THE UNIVERSITY of EDINBURGH
informatics

Distributed Systems Coursework

Björn Franke

Overview

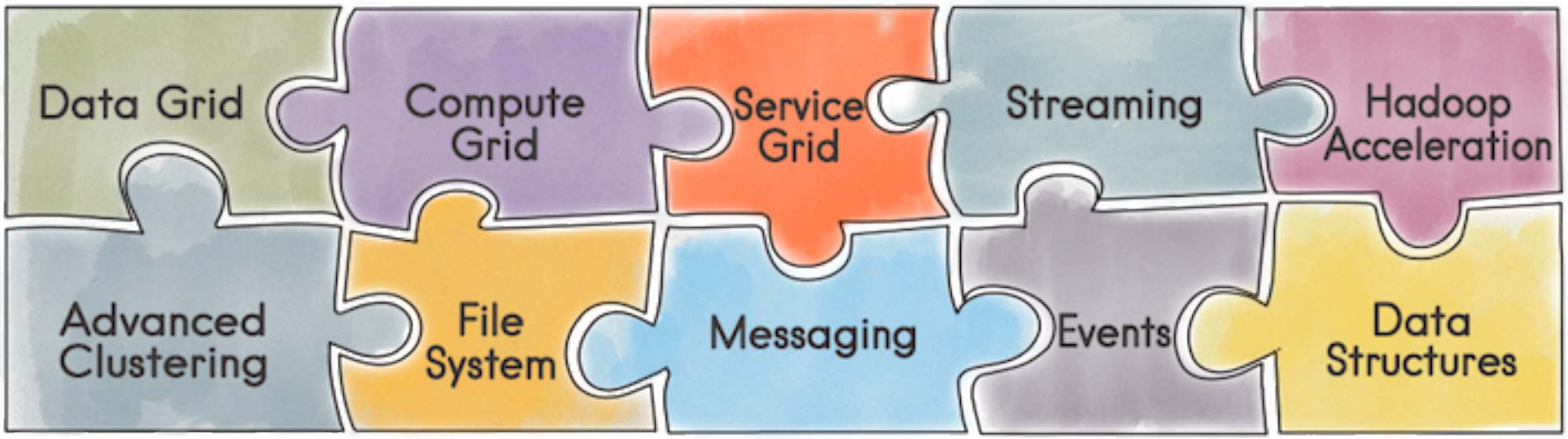
- Apache Ignite Framework
  - Overview
- Coursework
  - Getting started
  - Example 1: “Hello, world”
  - Example 2: Word count
  - Specification
- Submission Instructions

- Sources of information & examples in this lecture:
  - http://apacheignite.gridgain.org
  - http://ggfabric.blogspot.co.uk
    - https://www.gridgain.com/resources/papers/introducing-apache-ignite
- Note: Piazza online forum now available!

Apache Ignite Overview

- In-memory computing platform
  - High-performance transactions
  - Real-time streaming
  - Fast analytics
  - Single, comprehensive data access and processing layer
- Unified API: SQL, C++, .NET, Java/Scala/Groovy, Node.js
- Works on top of existing databases

Apache Ignite Overview



“collection of independent, well-integrated, in-memory components geared to improve performance and scalability of your application"

Cluster Functionality

Cluster functionality is provided via `IgniteCluster` interface. You can get an instance of `IgniteCluster` from `Ignite` as follows:

