System.out.println("Cache get:"+ cache.get(i));
}
```

Apache Ignite also provides the JCache entry processor functionality to eliminate the network roundtrips across the network when doing puts and updates in cache. JCache *EntryProcessor* allows for processing data directly on primary nodes, often transferring only the **deltas** instead of the full state.



EntryProcessor

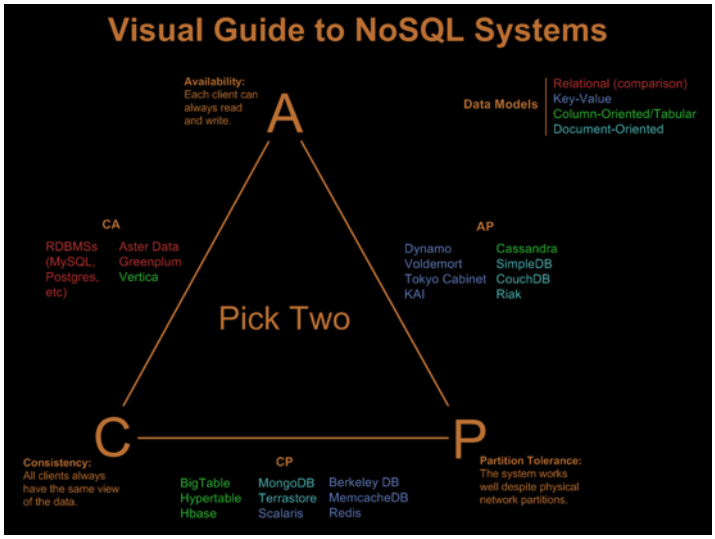
Moreover, you can add your own logic into EntryProcessors, for example, taking the previous cached value and incrementing it by 1.

```
IgniteCache<String, Integer> cache = ignite.jcache("mycache");
// Increment cache value 10 times.
for (int i = 0; i < 10; i++)
  cache.invoke("mykey", new EntryProcessor<String, Integer, Void>() {
    @Override
    public Object process(MutableEntry<Integer, String> entry, Object... args) {
      Integer val = entry.getValue();
      entry.setValue(val == null ? 1 : val + 1);
      return null;
    }
  });
```

CAP theorem and where does Ignite stand in?

When I have first started working with Apache Ignite, I was a wonder that Ignite supports ACID transactions and the other hand Ignite is a highly available distributed system. Supports ACID transactions and the same times providing high availability is one of the challenging features for any NoSQL data store. To scale horizontally, you need strong network partition tolerance which requires giving up either consistency or availability. NoSQL system typically accomplished this by relaxing from the relational availability or transactional semantics. Thus, a lot of popular NoSQL data stores like Cassandra and Riak still doesn't have the transaction support and classified as an AP system. Word AP means, availability and partition tolerance are generally considered to be more important than consistency, and the terminology comes from the famous CAP theorem[5].

In 2000, Eric Brewer[6] in his keynote speech at the ACM Symposium, said that one cannot guarantee consistency in a distributed system. This was his conjecture based on his experience with the distributed systems. This conjecture was later formally proved by Nancy Lynch and Seth Gilbert in 2002. Each NoSQL data store can be classified by the CAP theorem as follows.



CAP theorem

The above illustration is taken from the blog post[7] of the Nathan Hurst. As you can see, a distributed system can only have two of the following three properties:

- Partition tolerance: means, if you chop the cable between two nodes, the system still works.
- Consistency: each node in the cluster has the same data.
- Availability: a node will always answer the queries if possible.

[5] https://en.wikipedia.org/wiki/CAP_theorem
[6] https://en.wikipedia.org/wiki/Eric_Brewer_(scientist)
[7] http://blog.nahurst.com/visual-guide-to-nosql-systems

So, let us see how choosing two out of three options effects the system behavior as follows:

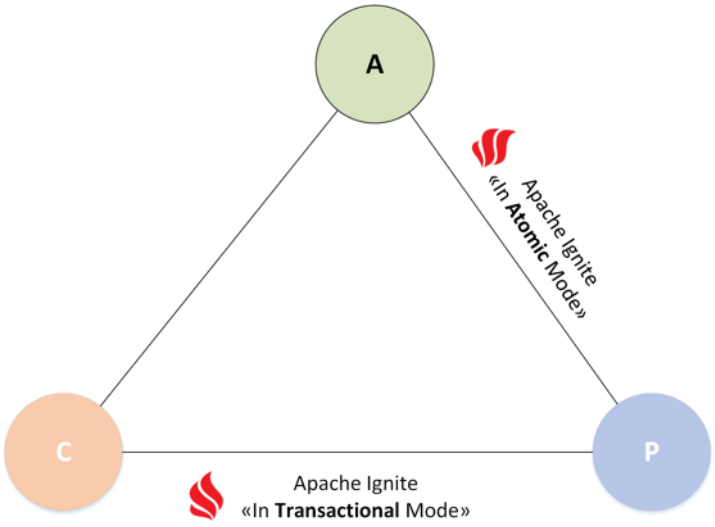
CA system: In this approach, you sacrifice partition-tolerance for getting consistency and availability. Your database system offers transactions and the system is highly available. Most of the relational database are classified as a CA system. This system will have serious problems in scaling.

CP system: the opposite of the CA system. In CP system availability is sacrificed for consistency and partition-tolerance. In the event of the node failure, some data will be lost.

AP system: This system is always available and partitioned tolerance, also this system is scaling easily by adding nodes in the cluster. Cassandra is a good example of this type of system.

Now, we can return back to our question, where does the Ignite stand in the CAP theorem? At the first glance, Ignite can be classified by CP, because Ignite supports fully ACID compliant distributed transactions with partitioned tolerance. But this is the half part of the history. Apache Ignite can also be considered as AP system. Why has Ignite two different classifications? Because of two different transactional modes for cache operations, transactional and atomic.

In transactional mode, you can group multiple DML operations in one transaction and makes a commit into the cache. In this situation, Ignite will lock data on access by a pessimistic lock. If you configure backup copy for the cache, Ignite will use 2p commit protocol for its transaction. We will detail look at the transaction in chapter four.



Ignite position in CAP theorem

On the other hand, in atomic mode, Ignite supports multiple atomic operations, one at a time. In atomic mode, each DML operation will either success or fail and neither READ or Write operation will lock the data at all. This mode gives a higher performance than the transactional mode. When you make a write in Ignite cache, for every piece of data there will be a master copy in primary node and a backup copy (if defined). When you read data from Ignite grid, you always read from the Primary node, unless the Primary node is down, at which time data will be read from the backup. From this point of view, you gain the system availability and the partition-tolerance of the entire

system as an AP system. In the atomic mode, Ignite is very similar to Apache Cassandra.

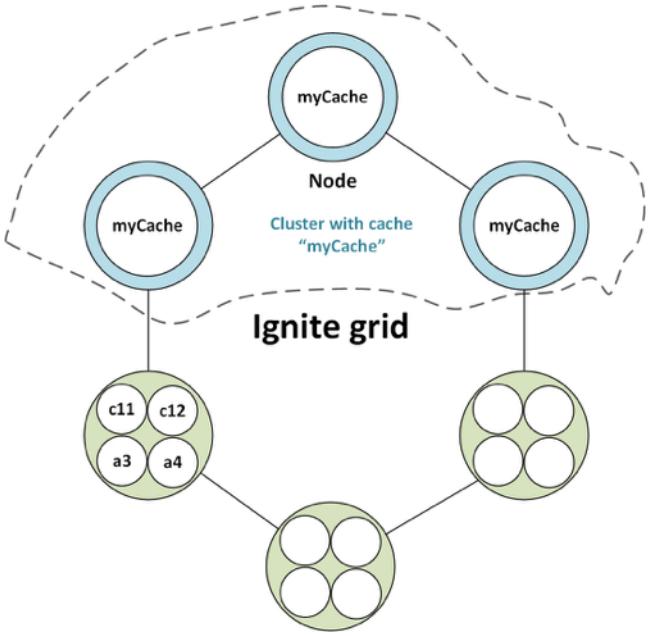
However, real world systems rarely fall neatly into all of these above categories, so it's more helpful to view CAP as a continuum. Most systems will make some effort to be consistent, available, and partition tolerant, and many can be tuned depending on what's most important.

Clustering

The design goal of the Apache Ignite is to handle high workloads across multiple nodes within a cluster. A cluster is arranged as a group of nodes. Clients can send read/write requests to any node in the cluster. Ignite nodes can automatically discover each other and data is distributed among all the nodes in a cluster. This help to scale the cluster when needed, without restarting the entire cluster at a time. Ignite provides an easy way to create logical groups of cluster nodes within your grid and also collocate the related data into similar nodes to improve performance and scalability of your application. In the next few subsections, we will discover a few very important and unique features of Apache Ignite such as cluster group, data allocation (sometimes calls *affinity collocation*) and ability to scaling and zero single points of failure.

Cluster group

Ignite `ClusterGroup` provides a simple way to create a logical group of nodes within a cluster. By design, all nodes in the Ignite cluster are same, however, Ignite allows users or developers to logically group nodes of any application-specific purpose. For instance, you can cluster all nodes on which cache with name *myCache* is deployed or all client nodes that access cache *myCache*. Moreover, you may wish to deploy a service only on remote nodes. You can limit job executions, service deployment, messaging, events, and other tasks to run only within some cluster group.



Cluster group

Ignite provides the following three ways to create a logical cluster into Ignite Grid:

Predefined cluster group. Ignite provides predefined implementations of ClusterGroup of an interface to create cluster group based on any predicate. Predicates can be Remote Node, Cache Nodes, Node with specified attributes and so on. Here is an example of cluster group with all the nodes having caching data for cache *myCache*.

```
IgniteCluster cluster = ignite.cluster();
// All the data nodes responsible for caching data for "myCache".
ClusterGroup dataGroup = cluster.forDataNodes("myCache");
```

Cluster group with Node Attributes. Although every node into the cluster is same, a user can configure nodes to be master or worker and data nodes. All cluster nodes on startup automatically register all environment and system properties as node attributes. However, users can choose to assign their own node attributes through configuration:

```
IgniteConfiguration cfg = new IgniteConfiguration();
Map<String, String> attrs = Collections.singletonMap("ROLE", "master");
cfg.setUserAttributes(attrs);
// Start Ignite node.
Ignite ignite = Ignition.start(cfg);
```

After stating the node, you can group the nodes with the attribute `master` as follows:

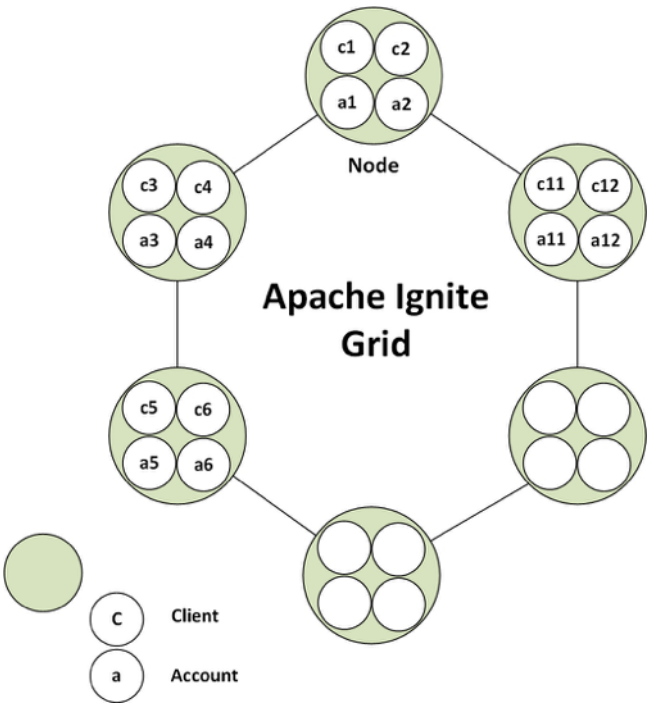
```
IgniteCluster cluster = ignite.cluster();
ClusterGroup workerGroup = cluster.forAttribute("ROLE", "master");
Collection<GridNode> workerNodes = workerGroup.nodes();
```

Custom cluster group. Sometimes it also calls dynamic cluster group. You can define dynamic cluster groups based on some predicate, predicates can be based on any metrics such as CPU utilization or free heap space. Such cluster groups will always only include the nodes that pass the predicate. Here is an example of a cluster group over nodes that have less than 256 MB heap memory used. Note that the nodes in this group will change over time based on their heap memory used.

```
IgniteCluster cluster = ignite.cluster();
// Nodes with less than 256MB heap memory used
ClusterGroup readyNodes = cluster.forPredicate((node) -> node.metrics().getHeapMemoryUsed(\
) < 256);
```

Data collocation

In this approach, network roundtrip for the related data is decreasing and the client application can get the data from the single node. In this case, multiple caches with the same set of fields allocated in the same node.



Data collocation

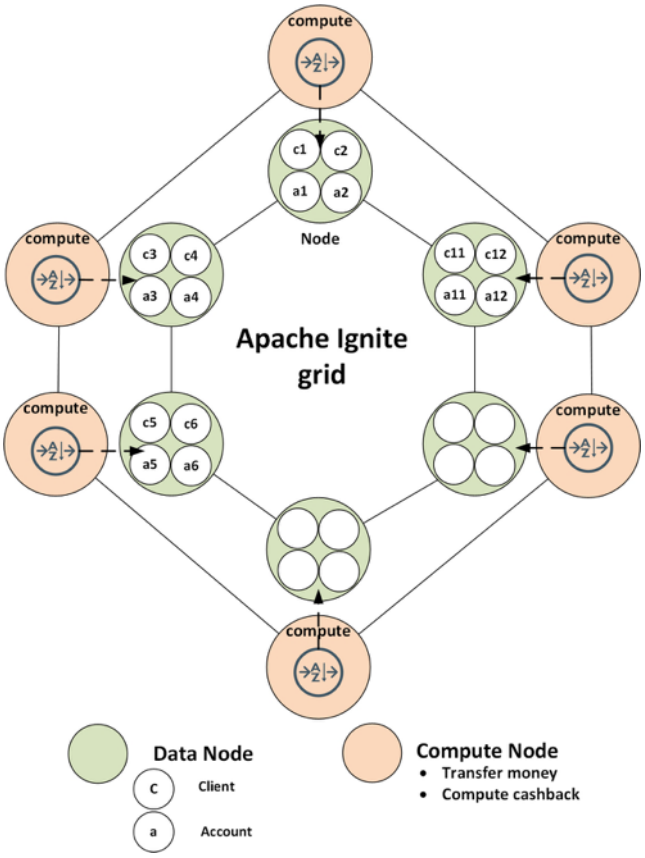
For example, the account information belongs to the client are located on the same Ignite host. To achieve that, cache key used to cache Client objects should have a field or method annotated with `@AffinityKeyMapped` annotation, which will provide the value of the account key for collocation. For convenience, you can also optionally use *AffinityKey* class as follows:

```
Object clientKey1 = new AffinityKey("Client1", "accId");
Object clientKey2 = new AffinityKey("Client2", "accId ");

Client c1 = new Client (clientKey1, ...);
Client c2 = new Client (clientKey2, ...);

// Both, the client and the account information objects will be cached on the same node.
cache.put("accId ", new Account(“credit card”));
cache.put(clientKey1, c1);
cache.put(clientKey2, c2);
```

To calculate the affinity function, you can use any set of fields, not necessary to use any kind of unique key. For example, to calculate the Client account affinity function, you can use the field *client ID* that owns the account id. We will briefly describe the topics with the complete example in chapter seven.

Compute collocation with Data

The Ignite also provides the possibility to route the data computation unit of work to the nodes where the desired data is cached. This concept is known as Collocation Of Computations And Data. It allows routing whole units of work to a certain node. To collocate compute with data you should use `IgniteCompute.affinityRun(...)` and `IgniteCompute.affinityCall(...)` methods.



Compute collocation with Data

Here is how you can collocate your computation with the same cluster node on which Client and his all the account information is allocated.

```
String accId = "acountId";
// Execute Runnable on the node where the key is cached.
ignite.compute().affinityRun("myCache", accId, () -> {
Account account = cache.get(accId);
Client c1 = cache.get(clientKey1);
Client c2 = cache.get(clientKey2);
  ...
});
```

Here, computation unit access to the Client data as local, this approach highly decreases the network roundtrip of the data across the cluster and increase the performance of the data processing.

Apache Ignite out of the box shipped with two affinity function implementations:

RendezvousAffinityFunction[8] - This function allows a bit of discrepancy in partition-to-node mapping (i.e. some nodes may be responsible for a slightly larger number of partitions than others),

[8] https://en.wikipedia.org/wiki/Rendezvous_hashing

however, it guarantees that when topology changes, partitions are migrated only to a joined node or only from a left node. No data exchange will happen between existing nodes in a cluster. This is the default affinity function used by the Apache Ignite.

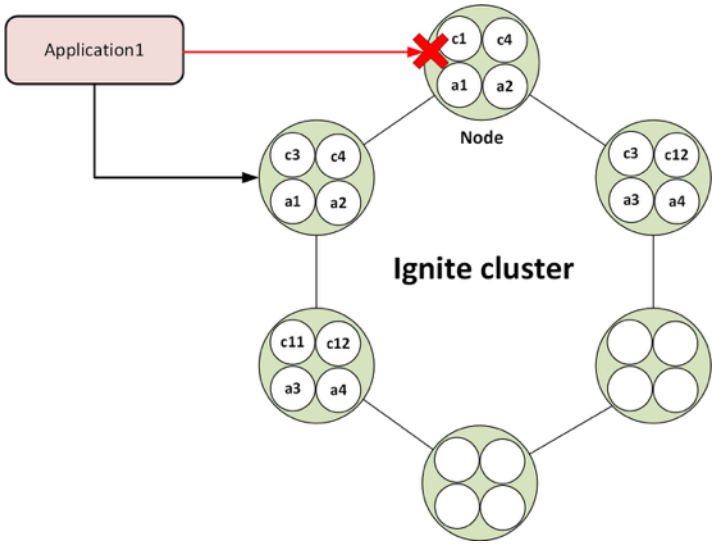
FairAffinityFunction - This functions tries to make sure that partition distribution among cluster nodes is even. This comes at a price of a possible partition migration between existing nodes in a cluster.

Later in this book, we will provide a complete real life example with the explanation in chapter seven.

Zero SPOF

In any distributed system, node failure should be expected, particularly as the size of the cluster grows. The Zero Single Point of Failure (SPOF) design pattern ensures that no single part of a system can stop the entire cluster or system from working. Sometimes, the system using master-slave replication or mixed master-master system falls into this category. Prior to Hadoop 2.0.0, the Hadoop NameNode was an SPOF in an HDFS cluster. Netflix has calculated the revenue loss for each ms of downtime or latency and it is not small at all. Most businesses do not want single points of failure for the obvious reason.

Apache Ignite, as a horizontally scalable distributed system, is designed in such way that all nodes in the cluster are same, you can read and write from any node of the cluster. There are no master-slave communications in the Ignite cluster.



Zero SPOF

Data is backed up or replicated across the cluster so that failure of any node doesn't bring down the entire cluster or the application. This way Ignite provides a dynamic form of **High Availability**. Another benefit of this approach is the ease of which new nodes can be added. When news nodes

are joined into the cluster, it can take over a portion of data from the existing nodes. Because all nodes are the same, this communication can happen seamlessly in a running cluster.

How SQL queries works in Ignite

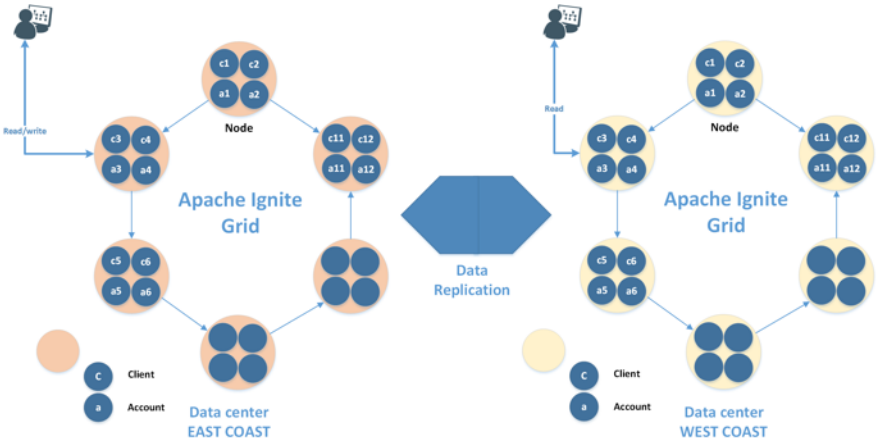
In chapter one, we introduced Ignite SQL query feature very superficially. In chapter four, we will have detailed a lot about Ignite SQL queries. Anyway, it's interesting to know how a query is processing under the hood of the Ignite. There are two main approaches to process SQL query in Ignite:

- in-memory Map-Reduce: If you are executing any SQL query against Partitioned cache, Ignite under the hood split the query into in-memory map queries and a single reduce query. The number of map queries depends on the size of the partitions and number of the partitions of the cluster. Then all the map queries are executed on all data nodes of participating caches, providing results to the reducing node, which will, in turn, run the reduce query over these intermediate results. If you are not familiar with Map-Reduce pattern, you can imagine it as a Java Fork-join process.
- H2 SQL engine: if you are executing SQL queries against Replicated or Local cache, Ignite admit that all the data is available locally and runs a simple local SQL query in the H2 database engine. Note that, in replicated cache, every node contains replica data for other nodes. H2 database is free database written in Java and can work as an embedded mode. Depending on the configuration, every Ignite node can have an embedded h2 SQL engine.

Multi-datacenter replication

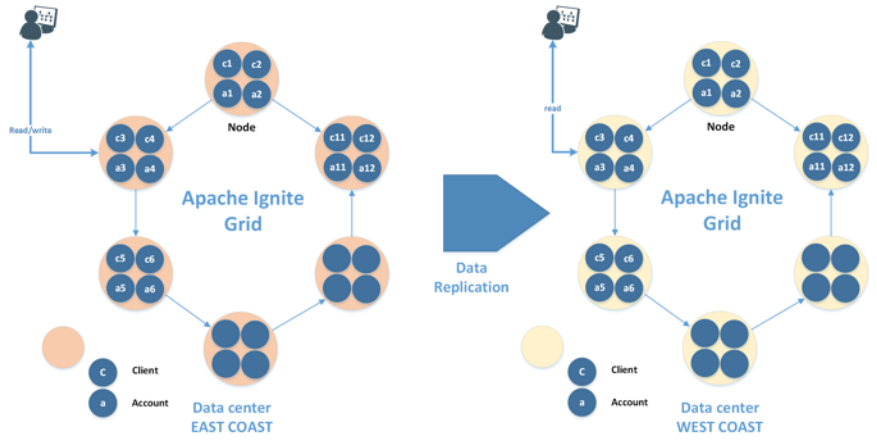
In the modern world, multi-datacenter replication is one of the major requirements for any Database, including RDBMS and NoSQL. In simple terms, multi-datacenter replication means, replication of data between different data centers. Multiple datacenter replications can have a few scenarios.

Geographical location scenario. In this scenario, data should be hosted in different data centers depending on the user location in order to provide a responsive exchange. In this case, data centers can be located in different geographical locations such as in different regions or in different countries. Data synchronization is completely transparent and bi-directional within data centers. The logic that defines which datacenter a user will be connected to resides into the application code.



Geolocational data replication

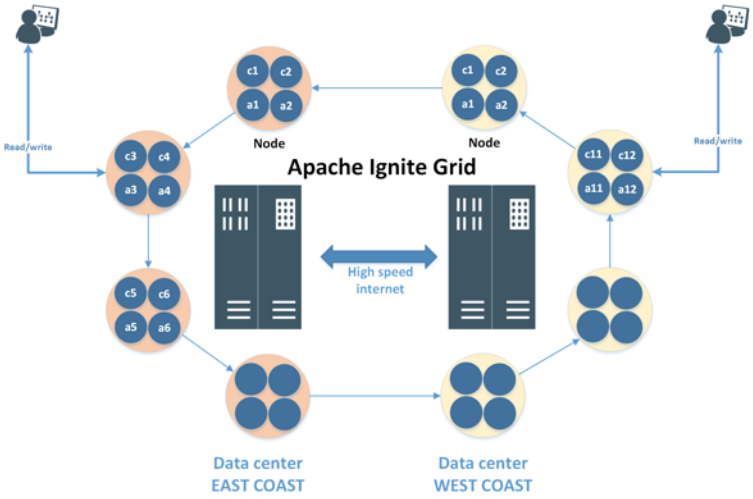
Live backup scenario. In this scenario, most users use different datacenter as a live backup that can quickly be used as a fallback cluster. This use case is very similar to disaster recovery. Sometimes it's also called passive replication. In passive replication, replication occurs in one direction: from master to the replica. Clients can connect to the master database in one data center and perform all the CRUD operation on the database.



Realtime backup

To ensure consistency between the two databases, the replica is started as a read-only database, where only transactions replicated from the master can modify the database contents.

Unfortunately, out of the box, Apache Ignite doesn't support multi-data center replication. However, you can span Ignite nodes in different data centers (for instance, 10 nodes in one data center and other 10 nodes in another).



Span Ignite grid into multiple DC

Span Ignite grid into multiple data center can introduce a few issues:

- Latency: this is going to hinder performance quite a bit on the server side. If any nodes from different datacenter will have a backup copy of your master data, transaction time can be very high. In the long run, you could have a problem with the data consistency also.
- Clients connected in different datacenters going to face very different latency for client operations.

However, GridGain[9](commercial version of Ignite) provides full functionality Data center replication in different geographical location. It also supports bi-directional, active-active data replication between data centers. You can read a more detail here in GridGain site.

Asynchronous support

Usually any plain(synchronous) put/get or execute call blocks the further execution of the application until the result is available from the server. Afterward, the result can be iterated and consumed as need by the client. This is probably the most common way to deal with any persistence store. However, asynchronous method execution can provide significant benefits and is a requirement of the modern system. Apache Ignite provides a flexible paradigm of using asynchronous and synchronous method call on all distributed API. It could be put/get any entries from the store or executes a job in compute grid. Ignite asynchronous method execution is a non-blocking operation, and return **IgniteFuture** object instead of the actual result. You can later get the result by calling **IgniteFuture.get()** method.

[9]https://gridgain.readme.io/docs/data-center-replication

> **Note:**
>
> Any asyncCache.future() call returns the IgniteFuture object immediately. IgniteFuture is general concurrency abstraction, also known as a promise, which promises to return a result in near future.

Here is a very simple example of using asynchronous invocation of get entries from the Ignite cache (see the github project-installation[10] for the complete example).