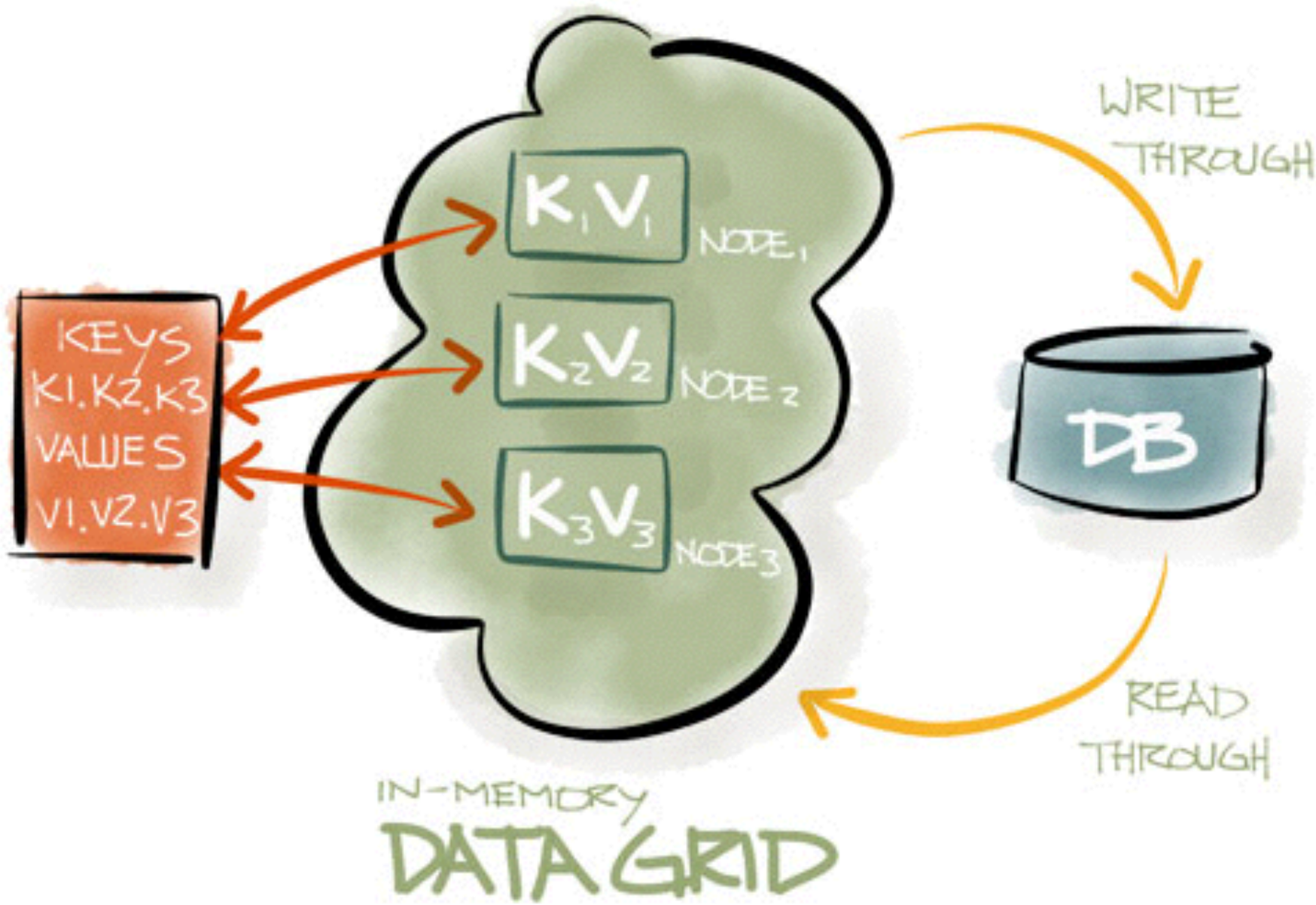
```
Ignite ignite = Ignition.ignite();

IgniteCluster cluster = ignite.cluster();
```

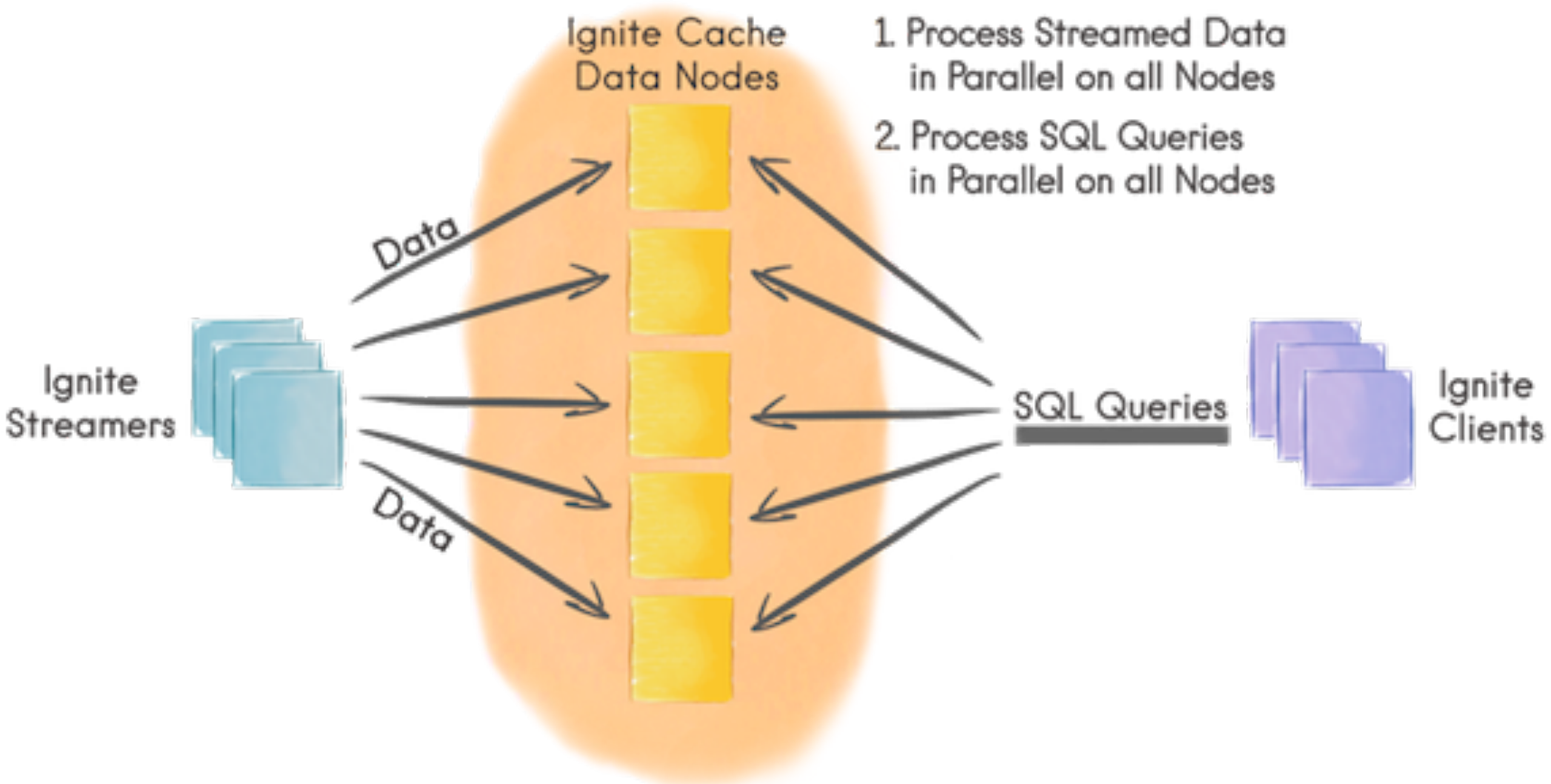
Through `IgniteCluster` interface you can:

- Start and stop remote cluster nodes
- Get a list of all cluster members
- Create logical Cluster Groups