```
// get or create cache
IgniteCache<Integer, String> cache = ignite.getOrCreateCache("testCache");
// get an asynchronous cache
IgniteCache<Integer, String> asynCache = cache.withAsync();

// put some cache elements
for(int i = 1; i <= 100; i++){
    cache.put(i, Integer.toString(i));
}

//get the first entries asynchronously
asynCache.withAsync().get(1);
// get the future promise
IgniteFuture<String> igniteFuture = asynCache.future();
// java 8 lamda expression
igniteFuture.listen(f-> System.out.println("Cache Value:" + f.get()));
```

In the above pseudo code, we have insert 100 entries synchronously into the Ignite cache *testCache*. After that, asynchronously request the first entry and got future for the invocation. Next, we asynchronously listen for the operation to complete (see the GitHub project-installation for the complete example). Note that, the main thread of the Java main() method doesn't wait for the task to complete, rather it hand over the task to another thread and move on.

Resilience

Ignite client node is completely resilience in nature. Word, resiliency means the ability of a server or a system to recover quickly and continue operating when there has been a failure. Ignite client node can disconnect from the cluster in several cases:

- In the case of a network problem.

[10] https://github.com/srecon/ignite-book-code-samples/tree/master/chapters/chapter-installation

- Host machine dies or restarted.
- Slow clients can be disconnected by the server.

When the client determines that it disconnected from the cluster, it tries to re-establish the connection with the server. This time it assigns to a local node new ID and tries to reconnect to the cluster.

Security

Apache Ignite is an open source project and does not provide any security features, however, the commercial version of Ignite has this functionality. The commercial version is called **GridGain Enterprise Edition**. GridGain enterprise edition provides extensible and customizable authentication and security features to satisfy a variety of security requirements for Enterprise.

Key API

Apache Ignite provides a rich set of different API's to work with the Data Fabrics. The APIs are implemented in a form of native libraries for such major languages and technologies as Java, .NET and C++. A very short list of useful API is described below.

Name	Description
org.apache.ignite.IgniteCache	The main cache interface, entry point for all Data Grid API's. The interface extends javax.cache.Cache interface.
org.apache.ignite.cache.store.CacheStore	Interface for cache persistence storage for read-through and write-through behavior.
org.apache.ignite.cache.store.CacheStoreAdapter	Cache storage convenience adapter, implements interface CacheStore. It's provides default implements for bulk operations, such as writeAll and readAll.
org.apache.ignite.cache.query.ScanQuery	Scan query over cache entries.
org.apache.ignite.cache.query.TextQuery	Query for Lucene based fulltext search.
org.apache.ignite.cache.query.SqlFieldsQuery	SQL Fields query. This query can return specific fields of data based on SQL clause.
org.apache.ignite.transactions.Transaction	Ignite cache transaction interface, have a default 2PC behavior and supports different isolation levels.
org.apache.ignite.IgniteFileSystem	Ignite file system API, provides a typical file system view on particular cache. Very similar to HDFS, but only on in-memory.
org.apache.ignite.IgniteDataStreamer	Data streamer is responsible for streaming external data into cache. This streamer will stream data concurrently by multiple internal threads.
org.apache.ignite.IgniteCompute	Defines compute grid functionality for executing tasks and closures over nodes ClusterGroup.

Name	Description
org.apache.ignite.services.Service	An instance of grid-managed service. Whenever service is deployed, Ignite will automatically calculate how many instances of this service should be deployed on each node within the cluster.
org.apache.ignite.IgniteMessaging	Interface, provides functionality for topic-based message exchange among nodes defined by ClusterGroup.

Conclusion

We covered the foundational concepts of the in-memory data grid. First of all, we briefly described the Ignite functional overview and various caching topologies with different topologies. We also presented some techniques based on standard data access patterns such as caching-aside, read-through and write-through. We go through the Ignite data collocation technics and briefly explained the Ignite key-value data store.

What's next

In the next chapter, we will look at the Ignite data grid implementions such as 2nd level cache, web session clustering and so on.

Chapter five: Accelerating Big Data computing

Hadoop has quickly become the standard for business intelligence on huge data sets. However, it's batch scheduling overhead and disk-based data storage have made it unsuitable for use in analysing live, real-time data in production environment. One of the main factors that limits performance scaling of Hadoop and Map/Reduce is the fact that Hadoop relies on a file system that generates a lot of file input/output (I/O). I/O adds latency that delays completion of the Map/Reduce computation. An alternative is to store the needed distributed data within memory. Placing Map/Reduce in-memory with the data it needs, eliminates file I/O latency.

Apache Ignite has offered a set of useful components allowing in-memory Hadoop job executing and file system operations. Even, Apache Ignite provides an implementation of Spark RDD which allows to share state in memory across Spark jobs.

In this chapter, we are going to explorer how big data computing with Hadoop/Spark can be performed by combining an in-memory data grid with an integrated, standalone Hadoop map/reduce execution engine, and how it can accelerate the analysis of large, static data sets.

Hadoop accelerator

Ignite in-memory Map/Reduce compute engine executes Map/Reduce programs in a seconds (or less) by incorporating several techniques. By avoiding Hadoop's batch scheduling, it can start up jobs in milliseconds instead of tens of seconds. In-memory data storage dramatically reduces access times by eliminating data motion from disk or across the network. Fast, highly optimized, memory-based storage, combining, data shuffling, and optional sorting further drive down overhead. The main advantages are that, all the operations are highly transparent, all of this is accomplished without changing a line of MapReduce code.

Ignite Hadoop in-memory plug and play accelerator can be group by in three different categories:

- **In-memory Map/Reduce**: It's an alternative implementation of Hadoop Job tracker and task tracker, which can accelerate job execution performance. It eliminates the overhead associated with job tracker and task trackers in a standard Hadoop architecture while providing low-latency, HPC-style distributed processing.
- **Ignite in-memory file system (IGFS)**: It's also an alternate implementation of Hadoop file system named **IgniteHadoopFileSystem**, which can store data in-memory. This in-memory file system minimizes disk IO and improve performances.

- **Hadoop file system cache**: This implementation works as a caching layer above HDFS, every read and write operation would go through this layer and can improve performance.

Conceptual architecture of the Ignite Hadoop accelerator is shown below:

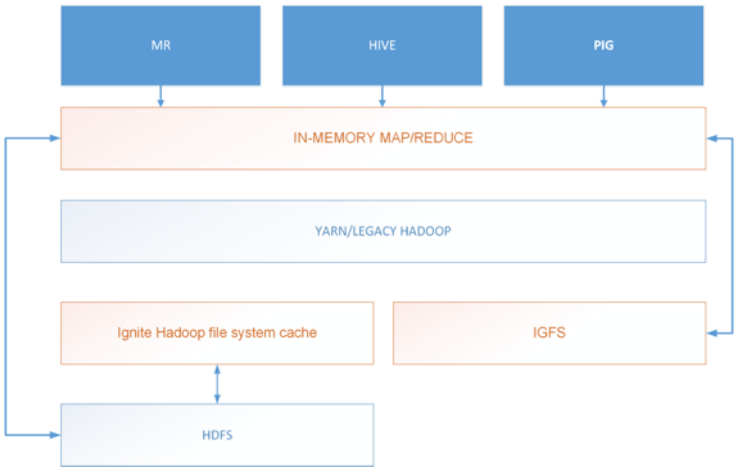


Figure 5.1

This Hadoop accelerator tools is very useful when you already have up and running existing Hadoop cluster and want to get more performance with minimum efforts. I can remember our first project in Hadoop at 2012. After a few months of use of our 64 nodes Hadoop cluster, we stuck with the problem of data motion between Hadoop nodes, it was very painful to overcome. This time, Spark was not so much matured to use. In the long run, we made a serious change to our infrastructure, replaced most of the hard drive to SSD. As a consequence, it was very costly.

Note:

Hadoop runs on commodity hardware is a *myth*. Most of the Hadoop process is IO intensive and requires homogenous and mid end servers to performance well.

When runs Map/Reduce using one of the most popular open source distribution of Hadoop, Hadoop Map/Reduce introduces numerous I/O overhead that extends analysis times to minutes.

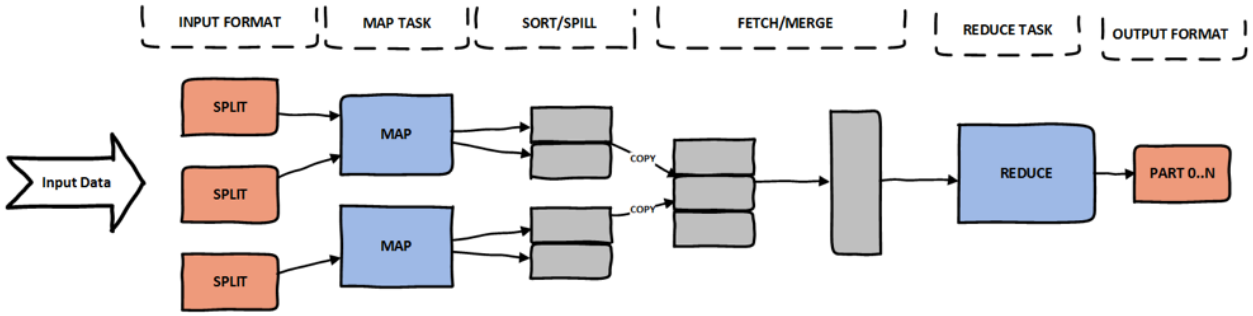


Figure 5.2

The generic phases of Hadoop job are shown in figure 5.2, phase sort, merge or shuffle are highly IO intensive. These overheads are prohibitive when running real-time analytics that returns result in milliseconds or seconds. With Ignite IGFS, you can replace the Hadoop HDFS and eliminate the IO overhead, which can boost Map/Reduce performance. Because in-memory data grid hosts fast-changing data in memory, Map/Reduce application can input data directly from the grid and output results back to the grid. This speed up the analysis by avoiding delaying in accessing HDFS during real-time analysis.

However, to decrease the access time for reading data into Hadoop from HDFS, the input data set can be cached within the Ignite cache storage. Ignite Hadoop file system (IGFS) cache provides a distributed caching feature that speeds access times by capturing data from HDFS or other data sources during Map/Reduce processing and working as a second level cache for HDFS. Ignite Hadoop accelerator is compatible with the latest versions of the most popular Hadoop platforms, including Apache, Cloudera and Horton. This means that you can run fully compatible MapReduce applications for any of these platforms on Ignite in-memory Map/Reduce engine.

Next, we will start explore the details of the Hadoop accelerator tools.

In-memory Map/Reduce

This is the Ignite in-memory Map/Reduce engine, which are 100% compatible with Hadoop HDFS and Yarn. It's reduce the startup and the execution time of the Job tracker and the Task tracker. Ignite in-memory Map/Reduce provides dramatic performance boosts for CPU-intensive tasks while requiring only minimal change to existing applications. This module also provides an implementation of weight based Map/Reduce planner, which assigns mappers and reducers based on their weights. Weight describes how much resources are required to execute the particular map and reduce task. This planning algorithm assigns mappers so that, total resulting weight on all nodes as minimal as possible. Reducers are assigned slightly different.

This approach minimizes the expensive data motion over network. Reducer assigned to a node with mapper are called local. Otherwise, it is considered as remote. High level architecture of the Ignite in-memory Map/Reduce is shown below:

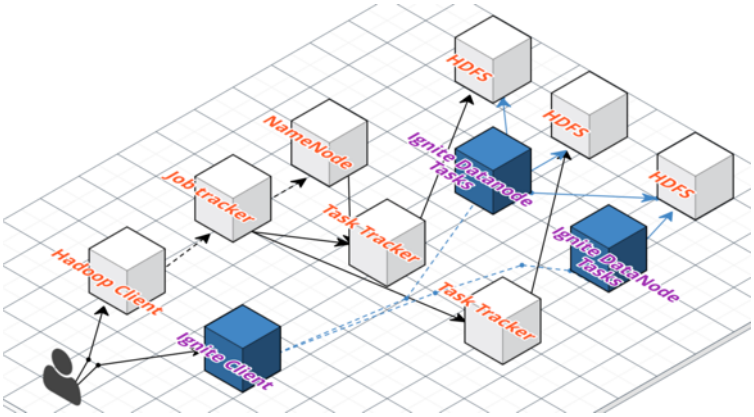


Figure 5.3

Ignite in-memory grid has pre-stage java based execution environment on all grid nodes and reuse it for multiple data processing. This execution environment consists of a set of Java virtual machines one on each server within the cluster. This JVM's forms the Ignite Map/Reduce engine as shown in figure 5.2. Also, the Ignite in-memory data grid can automatically deploy all necessary executable programs or libraries for the execution of the Map/Reduce across the grid, greatly reducing the startup time down to milliseconds.

Now that, we have got the basics, let's try to configure the sandbox and execute a few Map/Reduce jobs in Ignite Map/Reduce engine.

For simplicity, we are going to install a Hadoop *Pseudo-Distributed* cluster in a single virtual machine and will run Hadoop famous word count example as Map/Reduce job.

> **Note:**
>
> Hadoop Pseudo-Distributed cluster means, Hadoop datanode, namenode, tasktracker/jobtracker, everything will be on one virtual (Host) machine.

Let's have a look at our sandbox configuration as shown below.

Sandbox configuration:

VM	VMWare
OS	RedHat enterprise Linux
CPU	2
RAM	2 Gb
JVM version	1.7_60
Ignite version	1.6, single node cluster

First of all, we are going to install and configure Hadoop and will be proceed to Apache Ignite.

Assume that, Java has been installed and JAVA_HOME are in environment variables.

Step 1:

Unpack the Hadoop distribution archive and set the JAVA_HOME path in the `etc/hadoop/hadoop-env.sh` file as follows. This step is optional, if your JAVA_HOME is properly configured in linux box.

```
export JAVA_HOME=JAVA_HOME_PATH
```

Step 2:

Add the following configuration in `etc/hadoop/core-site.xml`.

```
<configuration>
    <property>
        <name>fs.defaultFS</name>
        <value>hdfs://localhost:9000</value>
    </property>
</configuration>
```

Also append the following data replication strategy into the `etc/hadoop/hdfs-site.xml`.

```
<configuration>
    <property>
        <name>dfs.replication</name>
        <value>1</value>
    </property>
</configuration>
```

Step 3:

Setup password less or passphrase less ssh for your operating system.

```
$ ssh-keygen -t dsa -P '' -f ~/.ssh/id_dsa
$ cat ~/.ssh/id_dsa.pub >> ~/.ssh/authorized_keys
$ chmod 0600 ~/.ssh/authorized_keys
```

Try the following command in your console.

```
$ ssh localhost
```

It shouldn't ask you for input password.

Step 4:

Format the Hadoop HDFS file system.

```
$ bin/hdfs namenode -format
```

Next, start the namenode/datanode daemon by the following command:

```
$ sbin/start-dfs.sh
```

Also, I would like to suggest you to add the `HADOOP_HOME` environmental variable to operating system.

Step 5:

Make a few directories in HDFS file system to run Map/Reduce jobs.

```
bin/hdfs dfs -mkdir /user
bin/hdfs dfs -mkdir /input
```

The above command will create two folder user and input in HDFS file system. Insert some text files in directory *input*.

```
bin/hdfs dfs -put $HADOOP_HOME/etc/hadoop /input
```

Step 6:

Run the Hadoop native Map/Reduce application to count the words of the file.

```
$ bin/hadoop jar $HADOOP_HOME/share/hadoop/mapreduce/hadoop-mapreduce-examples-2.7.2.jar w\
ordcount /input/hadoop output
```

You can view the result of the word count by the following command:

```
bin/hdfs dfs -cat output/*
```

In my case it's a huge file with word and its number of count, let's see the fragment of the file.

```
want 1
warnings. 1
when 9
where 4
which 7
while 1
who 6
will 23
window 1
window, 1
with 62
within 4
without 1
work 12
writing, 27
```

At this stage, our Hadoop pseudo cluster is configured and ready to use. Now let's start to configure Apache Ignite.

Step 7:

Unpack the distribution of the apache Ignite somewhere in your sandbox and add the IGNITE_HOME path to the root directory of the installation. For getting statistics about tasks and executions, you have to add the following properties in your `/config/default-config.xml`.

```
<bean id="ignite.cfg" class="org.apache.ignite.configuration.IgniteConfiguration">
  ....
  <property name="includeEventTypes">
    <list>
      <util:constant static-field="org.apache.ignite.events.EventType.EVT_TASK_FAILED"/>
      <util:constant static-field="org.apache.ignite.events.EventType.EVT_TASK_FINISHED"/>
      <util:constant static-field="org.apache.ignite.events.EventType.EVT_JOB_MAPPED"/>
    </list>
  </property>
</bean>
```

Above configuration will enable the event task for statistics.

Warning:

By default, all events are disabled. Whenever this above events is enabled, you can use the tasks command in *ignitevisor* to get statistics about tasks executions.

IgniteVisor **tasks** command is very useful to get aggregated result of all executed tasks for a given

period of time. Check the *chapter-bigdata/src/main/config/ignite-inmemory* directory from GitHub repository[11] for complete configuration of the `defult-config.xml`.

Step 8:

Add the following libraries in `$IGNITE_HOME/libs` directory.

```
asm-all-4.2.jar
ignite-hadoop-1.6.0.jar
hadoop-mapreduce-client-core-2.7.2.jar
hadoop-common-2.7.2.jar
hadoop-auth-2.7.2.jar
```

Note that, *asm-all-4.2.jar* library version is dependent on your Hadoop version.

Step 9:

We are going to use Ignite default configuration, `config/default-config.xml` to start the Ignite node. Start the Ignite node with the following command.

```
bin/ignite.sh
```

Step 10:

Add a few more staffs to use Ignite job tracker instead of Hadoop. Add the HADOOP_CLASSPATH to the environmental variables as follows.

```
export HADOOP_CLASSPATH=$HADOOP_CLASSPATH:$IGNITE_HOME/libs/ignite-core-1.6.0.jar:$IGNITE_\
HOME/libs/ignite-hadoop-1.6.0.jar:$IGNITE_HOME/libs/ignite-shmem-1.0.0.jar
```

Step 11:

At this stage, we are going to override the Hadoop `mapred-site.xml` file. For quick start, add the following fragment of xml to the mapred-site.xml.

[11] https://github.com/srecon/ignite-book-code-samples

```
<property>
  <name>mapreduce.framework.name</name>
  <value>ignite</value>
</property>
<property>
  <name>mapreduce.jobtracker.address</name>
  <value>127.0.0.1:11211</value>
</property>
```

Note that, we explicitly added the Map/Reduce framework to Ignite. Port 11211 is the default port to listening for the task.

> **Note:**
>
> You don't need to restart the Hadoop processes after making any changes into mapred-site.xml.

Step 12:

Run the above example of the word count Map/Reduce example again.

```
$bin/hadoop jar $HADOOP_HOME/share/hadoop/mapreduce/hadoop-mapreduce-examples-2.7.2.jar wo\
rdcount /input/hadoop output2
```

The output should be very similar as shown in figure 5.4.

```
May 30, 2016 12:21:40 PM org.apache.ignite.internal.client.impl.connection.GridClientNioTcpConnection <init>
INFO: Client TCP connection established: localhost/127.0.0.1:11211
May 30, 2016 12:21:40 PM org.apache.ignite.internal.client.impl.GridClientImpl <init>
INFO: Client started [id=4ce54600-c8c4-43cf-9e22-d6b3813c2cdd, protocol=TCP]
16/05/30 12:21:42 INFO input.FileInputFormat: Total input paths to process : 32
16/05/30 12:21:43 INFO mapreduce.JobSubmitter: number of splits:32
16/05/30 12:21:44 INFO mapreduce.JobSubmitter: Submitting tokens for job: job_92f230ed-adf0-4457-a16f-e853272fb88f_0003
16/05/30 12:21:44 INFO mapreduce.Job: The url to track the job: N/A
16/05/30 12:21:44 INFO mapreduce.Job: Running job: job_92f230ed-adf0-4457-a16f-e853272fb88f_0003
16/05/30 12:21:45 INFO mapreduce.Job: Job job_92f230ed-adf0-4457-a16f-e853272fb88f_0003 running in uber mode : false
16/05/30 12:21:45 INFO mapreduce.Job:  map 0% reduce 0%
16/05/30 12:21:51 INFO mapreduce.Job:  map 6% reduce 0%
16/05/30 12:21:52 INFO mapreduce.Job:  map 25% reduce 0%
16/05/30 12:21:54 INFO mapreduce.Job:  map 63% reduce 0%
16/05/30 12:21:55 INFO mapreduce.Job:  map 100% reduce 0%
16/05/30 12:21:56 INFO mapreduce.Job:  map 100% reduce 100%
16/05/30 12:21:56 INFO mapreduce.Job: Job job_92f230ed-adf0-4457-a16f-e853272fb88f_0003 completed successfully
16/05/30 12:21:56 INFO mapreduce.Job: Counters: 0
```

Figure 5.4

Now Execution time is faster than last time, when we have used Hadoop task tracker. Let's examine the Ignite task execution statistics through ignite visor:

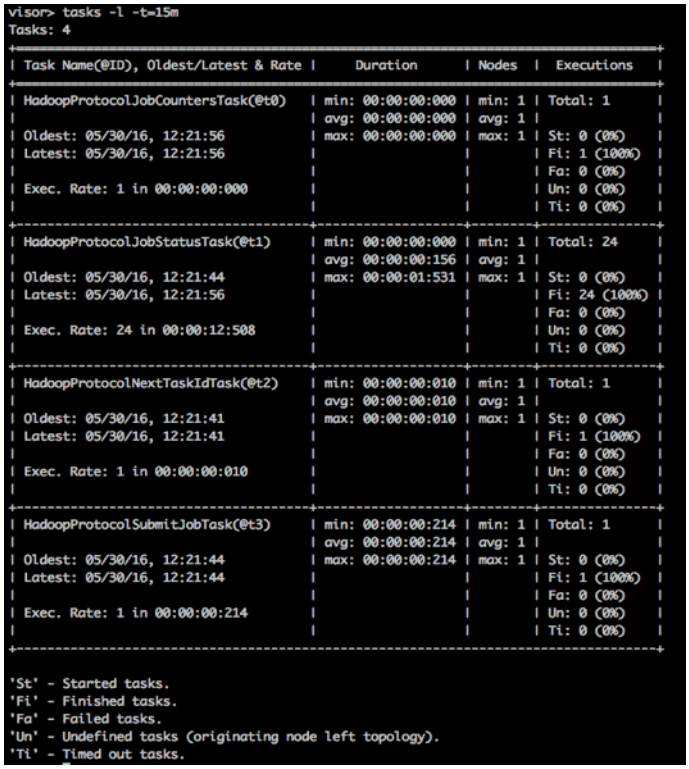


Figure 5.5

From the figure 5.5, we can notice that, the total executions and the durations times of the in-memory task tracker. In our case total executions task (*HadoopProtocolJobStatusTask(@t1)*) is 24 and the execution rate are 12 second.

Benchmark

To demonstrate the performance advantage of the Ignite Map/Reduce engine, measurements were made of the familiar Hadoop WordCount and PI sample application. This program was run both on the standard Apache Hadoop distribution and on an Ignite that included a built-in Hadoop MapReduce execution engine.

The Hadoop distribution comes with a number of benchmarks, which are bundled in hadoop-*test*.jar and hadoop-*examples*.jar. The two benchmarks we are going to use are WordCount and PI. The full list of available options for hadoop-*examples*.jar are shown bellows:

```
$ bin/hadoop jar hadoop-*examples*.jar
An example program must be given as the first argument.
Valid program names are:
  aggregatewordcount: An Aggregate based map/reduce program that counts the words in the i\
nput files.
  aggregatewordhist: An Aggregate based map/reduce program that computes the histogram of \
the words in the input files.
  dbcount: An example job that count the pageview counts from a database.
  grep: A map/reduce program that counts the matches of a regex in the input.
  join: A job that effects a join over sorted, equally partitioned datasets
  multifilewc: A job that counts words from several files.
  pentomino: A map/reduce tile laying program to find solutions to pentomino problems.
  pi: A map/reduce program that estimates Pi using monte-carlo method.
  randomtextwriter: A map/reduce program that writes 10GB of random textual data per node.
  randomwriter: A map/reduce program that writes 10GB of random data per node.
  secondarysort: An example defining a secondary sort to the reduce.
  sleep: A job that sleeps at each map and reduce task.
  sort: A map/reduce program that sorts the data written by the random writer.
  sudoku: A sudoku solver.
  teragen: Generate data for the terasort
  terasort: Run the terasort
  teravalidate: Checking results of terasort
  wordcount: A map/reduce program that counts the words in the input files.
```

The wordcount example, for instance we will be used to count the word from the `The Complete Works of William Shakespeare` file. On the other hand, we are going to use the PI example to calculate the digit of pi using Monte-Carlo method. However, it's not recommended to use Hadoop pseudo-distributed server for benchmarking, we will do it for academic purposes.

Sandbox for benchmark:

VM	**VMWare**
OS	RedHat enterprise Linux
CPU	2
RAM	2 Gb
JVM version	1.7_60
Ignite version	1.6, single node cluster
Hadoop version	2.7.2, pseudo cluster

First of all, we are going to use the wordcount example to count words from the *The Complete Works of William Shakespeare* file.

Step 1:

Create another input directory in HDFS to store the file `t8.shakespeare.txt`. You can download the file from the input directory of the GitHub project `chapter-bigdata/src/main/input/t8.shakespeare.txt`.

The file size is approximately 5.5 MB.

```
hdfs dfs -mkdir /wc-input
```

Step 2:

Store the file into the HDFS *wc-input* directory.

```
hdfs dfs -put /YOUR_PATH_TO_THE_FILE /t8.shakespeare.txt /wc-input
```

Step 3:

Comment the following fragment of the properties into the mapred-site.xml.

```
<property>
        <name>mapreduce.framework.name</name>
        <value>ignite</value>
</property>
<property>
        <name>mapreduce.jobtracker.address</name>
        <value>localhost:11211</value>
</property>
```

Step 4:

And before we start, here's a nifty trick for your tests: When running the benchmarks described in the following sections, you might want to use the Unix time command to measure the elapsed time. This saves you the hassle of navigating to the Hadoop *JobTracker* web interface to get the (almost) same information. Simply prefix every Hadoop command with time as follows:

```
time hadoop jar $HADOOP_HOME/share/hadoop/mapreduce/hadoop-mapreduce-examples-2.7.2.jar wo\
rdcount /wc-input/ output6
```

Run the above job a few times. You should get the relevant value (real) in the console as shown below:

```
16/09/05 16:05:56 INFO mapred.LocalJobRunner: 2 / 2 copied.
16/09/05 16:05:56 INFO mapred.Task: Task attempt_local1864495227_0001_r_000000_0 is allowe\
d to commit now
16/09/05 16:05:56 INFO output.FileOutputCommitter: Saved output of task 'attempt_local1864\
495227_0001_r_000000_0' to hdfs://localhost:9000/user/user/output20/_temporary/0/task_loca\
l1864495227_0001_r_000000
16/09/05 16:05:56 INFO mapred.LocalJobRunner: reduce > reduce
16/09/05 16:05:56 INFO mapred.Task: Task 'attempt_local1864495227_0001_r_000000_0' done.
16/09/05 16:05:57 INFO mapreduce.Job:  map 100% reduce 100%
16/09/05 16:05:57 INFO mapreduce.Job: Job job_local1864495227_0001 completed successfully
16/09/05 16:05:57 INFO mapreduce.Job: Counters: 35
                File System Counters
                        FILE: Number of bytes read=2948198
                        FILE: Number of bytes written=5833532
                        FILE: Number of read operations=0
                Map-Reduce Framework
                        Map input records=128803
                        Map output records=926965
                        Map output bytes=8787114
                        Map output materialized bytes=1063186
                        Input split bytes=219
                Shuffle Errors
                        BAD_ID=0
                        CONNECTION=0
                        IO_ERROR=0
                        WRONG_LENGTH=0
                        WRONG_MAP=0
                        WRONG_REDUCE=0
                File Input Format Counters
                        Bytes Read=5596513
                File Output Format Counters
                        Bytes Written=724175
real            0m25.732s
user            0m14.582s
sys             0m0.616s
```

Step 5:

Next, run the Ignite version of the Map/Reduce for wordcount example. Uncomment or add the following fragment of the xml into `mapred-site.xml`.

```
<property>
        <name>mapreduce.framework.name</name>
        <value>ignite</value>
</property>
<property>
        <name>mapreduce.jobtracker.address</name>
        <value>localhost:11211</value>
</property>
```

Execute the same command a few times as follows.