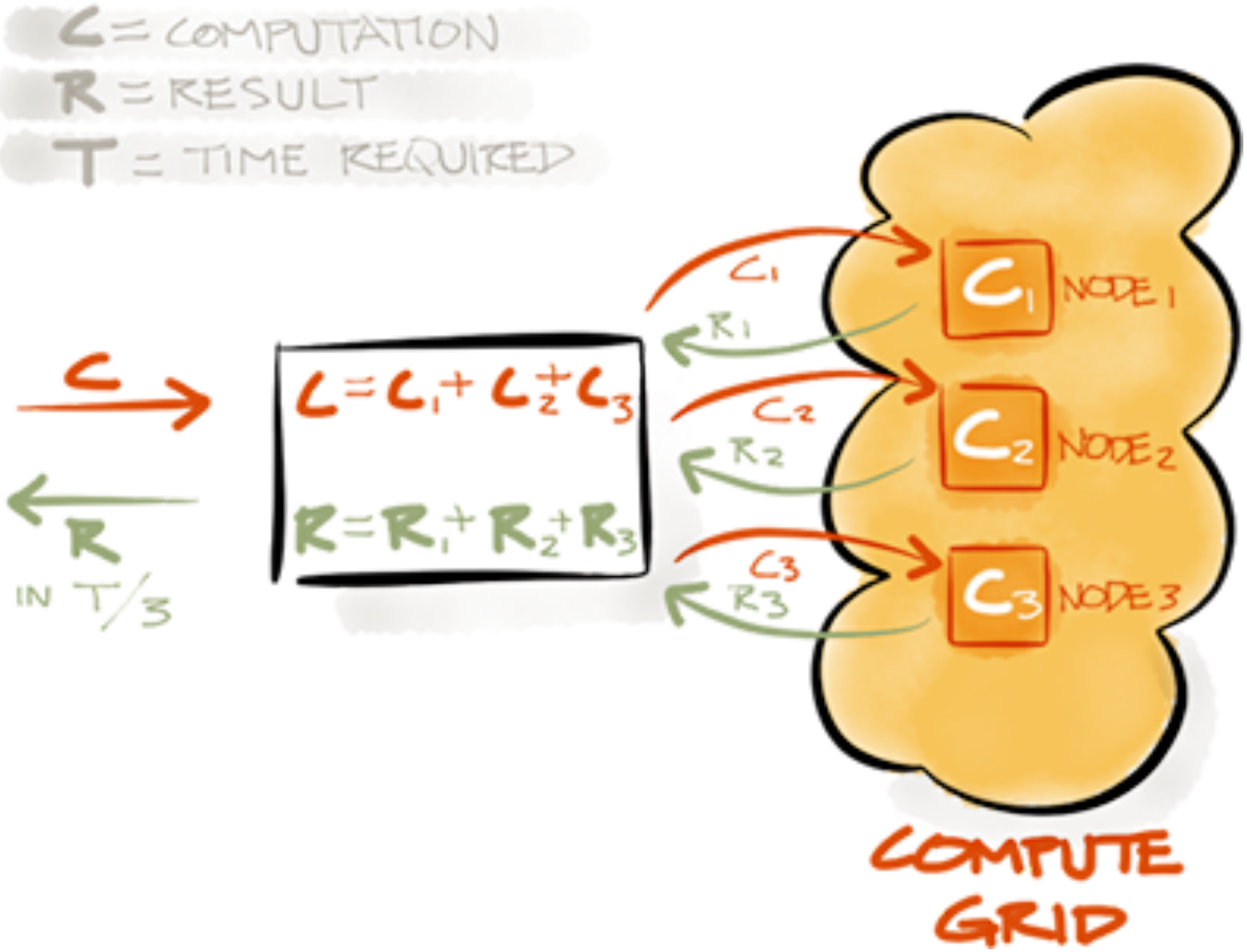
Data Grid Functionality



Data Streaming Functionality

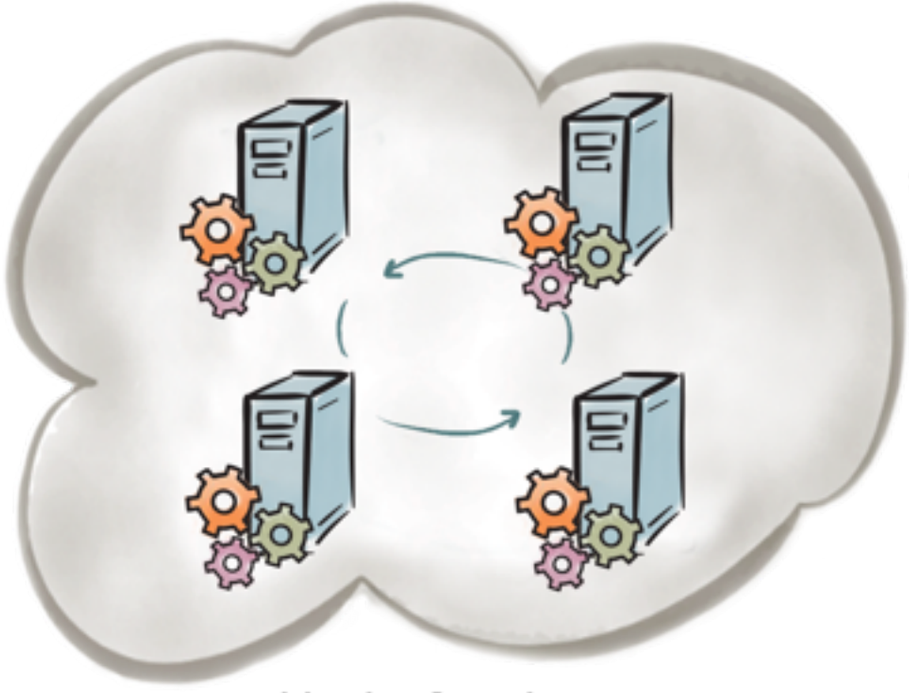


Compute Grid Functionality

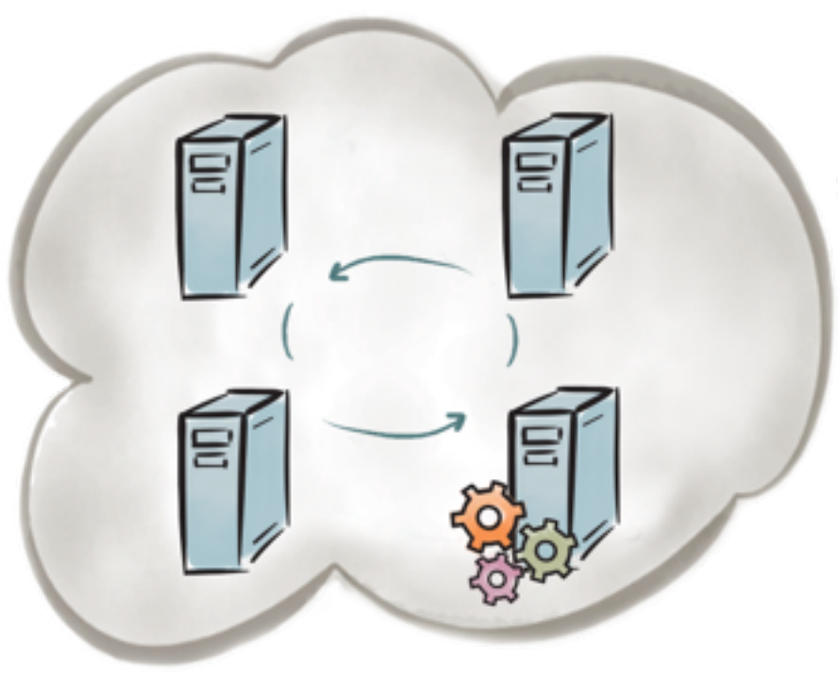


Service Grid Functionality

Service Grid allows for deployments of arbitrary user-defined services on the cluster. You can implement and deploy any service, such as custom counters, ID generators, hierarchical maps, etc.
Ignite allows you to control how many instances of your service should be deployed on each cluster node and will automatically ensure proper deployment and fault tolerance of all the services .



Node Singleton



Cluster Singleton

Distributed Data Structures

Ignite In-Memory Data Fabric, in addition to providing standard key-value map-like storage, also provides an implementation of a fast Distributed Blocking Queue and Distributed Set. `IgniteQueue` and `IgniteSet`, an implementation of `java.util.concurrent.BlockingQueue` and `java.util.Set` interface respectively, also support all operations from `java.util.Collection` interface. Both, queue and set can be created in either collocated or non-collocated mode.

```
Ignite ignite = Ignition.ignite();

IgniteQueue<String> queue = ignite.queue(
    "queueName", // Queue name.
    0,           // Queue capacity. 0 for unbounded queue.
    null         // Collection configuration.
);
```

Messaging Functionality

Distributed Messaging functionality in Ignite is provided via `IgniteMessaging` interface. You can get an instance of `IgniteMessaging`, like so:

```
Ignite ignite = Ignition.ignite();

IgniteMessaging rmtMsg = ignite.message(ignite.cluster().forRemotes());
```

```
// Add listener for unordered messages on all remote nodes.
rmtMsg.remoteListen("MyOrderedTopic", (nodeId, msg) -> {
    System.out.println("Received ordered message [msg=" + msg + ", from=" +
nodeId + ']');

    return true; // Return true to continue listening.
});

// Send ordered messages to remote nodes.
for (int i = 0; i < 10; i++)
    rmtMsg.sendOrdered("MyOrderedTopic", Integer.toString(i));
```

THE UNIVERSITY of EDINBURGH informatics

Distributed Events Functionality

```
Ignite ignite = Ignition.ignite();

// Local listener that listens to local events.
IgnitePredicate<CacheEvent> locLsnr = evt -> {
  System.out.println("Received event [evt=" + evt.name() + ", key=" + evt.key() +
    ", oldVal=" + evt.oldValue() + ", newVal=" + evt.newValue());

  return true; // Continue listening.
};

// Subscribe to specified cache events occurring on local node.
ignite.events().localListen(locLsnr,
  EventType.EVT_CACHE_OBJECT_PUT,
  EventType.EVT_CACHE_OBJECT_READ,
  EventType.EVT_CACHE_OBJECT_REMOVED);

// Get an instance of named cache.
final IgniteCache<Integer, String> cache = ignite.cache("cacheName");

// Generate cache events.
for (int i = 0; i < 20; i++)
  cache.put(i, Integer.toString(i));
```

Getting started

1. Download and Install Ignite

Download the latest binary distribution from the Apache Ignite website and extract the resulting `.zip` file to a location of your choice:

```
$ unzip apache-ignite-fabric-1.7.0-bin.zip
$ cd apache-ignite-fabric-1.7.0-bin
```

2. Set Environment Variable (this step is optional)

Set `IGNITE_HOME` environment variable to point to the installation folder and make sure there is no trailing / in the path. On my Mac, I have set this environment variable in `.bash_profile` file, like so:

```
export IGNITE_HOME=<path-to-ignite-installation-folder>
```

3. Start Ignite Cluster

Start a node using `bin/ignite.sh` command and specify an example configuration file provided in the Ignite installation:

```
$ bin/ignite.sh examples/config/example-ignite.xml
```

If the installation was successful, your Ignite node startup message should look like this:

Getting started

```
~/apache-ignite-fabric-1.5.0-b1-bin$ bin/ignite.sh examples/config/example-ignite.xml
Java HotSpot(TM) 64-Bit Server VM warning: ignoring option MaxPermSize=256m; support was removed
 in 8.0
[09:45:14]
[09:45:14]
[09:45:14]
[09:45:14]
[09:45:14]
[09:45:14]
[09:45:14] ver. 1.5.0-b1#20151201-sha1:062d440c
[09:45:14] 2015 Copyright(C) Apache Software Foundation
[09:45:14]
[09:45:14] Ignite documentation: http://ignite.apache.org
[09:45:14]
[09:45:14] Quiet mode.
[09:45:14]   ^-- Logging to file '/Users/prachig/apache-ignite-fabric-1.5.0-b1-bin/work/log/igni
te-977597db.0.log'
[09:45:14]   ^-- To see **FULL** console log here add -DIGNITE_QUIET=false or "-v" to ignite.{sh
|bat}
[09:45:14]
[09:45:14] OS: Mac OS X 10.10.5 x86_64
[09:45:14] VM information: Java(TM) SE Runtime Environment 1.8.0_31-b13 Oracle Corporation Java
HotSpot(TM) 64-Bit Server VM 25.31-b07
[09:45:14] Configured plugins:
[09:45:14]   ^-- None
[09:45:14]
[09:45:14] Security status [authentication=off, tls/ssl=off]
[09:45:15] Performance suggestions for grid  (fix if possible)
[09:45:15] To disable, set -DIGNITE_PERFORMANCE_SUGGESTIONS_DISABLED=true
[09:45:15]   ^-- Disable peer class loading (set 'peerClassLoadingEnabled' to false)
[09:45:15]   ^-- Disable grid events (remove 'includeEventTypes' from configuration)
[09:45:15]
[09:45:15] To start Console Management & Monitoring run ignitevisorcmd.{sh|bat}
[09:45:15]
[09:45:15] Ignite node started OK (id=977597db)
[09:45:15] Topology snapshot [ver=1, servers=1, clients=0, CPUs=4, heap=1.0GB]
```