```
time hadoop jar $HADOOP_HOME/share/hadoop/mapreduce/hadoop-mapreduce-examples-2.7.2.jar wo\
rdcount /wc-input/ output7
```

In console, you should get the following output.

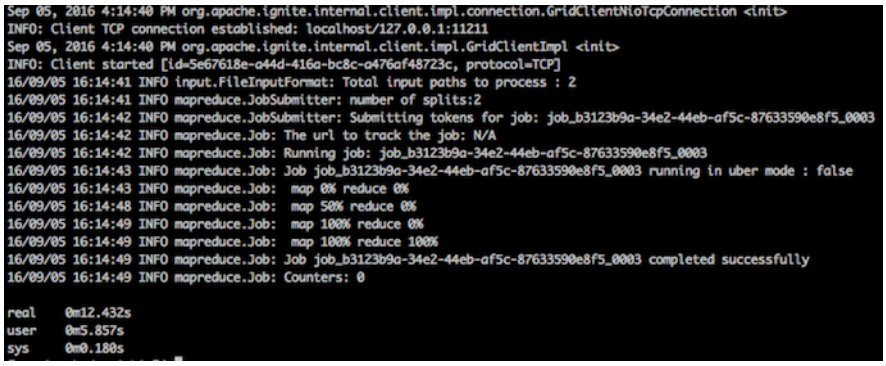


Figure 5.6

Step 6:

For the second benchmark test, we executes the PI example with 16 maps and 1000000 sample per map. Run the following command for Hadoop and Ignite Map/Reduce as follows:

```
time hadoop jar $HADOOP_HOME/share/hadoop/mapreduce/hadoop-mapreduce-examples-2.7.2.jar pi\
 16 1000000
```

The output should be the same as the shown below:

```
Sep 05, 2016 4:21:39 PM org.apache.ignite.internal.client.impl.connection.GridClientNioTcpConnection <init>
INFO: Client TCP connection established: localhost/127.0.0.1:11211
Sep 05, 2016 4:21:39 PM org.apache.ignite.internal.client.impl.GridClientImpl <init>
INFO: Client started [id=d011a8e1-8a96-4af4-afc6-baa7ca6f04be, protocol=TCP]
16/09/05 16:21:39 INFO input.FileInputFormat: Total input paths to process : 16
16/09/05 16:21:40 INFO mapreduce.JobSubmitter: number of splits:16
16/09/05 16:21:40 INFO mapreduce.JobSubmitter: Submitting tokens for job: job_b3123b9a-34e2-44eb-af5c-87633590e8f5_0005
16/09/05 16:21:41 INFO mapreduce.Job: The url to track the job: N/A
16/09/05 16:21:41 INFO mapreduce.Job: Running job: job_b3123b9a-34e2-44eb-af5c-87633590e8f5_0005
16/09/05 16:21:42 INFO mapreduce.Job: Job job_b3123b9a-34e2-44eb-af5c-87633590e8f5_0005 running in uber mode : false
16/09/05 16:21:42 INFO mapreduce.Job:  map 0% reduce 0%
16/09/05 16:21:46 INFO mapreduce.Job:  map 31% reduce 0%
16/09/05 16:21:47 INFO mapreduce.Job:  map 100% reduce 0%
16/09/05 16:21:50 INFO mapreduce.Job:  map 100% reduce 100%
16/09/05 16:21:50 INFO mapreduce.Job: Job job_b3123b9a-34e2-44eb-af5c-87633590e8f5_0005 completed successfully
16/09/05 16:21:50 INFO mapreduce.Job: Counters: 0
Job Finished in 11.013 seconds
Estimated value of Pi is 3.14159125000000000000

real    0m17.814s
user    0m6.349s
sys     0m0.246s
```

Figure 5.7

After running the benchmark test, we can demonstrate the performance gain of the Ignite in-memory Map/Reduce. Two different test were run with same data sets 3 times and Ignite demonstrate the 1.7% performance gain on both test as shown in figure 5.7 below.

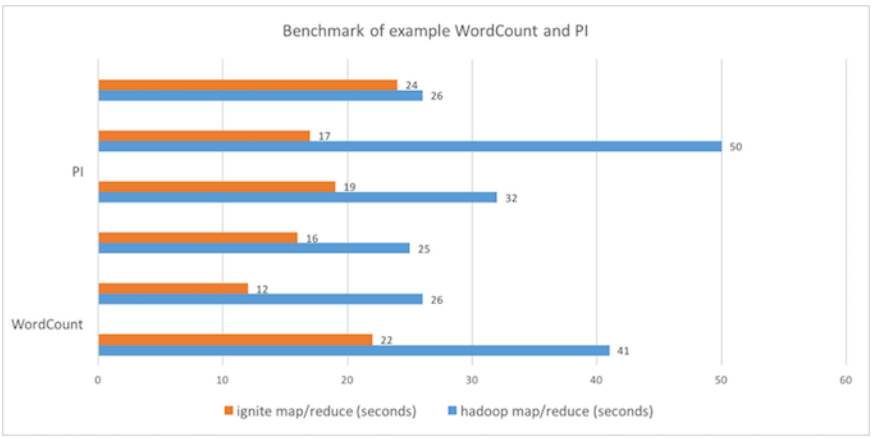


Figure 5.8

Note that, both of the test executes on single node machine, and the result will be varying on real cluster. Anyway, we have seen how the Ignite can enable significant speed reduction in analysis time, the Ignite also allows the input data set to be updated while the MapReduce analysis is in progress. Using the standard Hadoop MapReduce distribution, live updates are not possible since data in HDFS can only be appended and not updated.

Here, we are going to finish this section. In the next section, we will use Apache Pig for data analysis.

Using Apache Pig for data analysis

Apache Pig provides a platform for analysing very large scale data set. With Apache Pig you can easily analyse your data from Hadoop HDFS. Apache pig compiles instruction to sequences of Map-Reduce programs which will run on Hadoop cluster. Apache Pig provides PigLatin scripting

language, which can perform operations like ETL or AdHoc data analysis. Pig was built to make programming Map/Reduce easier, before Pig, Java was only way to process the data stored on HDFS.

Apache Ignite provides a transparent way to run PigLatin scripts in Ignite in-memory Map/Reduce. Almost nothing you have to configure to run PigLatin script. Our setup from the previous section is enough to run in-memory Map/Reduce through PigLatin script. We just have to install Apache Pig in our environment to execute the PigLatin script.

Let's have a look at the features of Pig. Apache Pig comes with the following features:

- **Ease of programming** – PigLatin script is very much similar to SQL script. It's very easy to scripting in Pig, if you are good at SQL.
- **Analytical functions** – Pig provides a lot of functions and operators to perform operations like, Filter, GroupBy, Sort etc.
- **Extensibility** – With existing operators, user can develop their custom functions to read, write or process data. For example, we have developed a Pig function to parse xml and validate XML documents from HDFS.
- **Handles all kinds of Data** - Apache Pig can process or handle any kind of data, both structured or semi structured. It can store result into HDFS, Cassandra or Hbase.

Usually, Apache Pig is used by the data scientist or data analyst for performing ad-hoc scripting and quick prototyping. Apache Pig is hugely used in batch processing, such as

- Processing time sensitive data.
- Data analysis through sampling, for example weblogs.
- Data processing for search platform.

Although Map/Reduce is a powerful programming model, there are a significant difference between Apache Pig and Map/Reduce. The major difference between Pig and the Map/Reduce are shown below:

Pig	MapReduce
Apache Pig is a data flow language.	Map/Reduce is a data processing paradigm.
Apache Pig is a high level language.	Map/Reduce is a low level language, almost written in java or Python.
During execution of the PigLatin script, every Pig operator converted internally into a Map/Reduce job.	Map/Reduce job have a long compilation process.

Here, we are going to use two different datasets for our examples, one of them are `Shakespeare all works` in text file and another one is the `movies_data.csv` csv file, which contain a list of movies name, release year, rating etc. Both of them are reside in the directory */chapter-*

bigdata/src/main/input.

Next, we explains how to install, setup and run PigLatin scripts in in-memory Map/Reduce.

It is essential that you have Java and Hadoop installed and configured in your sandbox to run Pig. Check the previous section to configure Hadoop and Ignite to your system.

Let's have a look at our sandbox configuration as shown below.

VM	**VMWare**
OS	RedHat enterprise Linux
CPU	2
RAM	2 Gb
JVM version	1.7_60
Ignite version	1.6, single node cluster
Hadoop version	2.7.2, pseudo cluster
Pig version	0.16.0

Next, we will download and install Pig in our sandbox.

Step 1:

Download the latest version of the Apache Pig from the following link[12]. In our case the Pig version is 0.16.0.

Step 2:

Untar the zip archive anywhere in your sandbox.

```
tar xvzf pig-0.16.0.tar.gz
```

And rename the folder for easier access as follows:

```
mv pig-0.16.0 pig
```

Step 3:

Add /pig/bin to your path. Use export (bash, sh) or setenv (csh).

```
export PATH=/<my-path-to-pig>/pig/bin:$PATH
```

Step 4:

Test the pig installation with the following simple command.

[12] https://github.com/srecon/ignite-book-code-samples

```
pig --help
```

That's it, now you are ready to run PigLatin scripts. Apache Pig scripts can be executed in three different ways, interactive mode, batch mode and embedded mode.

1. Interactive mode or Grunt shell – In this shell, you can enter the PigLatin statements and get the output or results.
2. Batch mode or script mode – You can run Apache Pig scripts in batch mode by writing the Pig Latin scripts in a single file with extension pig.
3. Embedded mode - Apache Pig provides the provision of defining our own functions (User Defined Functions) in programming languages such as Java, and using them in your script.

You can run the Grunt shell in desired mode (local/cluster) using the –x option as follows:

Figure 5.9

With –x option, Grunt shell will start in cluster mode as above. In figure 5.9 we can also notice that, Pig is connected to Ignite in-memory job tracker at port 11211. Now, we executes example of classic wordcount application with Apache Pig. For that, we are going to use our previously inserted `t8.shakespeare.txt` file from Hadoop HDFS.

Step 5:

Use the following command to load the data from HDFS.

```
A = load '/wc-input/t8.shakespeare.txt';
```

The above statement is made up of two parts. The part to the left of "=" is called the relation or alias. It looks like a variable but you should notice that this is not a variable. When this statement is executed, no MapReduce task is executed. On the other hand, all the data loads from the HDFS to variable A.

Step 6:

Let's generate data transformation based on column of data. Sometimes, we want to eliminate nesting, this can be accomplished by flatten keywords.

```
B = foreach A generate flatten(TOKENIZE((chararray)$0)) as word;
```

Step 7:

By the group keyword we can group together all the tuples that gave the same group key.

```
C = group B by word;
```

Step 8:

Use the count function to compute the number of elements in the bags.

```
D = foreach C generate COUNT(B), group;
```

That's is. Only four lines of code and the wordcount example is ready to go. At this moment, we can dump the results into the console or store the result into HDFS file. Let's dump the output into console.

```
E = limit D 10;
dump E;
```

Before dump the result, we limit it to 100 rows for demonstrativeness. Whenever you execute the DUMP command, in-memory Map/Reduce will run and compute the count of all word in text file and output the result into the console as shown below.

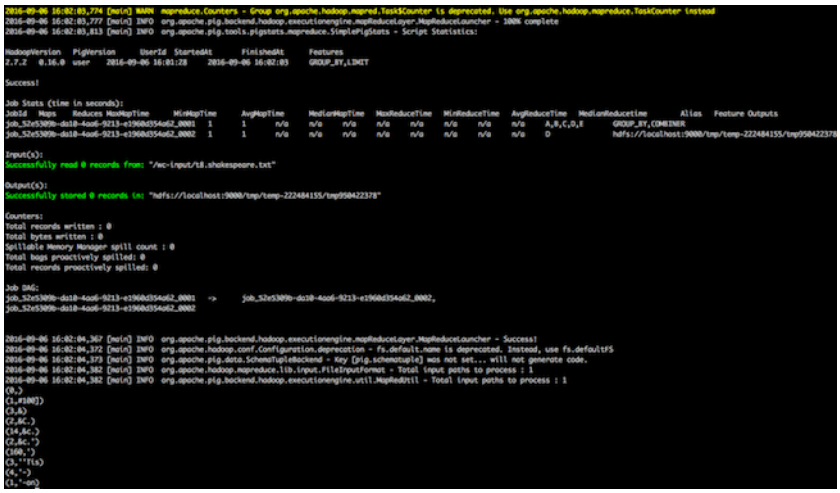


Figure 5.10

Let's have a look at the Ignite task statistics through ignitevisor as follows:

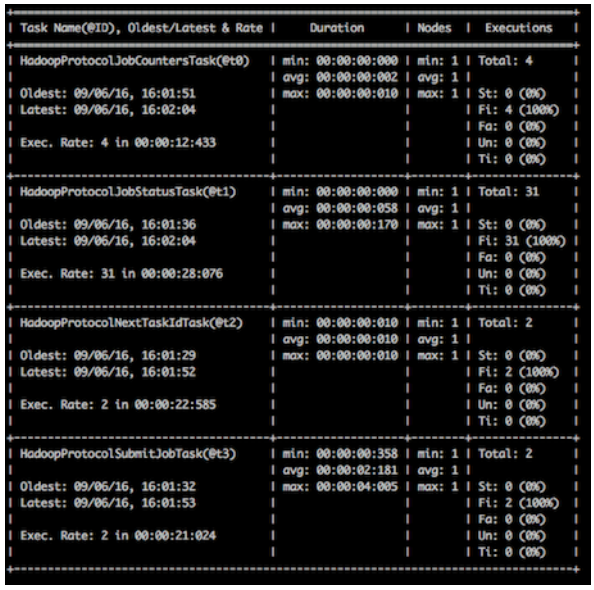


Figure 5.11

In the figure 5.11, we can see the different statistics for different task execution. Total execution task is 39 with average 12 seconds. Now that we have got the basics, let's write more complex Pig script. Here we will use another dataset, movies_data.csv. A sample dataset is as follows:

```
1,The Nightmare Before Christmas,1993,3.9,4568
2,The Mummy,1932,3.5,4388
3,Orphans of the Storm,1921,3.2,9062
4,The Object of Beauty,1991,2.8,6150
5,Night Tide,1963,2.8,5126
6,One Magic Christmas,1985,3.8,5333
7,Muriel's Wedding,1994,3.5,6323
8,Mother's Boys,1994,3.4,5733
9,Nosferatu: Original Version,1929,3.5,5651
10,Nick of Time,1995,3.4,5333
```

Where, the 2nd column is the name of the move, next column is the movie release year and the 4th column will be the overall rating of the certain movies. Let's upload the movies_data.csv file into Hadoop HDFS.

Step 1:

Upload `movies_data.csv` file in HDFS.