Getting started

I have started one more node in another terminal, by repeating the above command (in step 3). I now have an Ignite cluster setup with two server nodes running. You can start as many nodes as you like. Ignite will automatically discover all the nodes.

```
~/apache-ignite-fabric-1.5.0-b1-bin$ bin/ignite.sh examples/config/example-ignite.xml
Java HotSpot(TM) 64-Bit Server VM warning: ignoring option MaxPermSize=256m; support was removed
 in 8.0
[10:06:40]
[10:06:40]
[10:06:40]
[10:06:40]
[10:06:40]
[10:06:40] ver. 1.5.0-b1#20151201-sha1:062d440c
[10:06:40] 2015 Copyright(C) Apache Software Foundation
[10:06:40]
[10:06:40] Ignite documentation: http://ignite.apache.org
[10:06:40]
[10:06:40] Quiet mode.
[10:06:40]   ^-- Logging to file '/Users/prachig/apache-ignite-fabric-1.5.0-b1-bin/work/log/igni
te-9a70787a.0.log'
[10:06:40]   ^-- To see **FULL** console log here add -DIGNITE_QUIET=false or "-v" to ignite.{sh
|bat}
[10:06:40]
[10:06:40] OS: Mac OS X 10.10.5 x86_64
[10:06:40] VM information: Java(TM) SE Runtime Environment 1.8.0_31-b13 Oracle Corporation Java
HotSpot(TM) 64-Bit Server VM 25.31-b07
[10:06:40] Configured plugins:
[10:06:40]   ^-- None
[10:06:40]
[10:06:41] Security status [authentication=off, tls/ssl=off]
[10:06:42] Performance suggestions for grid  (fix if possible)
[10:06:42] To disable, set -DIGNITE_PERFORMANCE_SUGGESTIONS_DISABLED=true
[10:06:42]   ^-- Disable peer class loading (set 'peerClassLoadingEnabled' to false)
[10:06:42]   ^-- Disable grid events (remove 'includeEventTypes' from configuration)
[10:06:42]
[10:06:42] To start Console Management & Monitoring run ignitevisorcmd.{sh|bat}
[10:06:42]
[10:06:42] Ignite node started OK (id=9a70787a)
[10:06:42] Topology snapshot [ver=1, servers=1, clients=0, CPUs=4, heap=1.0GB]
[10:07:15] Topology snapshot [ver=2, servers=2, clients=0, CPUs=4, heap=2.0GB]
```

```
~/apache-ignite-fabric-1.5.0-b1-bin$ bin/ignite.sh examples/config/example-ignite.xml
Java HotSpot(TM) 64-Bit Server VM warning: ignoring option MaxPermSize=256m; support was remove
d in 8.0
[10:07:14]
[10:07:14]
[10:07:14]
[10:07:14]
[10:07:14]
[10:07:14] ver. 1.5.0-b1#20151201-sha1:062d440c
[10:07:14] 2015 Copyright(C) Apache Software Foundation
[10:07:14]
[10:07:14] Ignite documentation: http://ignite.apache.org
[10:07:14]
[10:07:14] Quiet mode.
[10:07:14]   ^-- Logging to file '/Users/prachig/apache-ignite-fabric-1.5.0-b1-bin/work/log/ign
ite-30db9917.0.log'
[10:07:14]   ^-- To see **FULL** console log here add -DIGNITE_QUIET=false or "-v" to ignite.{s
h|bat}
[10:07:14]
[10:07:14] OS: Mac OS X 10.10.5 x86_64
[10:07:14] VM information: Java(TM) SE Runtime Environment 1.8.0_31-b13 Oracle Corporation Java
 HotSpot(TM) 64-Bit Server VM 25.31-b07
[10:07:14] Configured plugins:
[10:07:14]   ^-- None
[10:07:14]
[10:07:14] Security status [authentication=off, tls/ssl=off]
[10:07:16] Performance suggestions for grid  (fix if possible)
[10:07:16] To disable, set -DIGNITE_PERFORMANCE_SUGGESTIONS_DISABLED=true
[10:07:16]   ^-- Disable peer class loading (set 'peerClassLoadingEnabled' to false)
[10:07:16]   ^-- Disable grid events (remove 'includeEventTypes' from configuration)
[10:07:16]
[10:07:16] To start Console Management & Monitoring run ignitevisorcmd.{sh|bat}
[10:07:16]
[10:07:16] Ignite node started OK (id=30db9917)
[10:07:16] Topology snapshot [ver=2, servers=2, clients=0, CPUs=4, heap=2.0GB]
```