```
bin/hdfs dfs -put /YOUR_PATH_TO_THE_FILE/movies_data.csv/wc-input
```

Step 2:

Execute the following pig statement to load the file from the HDFS.

```
movies = LOAD '/wc-input/hadoop/movies_data.csv' USING PigStorage(',') as (id:int,name:cha\
rarray,year:int,rating:double,duration:int);
```

Step 3:

Let's make a search of movies with rating greater than four.

```
movies_rating_greater_than_four = FILTER movies BY (float) rating>4.0;
```

Step 4:

Dump the result into console.

```
DUMP movies_rating_greater_than_four;
```

The output should be huge.

Step 5:

Search for the movie with the name "Mummy";

```
movie_mummy = FILTER movies by (name matches '.*Mummy.*');
```

The output should be the same as below:

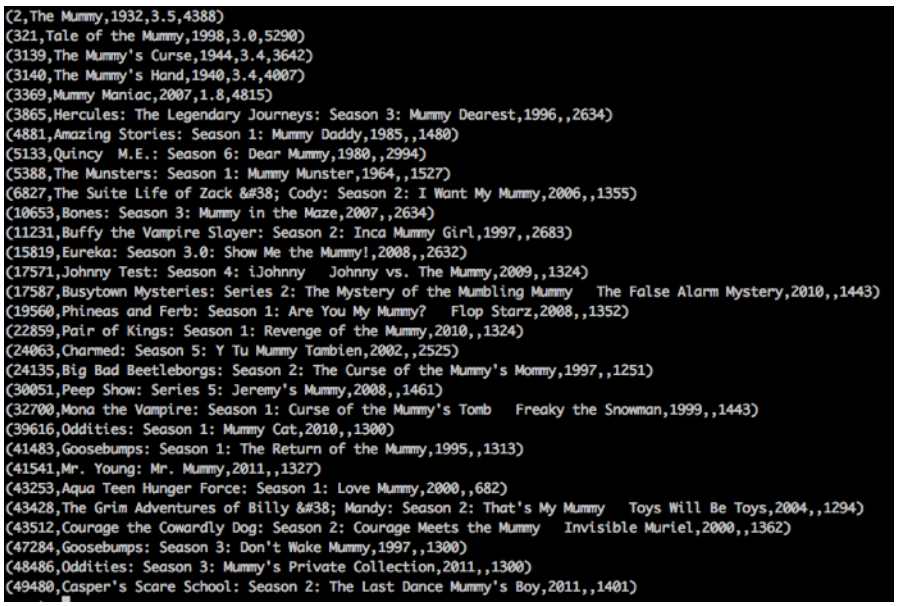


Figure 5.12

You can group movies by year, even you can count movies by year. The full source code of the Pig script is as follows:

```
movies = LOAD '/input/hadoop/movies_data.csv' USING PigStorage(',') as (id:int,name:charar\
ray,year:int,rating:double,duration:int);
movies_rating_greater_than_four = FILTER movies BY (float)rating > 4.0;
DUMP movies_rating_greater_than_four;
movie_mummy = FILTER movies by (name matches '.*Mummy.*');
grouped_by_year = group movies by year;
count_by_year = FOREACH grouped_by_year GENERATE group, COUNT(movies);
group_all = GROUP count_by_year ALL;
sum_all = FOREACH group_all GENERATE SUM(count_by_year.$1);
DUMP sum_all;
```

The dump command is only used to display the informations onto the standard output. If you need to store the result to a file, you can use the pig Store command as follows:

```
store sum_all into '/user/hadoop/sum_all_result;
```

In this section we got a good feel of Apache Pig. We installed Apache Pig from the scratch, loaded some data and executed some basic commands to query by in-memory Map/Reduce of Ignite. The next section will cover Apache Hive to analysis Big Data by Ignite in-memory Map/Reduce.

Near real time data analysis with Hive

Apache Hive is a data warehouse framework for querying and analysis of data that is stored in Hadoop HDFS. Unlike Apache Pig, Hive provides SQL like declarative language, called HiveQL, which is used for expressing queries. Hive was designed to appeal to a community comfortable with SQL. Its philosophy was that we don't need yet another scripting language. Usually Hive engine compiles the HiveQL quires into Hadoop Map/Reduce jobs to be executed on Hadoop. In addition, custom Map/Reduce scripts can also be plugged into queries.

Hive operates on data stored in tables which consists of primitive data types and collection data types like arrays and maps. Hive query language is similar to SQL, where it supports subqueries. With Hive query language, it is possible to take a MapReduce joins across Hive tables. It has a support for simple SQL like functions- CONCAT, SUBSTR, ROUND etc., and aggregation functions like SUM, COUNT, MAX etc. It also supports GROUP BY and SORT BY clauses. It is also possible to write user defined functions in Hive query language.

Apache Ignite transparently support Apache Hive to analysis data from the HDFS through in-memory Map/Reduce. No additional configurations for Ignite or Hadoop cluster is not necessary. Hive engines compiles the HiveQL quires into Hadoop Map/Reduce jobs, which will be delegated into Ignite in-memory Map/Reduce jobs. Accordingly, the execution of the HiveQL quires is much faster than usual. Let's have a quick look at the features of Apache Hive. Hive provides the following features:

- It stores schema in database such as derby and processed data into HDFS.

- It provides SQL type language for scripting called HiveQL or HQL.
- It is fast, scalable and extensible.

Hive makes daily jobs easy for performing operation like:

- Ad-hoc quires.
- Analysis for huge datasets.
- Data encapsulation.

Unlike Apache Pig, Hive has a few important characteristics as follows:

1. In Hive, tables and databases are created first and then data is loaded into these tables.
2. Hive was designed for managing and querying only **structured** data that is stored in tables.
3. A new and important component of Hive i.e. Metastore used for storing schema information. This Metastore typically resides in a relational database.
4. For single user metadata storage, Hive uses derby database and for multiple user Metadata or shared Metadata case, Hive uses MYSQL.
5. Hive supports partition and buckets concepts for easy retrieval of data when the client executes the query.

For demonstration purpose, we are going run wordcount example through HiveQL in the file `Shakespeare all works`. As we discussed before, we are not going to make any change to our Ignite or Hadoop cluster. In this section, we explain how to properly configure and start Hive to execute HiveQL over Ignite Map/Reduce engine. Let's have a look at our sandbox configuration:

VM	**VMWare**
OS	RedHat enterprise Linux
CPU	2
RAM	2 Gb
JVM version	1.7_60
Ignite version	1.6, single node cluster
Hadoop version	2.7.2, pseudo cluster
Hive version	2.1.0

We are going to use Hive 2.1.0 version in our sandbox. You can download it by visiting the following link[13]. Let's assume that it gets downloaded onto any of your local directory of the sandbox.

Step 1:

To install Hive, do the following:

[13] http://apache-mirror.rbc.ru/pub/apache/hive/hive-2.1.0/

```
tar zxvf apache-hive-2.1.0-bin.tar.gz
```

The above command will extract the archive into directory called hive-2.1.0-bin. This directory will be your Hive home directory.

Step 2:

Let's create a new directory under HADOOP_HOME/etc with the following command and copy all the files from the hadoop directory. Execute the following command from the HADOOP_HOME/etc directory.

```
$ cd $HADOOP_HOME/etc
$ mkdir hadoop-hive
$ cp ./hadoop/*.* ./hadoop-hive
```

This `hadoop-hive` directory will be our `HIVE_CONF_DIRECTORY`.

Step 3:

Create a new file named `hive-site.xml` onto hadoop-hive directory with the following contents.

```
<?xml version="1.0"?>
<?xml-stylesheet type="text/xsl" href="configuration.xsl"?>
<configuration>
    <!--
        Ignite requires query plan to be passed not using local resource.
    -->
    <property>
        <name>hive.rpc.query.plan</name>
        <value>true</value>
    </property>
</configuration>
```

Step 4:

Here, we will create a simple bash script, which will properly set all required variables and run Hive like this:

```
#!/usr/bin/env bash
# Specify Hive home directory:
export HIVE_HOME=<Hive installation directory>

# If you did not set hadoop executable in PATH, specify Hadoop home explicitly:
export HADOOP_HOME=<Hadoop installation folder>

# Specify configuration files location:
export HIVE_CONF_DIR=$HADOOP_HOME/etc/hadoop-hive

# Avoid problem with different 'jline' library in Hadoop:
export HADOOP_USER_CLASSPATH_FIRST=true

${HIVE_HOME}/bin/hive "${@}"
```

Place the bash script onto the `$HIVE_HOME/bin` with name hive-ig.sh. Make the file runnable with the following command:

```
chmod +x ./hive-ig.sh
```

Step 5:

By default, Hive store metadata information onto Derby database. Before run Hive interactive console, run the following command to initialize Derby database.

```
schematool -initSchema -dbType derby
```

The above command will create a directory called metastore-db.

Warning:

Note that, if you have any existing directory called metastore-db, you have to delete it before initialize derby db.

Step 6:

Start your Hive interactive console with the following command:

```
hive-ig.sh
```

It will take a few moments to run the console. If everything goes fine, you should have the following screen in your console.

Figure 5.13

Step 7:

Now, you can run HiveQL in console. Let's create a table in Hive and load the file `t8.shakespeare.txt`, then run the SQL query to count the words from the file.

```
CREATE TABLE input (line STRING);
```

Check the table by the following command.

```
hive> show tables;
OK
input
Time taken: 0.028 seconds, Fetched: 1 row(s)
```

Now, we can load the data from the host file system by Hive load command.

```
LOAD DATA LOCAL INPATH '/home/user/hadoop/t8.shakespeare.txt' OVERWRITE INTO TABLE input;
```

Note that, you have to change the INPATH of the file according to your local path. The above command loads the whole file into the column `line` in table `input`. Here, we are ready to execute any HiveQL quires on our data, let's run the query to wordcount from the table called `input`.

```
SELECT word, COUNT(*) FROM input LATERAL VIEW explode(split(line, ' ')) lTable as word GRO\
UP BY word;
```

After running the above query, you should find the following information into your console.

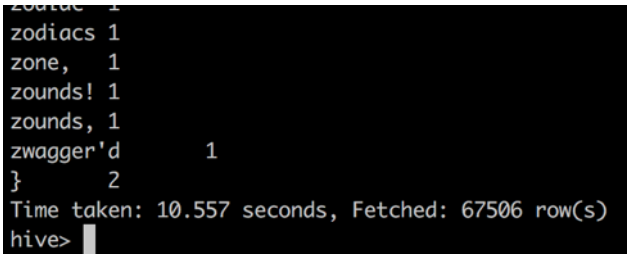


Figure 5.14

If you switch to the Ignite console, you should have a huge amount of logs in console as follows:

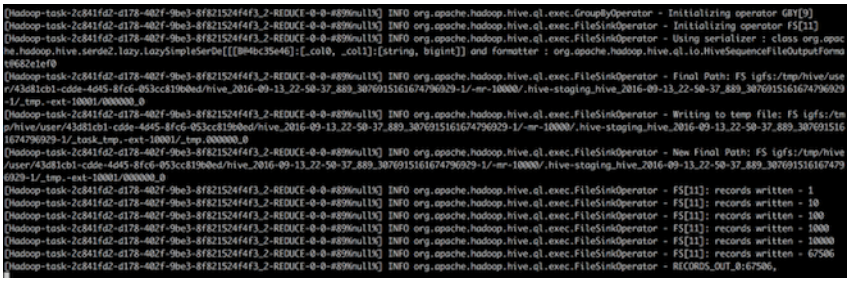


Figure 5.15

You can also use Limit keyword to restrict the maximum number of rows for the result set. With Limit clause, the above statement will look as follows:

```
SELECT word, COUNT(*) FROM input LATERAL VIEW explode(split(line, ' ')) lTable as word GRO\
UP BY word limit 5;
```

Now that, we have got the basics, let's try one more advance example. We will use the dump of movies from the previous section to create a table in Hive and execute some HiveQL quires.

Step 8:

Create a new table into Hive with the following commands:

```
CREATE TABLE IF NOT EXISTS movies
 (id STRING,
 title STRING,
 releasedate STRING,
 rating INT,
 Publisher STRING)
 ROW FORMAT DELIMITED
 FIELDS TERMINATED BY ','
 STORED AS TEXTFILE;
```

Load some data from local directory as follows:

```
LOAD DATA local INPATH '/home/user/hadoop/hadoop-2.7.2/etc/hadoop/movies_data.csv' OVERWRI\
TE INTO TABLE movies;
```

You can get the movies_data.csv data from the GitHub project `/chapter-bigdata/src/main/input`.

Tip:

Note that, you can also load the data from the HDFS and IGFS file system. If you wish to load the data from the IGFS, you should configure the IGFS file system along with HDFS. In the next chapter we will describe the complete process of deployment of the IGFS file system and run some Hive query.

Step 9:

Now that we have the data ready, let's do something interesting with it. The simple example is to see how many movies were released per year. We'll start with that, then see if we can do a bit more.

```
Select releasedate, count(releasedate) from movies m group by m.releasedate;
```

The above query should return the following output.

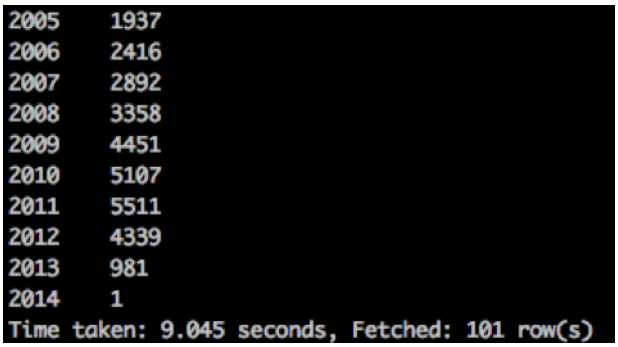


Figure 5.16

You can see the listing of years, along with the number of films released by that year. There's a lot more data in the set beyond years and films counts. Let's finding films with rating more than 3 per year. In Hive, this can be accomplished by the following query.

```
Select releasedate, count(releasedate) from movies m where rating >3  group by m.releaseda\
te;
```

The execution time of all the queries in Hive are very impressive. Execution time is around 9 second for the last query. It's very hard to compare the executions time between the Hive and Pig. This is the end of the section of Hive. In this section, we described how to install and configure to use Hive with Ignite in-memory Map/Reduce. We also loaded a few sample of data and executes HiveQL quires. However, we can improve the query performance by using IGFS file system instead of HDFS. In the next section, we will briefly discuss the benefits of IGFS and how to use it.

Chapter six: Streaming and complex event processing

There is no broadly or highly accepted definition of the term Complex Event Processing or CEP. What Complex Event Processing is may be briefly described as the following quote from the Wikipedia:

Complex Event Processing, or CEP, is primarily an event processing concept that deals with the task of processing multiple events with the goal of identifying the meaningful events within the event cloud. CEP employs techniques such as detection of complex patterns of many events, event correlation and abstraction, event hierarchies, and relationships between events such as causality, membership, and timing, and event-driven processes.

For simplicity, Complex Event Processing (CEP) is a technology for low-latency filtering, aggregating and computing on real-world never ending or streaming event data. The quantity and speed of both raw infrastructure and business events are exponentially growing in IT environments. In addition, the explosion of mobile devices and the ubiquity of high-speed connectivity add to the explosion of mobile data. At the same time, demand for business process agility and execution has only grown. These two trends have put pressure on organizations to increase their capability to support event-driven architecture patterns of implementation. Real-time event processing requires both the infrastructure and the application development environment to execute on event processing requirements. These requirements often include the need to scale from everyday use cases to extremely high velocities or varieties of data and event throughput, potentially with latencies measured in microseconds rather than seconds of response time.

Apache Ignite allows processing continuous never-ending streams of data in scalable and fault-tolerant fashion in in-memory, rather than analyzing data after it's reached the database. Not only does this enable you to correlate relationships and detect meaningful patterns from significantly more data, you can do it faster and much more efficiently. Event history can live in memory for any length of time (critical for long-running event sequences) or be recorded as transactions in a stored database.

Apache Ignite CEP can be used in a wealth of industries area, the following are some first class use cases:

1. **Financial services**: the ability to perform real-time risk analysis, monitoring and reporting of financial trading and fraud detection.
2. **Telecommunication**: ability to perform real-time call detail record and SMS monitoring and DDoS attack.

3. **IT systems and infrastructure**: the ability to detect failed or unavailable application or servers in real time.
4. **Logistics**: ability to track shipments and order processing in real-time and reports on potential delays on arrival.

There are a few more industrials or functional areas, where you can use Apache Ignite to process streams event data such as Insurance, transportation and Public sector. Complex event processing or CEP contains three main parts of its process:

1. Event Capture or data ingesting.
2. Compute or calculation of these data.
3. Response or action.

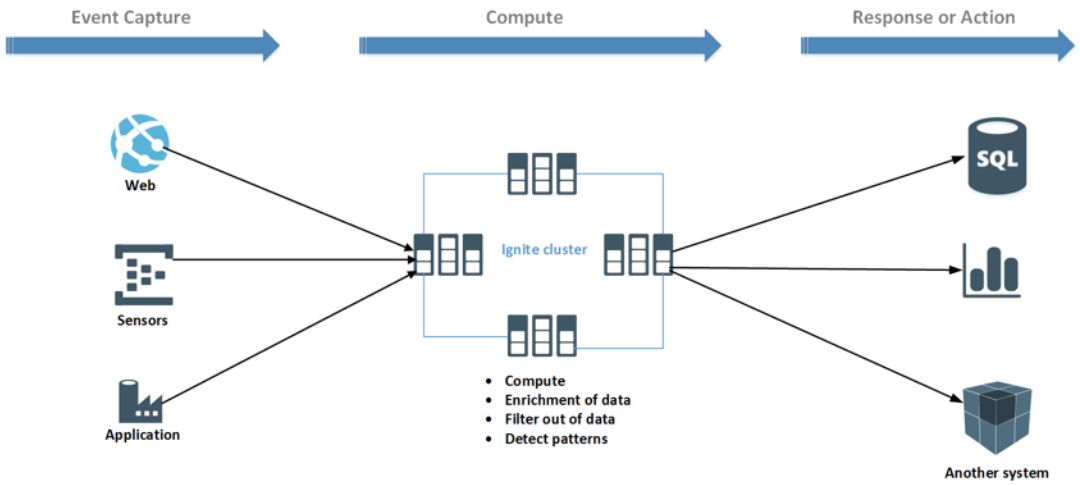


Figure 6.1

As shown in figure 6.1, data are ingesting from difference sources. Sources can be any sensors (IoT), web application or industry applications. Stream data can be concurrently processed directly on the Ignite cluster in collecting fashion. In addition, data can be enriched from other sources or filter out. After computing the data, computed or aggregated data can be exported to other systems for visualizing or taking an action.

Storm data streamer

Apache storm is a distributed fault-tolerant real-time computing system. In the era of *IoT* (Internet Of Things - the next big thing), many companies regularly generate terabytes of data in their daily operations. The sources include everything from data captured from network sensors, vehicles, physical devices, web, social data, transactional business data. With the volume of data being

generated, real-time computing has become a major challenge for most of the organization. In a short time, Apache Storm became a standard for distributed real-time processing system that allows you to process a large amount of data. Apache Storm project is open source and written in Java and Clojure. It became a first choose for real-time analytics. Apache Ignite Storm streamer module provides a convenience way to streaming data via Storm to Ignite cache.

Although Hadoop and Storm frameworks are used for analysing and processing big data, both of them complement each other and differ in a few aspects. Like Hadoop, Storm can process huge amount of data, but does it in real-time, with guaranteed reliability, means, every message will be processed. It has these advantages as well:

1. Simple scalability, to scale horizontally, you simply add machines and change parallelism settings of the topology.
2. Stateless message processing.
3. It guarantees processing of every message from the source.
4. It is fault tolerance.
5. Topology of Storm can be written in any languages, although mostly Java is used.

Key concepts:

Apache Storm reads raw stream of data from the one end and passes it through a sequence of small processing units and output the processed information at the other end. Let's have a detailed look at the main components of Apache Storm –

Tuples – It is the main data structure of the Storm. It's an ordered list of elements. Generally, tuple supports all primitives data types.

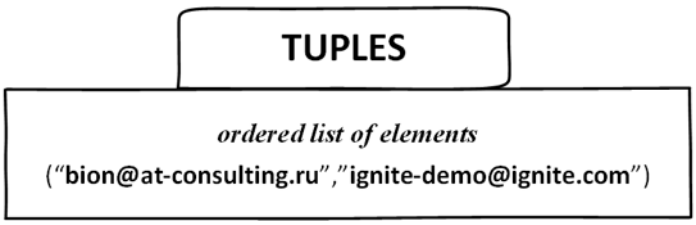


Figure 6.19

Streams – It's an unbound and un ordered sequence of tuples.

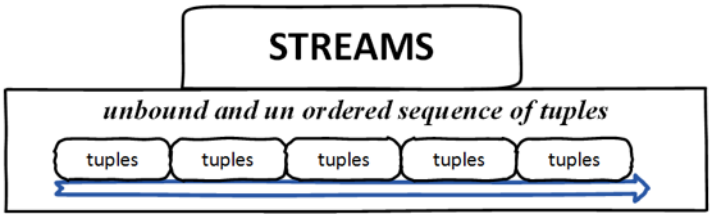


Figure 6.20

Spouts - Source of streams, in simple terms, a spout reads the data from a source for use in topology. A spout can reliable or unreliable. A spout can talk with Queues, Web logs, event data etc.

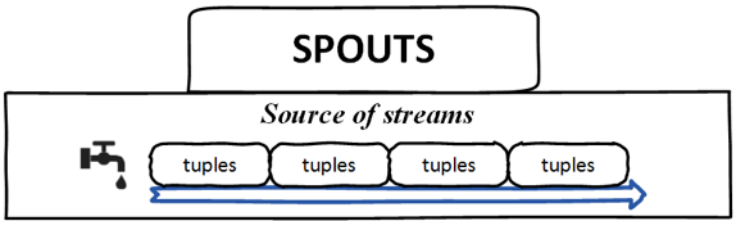


Figure 6.21

Bolts - Bolts are logical processing units, it is responsible for processing data and creating new streams. Bolts can perform the operations of filtering, aggregation, joining, interacting with files/database and so on. Bolts receives data from spout and emit to one or more bolts.

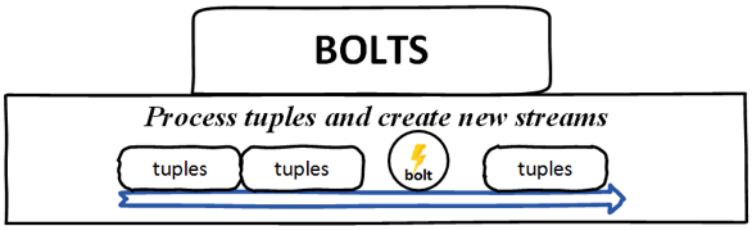


Figure 6.22

Topology – A topology is a directed graph of Spouts and Bolts, each node of this graph contains the data processing logic (bolts) while connecting edges define the flow of the data (streams).

Unlike Hadoop, Storm keeps the topology running forever until you kill it. A simple topology starts with spouts, emit stream from the sources to bolt for processing data. Apache Storm main job is to run the topology and will run any number of topology at given time.

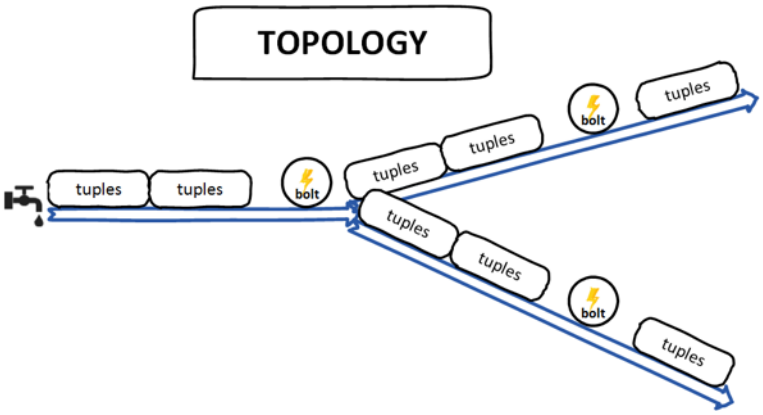


Figure 6.23

Ignite out of the box provides an implementation of Storm Bolt (StormStreamer) to streaming the computed data into Ignite cache. On the other hand, you can write down your custom Strom Bolt to ingest stream data into Ignite. To develop a custom Storm Bolt, you just have to implement *BaseBasicBolt* or *IRichBolt* Storm interface. However, if you decide to use StormStreamer, you have to configure a few properties to work the Ignite Bolt correctly. All mandatory properties are shown below:

№	Property Name	Description
1	CacheName	Cache name of the Ignite cache, in which the data will be store.
2	IgniteTupleField	Names the Ignite Tuple field, by which tuple data is obtained in topology. By default the value is *ignite*.
3	IgniteConfigFile	This property will set the Ignite spring configuration file. Allows you to send and consume message to and from Ignite topics.
4	AllowOverwrite	It will enabling overwriting existing values in the cache, default value is false.
5	AutoFlushFrequency	Automatic flush frequency in milliseconds. Essentially, this is the time after which the streamer will make an attempt to submit all data added so far to remote nodes. Default is 10 sec.

Now that we have got the basics, let's build something useful to check how the Ignite *StormStreamer* works. The basic idea behind the application is to design one topology of spout and bolt that can process a huge amount of data from a traffic log files and trigger an alert when a specific value crosses a predefined threshold. Using a topology, the log file is read line by line and the topology is designed to monitor the incoming data. In our case, the log file will contain data, such as vehicle registration number, speed and the highway name from highway traffic camera. If the vehicle crosses the speed limit (for example 120km/h), Storm topology will send the data to Ignite cache.

Next listing will show a CSV file of the type we are going to use in our example, which contain vehicle data information such as vehicle registration number, the speed at which the vehicle is traveling and the location of the highway.

```
AB 123, 160, North city
BC 123, 170, South city
CD 234, 40, South city
DE 123, 40, East city
EF 123, 190, South city
GH 123, 150, West city
XY 123, 110, North city
GF 123, 100, South city
PO 234, 140, South city
XX 123, 110, East city
YY 123, 120, South city
ZQ 123, 100, West city
```

The idea of the above example is taken from the *Dr. Dobbs* journal. Since this book is not for studying Apache Storm, I am going to keep the example simple as possible. Also, I have added the famous word count example of Storm, which ingests the word count value into Ignite cache through StormStreamer module. If you are curious about the code, it's available at **chapter-cep/storm**. The above csv file will be the source for the Storm topology.

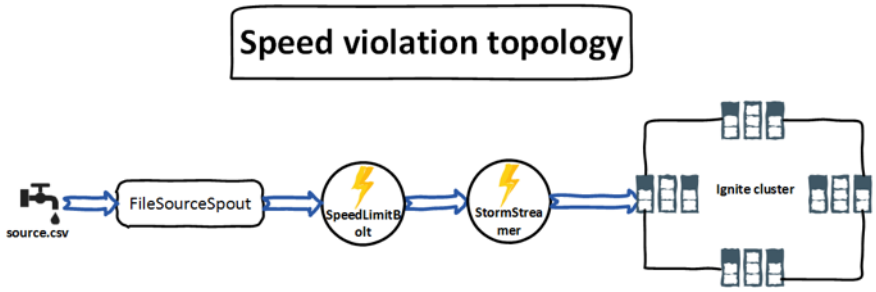


Figure 6.24

As shown in figure 6.24, the *FileSourceSpout* accepts the input csv log file, reads the data line by line and emits the data to the SpeedLimitBolt for further threshold processing. Once the processing is done and found any car with exceeding the speed limit, the data is emitted to the Ignite StormStreamer bolt, where it is ingested into the cache. Let's dive into the detailed explanation of our Storm topology.

Step 1:

Because this is a Storm topology, you must add the Storm and the Ignite StormStreamer dependency in the maven project.

```
<dependency>
    <groupId>org.apache.ignite</groupId>
    <artifactId>ignite-storm</artifactId>
    <version>1.6.0</version>
</dependency>
<dependency>
    <groupId>org.apache.ignite</groupId>
    <artifactId>ignite-core</artifactId>
    <version>1.6.0</version>
</dependency>
<dependency>
    <groupId>org.apache.ignite</groupId>
    <artifactId>ignite-spring</artifactId>
    <version>1.6.0</version>
</dependency>
<dependency>
    <groupId>org.apache.storm</groupId>
    <artifactId>storm-core</artifactId>
    <version>0.10.0</version>
    <exclusions>
        <exclusion>
            <groupId>log4j</groupId>
            <artifactId>log4j</artifactId>
        </exclusion>
        <exclusion>
            <groupId>org.slf4j</groupId>
            <artifactId>slf4j-log4j12</artifactId>
        </exclusion>
        <exclusion>
            <groupId>commons-logging</groupId>
            <artifactId>commons-logging</artifactId>
        </exclusion>
        <exclusion>
            <groupId>org.slf4j</groupId>
            <artifactId>slf4j-simple</artifactId>
        </exclusion>
        <exclusion>
            <groupId>org.slf4j</groupId>
            <artifactId>log4j-over-slf4j</artifactId>
        </exclusion>
        <exclusion>
            <groupId>org.apache.zookeeper</groupId>
            <artifactId>zookeeper</artifactId>
        </exclusion>
    </exclusions>
```

```
</dependency>
```

At the time of writing this book, Apache Storm version 0.10.0 is only supported.

> **Note:**
>
> You do not need any **Kafka** module to run or execute this example.

Step 2:

Create an Ignite configuration file (see example-ignite.xml file in `/chapter-cep/storm/src/resources/example-ignite.xml`) and make sure that it is available from the classpath. The content of the Ignite configuration is identical from the previous section of this chapter.

```
<beans xmlns="http://www.springframework.org/schema/beans"
       xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
       xmlns:util="http://www.springframework.org/schema/util"
       xsi:schemaLocation="
        http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/util
        http://www.springframework.org/schema/util/spring-util.xsd">
    <bean id="ignite.cfg" class="org.apache.ignite.configuration.IgniteConfiguration">
        <!-- Enable client mode. -->
        <property name="clientMode" value="true"/>
        <!-- Cache accessed from IgniteSink. -->
        <property name="cacheConfiguration">
            <list>
                <!-- Partitioned cache example configuration with configurations adjusted \
to server nodes'. -->
                <bean class="org.apache.ignite.configuration.CacheConfiguration">
                    <property name="atomicityMode" value="ATOMIC"/>

                    <property name="name" value="testCache"/>
                </bean>
            </list>
        </property>
        <!-- Enable cache events. -->
        <property name="includeEventTypes">
            <list>
                <!-- Cache events (only EVT_CACHE_OBJECT_PUT for tests). -->
                <util:constant static-field="org.apache.ignite.events.EventType.EVT_CACHE_\
OBJECT_PUT"/>
```

```
            </list>
        </property>
       <!-- Explicitly configure TCP discovery SPI to provide list of initial nodes. -->
        <property name="discoverySpi">
            <bean class="org.apache.ignite.spi.discovery.tcp.TcpDiscoverySpi">
                <property name="ipFinder">
                    <bean class="org.apache.ignite.spi.discovery.tcp.ipfinder.vm.TcpDiscov\
eryVmIpFinder">
                        <property name="addresses">
                            <list>
                                <value>127.0.0.1:47500</value>
                            </list>
                        </property>
                    </bean>
                </property>
            </bean>
        </property>
    </bean>
</beans>
```

Step 3:

Create a ignite-storm.properties file to add the cache name, tuple name and the name of the Ignite configuration as shown below.

```
cache.name=testCache
tuple.name=ignite
ignite.spring.xml=example-ignite.xml
```

Step 4:

Next, create FileSourceSpout Java class as shown below,

```
public class FileSourceSpout extends BaseRichSpout {
    private static final Logger LOGGER = LogManager.getLogger(FileSourceSpout.class);
    private SpoutOutputCollector outputCollector;
    @Override
    public void open(Map map, TopologyContext topologyContext, SpoutOutputCollector spoutO\
utputCollector) {
        this.outputCollector = spoutOutputCollector;
    }
@Override
    public void nextTuple() {
        try {
            Path filePath = Paths.get(this.getClass().getClassLoader().getResource("source\
```

```
.csv").toURI());
            try(Stream<String> lines = Files.lines(filePath)){
                lines.forEach(line ->{
                    outputCollector.emit(new Values(line));
                });
            } catch(IOException e){
                LOGGER.error(e.getMessage());
            }
        } catch (URISyntaxException e) {
            LOGGER.error(e.getMessage());
        }
    }
    @Override
    public void declareOutputFields(OutputFieldsDeclarer outputFieldsDeclarer) {
        outputFieldsDeclarer.declare(new Fields("trafficLog"));
    }
}
```

The *FileSourceSpout* code has three important methods

- **open()**: This method would get called at the start of the spout and will give you context information.
- **nextTuple()**: This method would allow you to pass one tuple to Storm topology for processing at a time, in this method, I am reading the CSV file line by line and emitting the line as a tuple to the bolt.
- **declareOutputFields()**: This method declares the name of the output tuple, in our case, the name should be trafficLog.

Step 5: Now create *SpeedLimitBolt.java* class which implements *BaseBasicBolt* interface.

```
public class SpeedLimitBolt extends BaseBasicBolt {
    private static final String IGNITE_FIELD = "ignite";
    private static final int SPEED_THRESHOLD = 120;
    private static final Logger LOGGER = LogManager.getLogger(SpeedLimitBolt.class);
    @Override
    public void execute(Tuple tuple, BasicOutputCollector basicOutputCollector) {
        String line = (String)tuple.getValue(0);
        if(!line.isEmpty()){
            String[] elements = line.split(",");
            // we are interested in speed and the car registration number
            int speed = Integer.valueOf((elements[1]).trim());
            String car = elements[0];
            if(speed > SPEED_THRESHOLD){
```

```
                TreeMap<String, Integer> carValue = new TreeMap<String, Integer>();
                carValue.put(car, speed);
                basicOutputCollector.emit(new Values(carValue));
                LOGGER.info("Speed violation found:"+ car + " speed:" + speed);
            }
        }
    }
    @Override
    public void declareOutputFields(OutputFieldsDeclarer outputFieldsDeclarer) {
        outputFieldsDeclarer.declare(new Fields(IGNITE_FIELD));
    }
}
```

Let's go through line by line again.

- *execute():* This is the method where you implement the business logic of your bolt, in this case, I am splitting the line by the comma and check the speed limit of the car. If the speed limit of the given car is higher than the threshold, we are creating a new treemap data type from this tuple and emit the tuple to the next bolt, in our case the next bolt will be the StormStreamer.
- *declareOutputFields():* This method is similar to declareOutputFields() method in FileSourceSpout, it declares that it is going to return Ignite tuple for further processing.

> **Note:**
>
> The tuple name IGNITE is important here, the StormStreamer will only process the tuple with name ignite.

Note that, Bolts can do anything, for example, computation, persistence or talking to external components.

Step 6:

It's the time to create our topology to run our example. Topology ties the spouts and bolts together in a graph, which defines how the data flows between the components. It also provides parallelism hints that Storm uses when creating instances of the components within the cluster. To implement the topology, create a new file named SpeedViolationTopology.java in the `src\main\java\com\blu\imdg\storm\topology` directory. Use the following as the contents of the file:

```
public class SpeedViolationTopology {
    private static final int STORM_EXECUTORS = 2;

    public static void main(String[] args) throws Exception {
        if (getProperties() == null || getProperties().isEmpty()) {
            System.out.println("Property file <ignite-storm.property> is not found or empt\
y");
            return;
        }
        // Ignite Stream Ibolt
        final StormStreamer<String, String> stormStreamer = new StormStreamer<>();

        stormStreamer.setAutoFlushFrequency(10L);
        stormStreamer.setAllowOverwrite(true);
        stormStreamer.setCacheName(getProperties().getProperty("cache.name"));

        stormStreamer.setIgniteTupleField(getProperties().getProperty("tuple.name"));
        stormStreamer.setIgniteConfigFile(getProperties().getProperty("ignite.spring.xml")\
);



        TopologyBuilder builder = new TopologyBuilder();

        builder.setSpout("spout", new FileSourceSpout(), 1);
        builder.setBolt("limit", new SpeedLimitBolt(), 1).fieldsGrouping("spout", new Fiel\
ds("trafficLog"));
        // set ignite bolt
        builder.setBolt("ignite-bolt", stormStreamer, STORM_EXECUTORS).shuffleGrouping("li\
mit");
        Config conf = new Config();
        conf.setDebug(false);
        conf.setMaxTaskParallelism(1);
        LocalCluster cluster = new LocalCluster();
        cluster.submitTopology("speed-violation", conf, builder.createTopology());
        Thread.sleep(10000);
        cluster.shutdown();
    }
    private static Properties getProperties() {
        Properties properties = new Properties();
        InputStream ins = SpeedViolationTopology.class.getClassLoader().getResourceAsStrea\
m("ignite-storm.properties");
        try {
            properties.load(ins);
        } catch (IOException e) {
            e.printStackTrace();
```

```
            properties = null;
        }
        return properties;
    }
}
```

Let's go through line by line again. First, we read the ignite-strom.properties file to get all the necessary parameters to configure the StormStreamer bolt next. The storm topology is basically a Thrift structure. The *TopologyBuilder* class provides simple and elegant way to build complex Storm topology. The TopologyBuilder class has methods to setSpout and setBolt. Next we used the Topology builder to build the Storm topology and added the spout with name *spout* and parallelism hint of 1 executor. We also define the *SpeedLimitBolt* to the topology with parallelism hint of 1 executor. Next, we set the StormStreamer bolt with *shufflegrouping*, which subscribes to the bolt, and equally distributes tuples (limit) across the instances of the StormStreamer bolt.

For development purpose, we create a local cluster using *LocalCluster* instance and submit the topology using the *submitTopology* method. Once the topology is submitted to the cluster, we will wait 10 seconds for the cluster to compute the submitted topology and then shutdown the cluster using *shutdown* method of *LocalCluster*.

Step 7:

Next, run a local node of Apache Ignite or cluster first. After building the maven project, use the following command to run the topology locally.

```
mvn compile exec:java -Dstorm.topology=com.blu.imdg.storm.topology.SpeedViolationTopology
```

The application will produce a lot of system logs as follows.

```
16886 [Thread-12-limit] INFO  c.b.i.s.b.SpeedLimitBolt - Speed violation found:BC 123 speed:170
16886 [Thread-12-limit] INFO  b.s.util - Async loop interrupted!
16886 [com.blu.imdg.storm.topology.SpeedViolationTopology.main()] INFO  b.s.d.executor - Shut down executor limit:[3 3]
16886 [com.blu.imdg.storm.topology.SpeedViolationTopology.main()] INFO  b.s.d.executor - Shutting down executor __acker:[1 1]
16886 [Thread-13-disruptor-executor[1 1]-send-queue] INFO  b.s.util - Async loop interrupted!
16886 [Thread-14-__acker] INFO  b.s.util - Async loop interrupted!
16893 [com.blu.imdg.storm.topology.SpeedViolationTopology.main()] INFO  b.s.d.executor - Shut down executor __acker:[1 1]
16893 [com.blu.imdg.storm.topology.SpeedViolationTopology.main()] INFO  b.s.d.executor - Shutting down executor __system:[-1 -1]
16893 [Thread-16-__system] INFO  b.s.util - Async loop interrupted!
16893 [Thread-15-disruptor-executor[-1 -1]-send-queue] INFO  b.s.util - Async loop interrupted!
16894 [com.blu.imdg.storm.topology.SpeedViolationTopology.main()] INFO  b.s.d.executor - Shut down executor __system:[-1 -1]
16894 [com.blu.imdg.storm.topology.SpeedViolationTopology.main()] INFO  b.s.d.executor - Shutting down executor spout:[4 4]
16895 [Thread-18-spout] INFO  b.s.util - Async loop interrupted!
```

Figure 6.25

Now, if we verify the Ignite cache through ignitevisior, we should get the following output into the console.

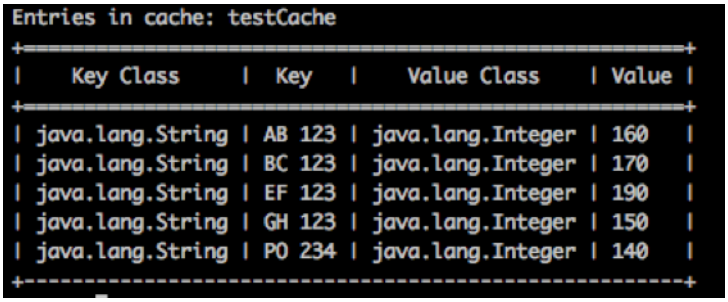


Figure 6.26

The output shows the result, what we expected. From our `source.csv` log file, only five vehicles exceed the speed limit of 120 km/h.

This is pretty much sums up the practical overview of the Ignite Storm Streamer.

Conclusion

In this chapter, we familiar with the Real-time data streaming and the complex event processing. We go through the theory to practice of the following Ignite Data streamer components:

- Ignite DataStream.
- Camel Data Streamer.
- Flume Data Streamer.
- Storm Data Streamer.

For each section, we provide complete sample code and shows how to build real-time data processing application with these modules.

What's next

In the next chapter and the final chapter of this book, we are going to familiar with the Ignite compute grid, which provides a set of simple APIs that allow users distribute computations and data processing across multiple computers in the cluster.