Getting started

4. Add Ignite Dependency (only if you are using Maven)

Add the following Ignite dependencies in your project's `pom.xml` file:

```
<dependency>
    <groupid>org.apache.ignite</groupid>
    <artifactid>ignite-core</artifactid>
    <version>1.5.0-b1</version>
</dependency>

<dependency>
    <groupid>org.apache.ignite</groupid>
    <artifactid>ignite-spring</artifactid>
    <version>1.5.0-b1</version>
</dependency>
```

Introduction to Maven: **https://maven.apache.org/guides/getting-started/maven-in-five-minutes.html**

“Hello world” Example

Here is a sample `HelloWord.java` file that prints ‘Hello World’ on all the nodes in the cluster.

```
import org.apache.ignite.Ignite;
import org.apache.ignite.IgniteCache;
import org.apache.ignite.IgniteException;
import org.apache.ignite.Ignition;

public class HelloWorld {
  public static void main(String[] args) throws IgniteException {
    try (Ignite ignite = Ignition.start("examples/config/example-ignite.xml"))
    {
      // Put values in cache.
      IgniteCache<Integer, String> cache = ignite.getOrCreateCache("myCache");

      cache.put(1, "Hello");
      cache.put(2, "World!");

      // Get values from cache and
      // broadcast 'Hello World' on all the nodes in the cluster.
      ignite.compute().broadcast(() -> {
        String hello = cache.get(1);
        String world = cache.get(2);

        System.out.println(hello + " " + world);
      });
    }
  }
}
```

“Hello world” Example

Run HelloWorld

```
/Library/Java/JavaVirtualMachines/jdk1.8.0_31.jdk/Contents/Home/bin/java ...
[10:33:49]    _________  ________________
[10:33:49]   /  _/ __/ |/ /  _/_  __/ __/
[10:33:49]  _/ // (7 7    // /  / / / _/
[10:33:49] /___/\___/_/|_/___/ /_/ /___/
[10:33:49]
[10:33:49] ver. 1.5.0-b1#20151201-sha1:062d440c
[10:33:49] 2015 Copyright(C) Apache Software Foundation
[10:33:49]
[10:33:49] Ignite documentation: http://ignite.apache.org
[10:33:49]
[10:33:49] Quiet mode.
[10:33:49]   ^-- Logging to file '/Users/prachig/apache-ignite-fabric-1.5.0-b1-bin/work/log/ignite-7b47f26c.0.log'
[10:33:49]   ^-- To see **FULL** console log here add -DIGNITE_QUIET=false or "-v" to ignite.{sh|bat}
[10:33:49]
[10:33:49] OS: Mac OS X 10.10.5 x86_64
[10:33:49] VM information: Java(TM) SE Runtime Environment 1.8.0_31-b13 Oracle Corporation Java HotSpot(TM) 64-Bit Server VM 25.31-b07
[10:33:49] Initial heap size is 256MB (should be no less than 512MB, use -Xms512m -Xmx512m).
[10:33:50] Configured plugins:
[10:33:50]   ^-- None
[10:33:50]
[10:33:50] Security status [authentication=off, tls/ssl=off]
[10:33:52] Performance suggestions for grid  (fix if possible)
[10:33:52] To disable, set -DIGNITE_PERFORMANCE_SUGGESTIONS_DISABLED=true
[10:33:52]   ^-- Disable peer class loading (set 'peerClassLoadingEnabled' to false)
[10:33:52]   ^-- Disable grid events (remove 'includeEventTypes' from configuration)
[10:33:52]
[10:33:52] To start Console Management & Monitoring run ignitevisorcmd.{sh|bat}
[10:33:52]
[10:33:52] Ignite node started OK (id=7b47f26c)
[10:33:52] Topology snapshot [ver=3, servers=3, clients=0, CPUs=4, heap=5.6GB]
Hello World!
[10:33:52] Ignite node stopped OK [uptime=00:00:00:549]

Process finished with exit code 0
```

2: Favorites

“Hello world” Example

```
[10:33:35]
[10:33:35] Ignite node started OK (id=5b1b8654)
[10:33:35] Topology snapshot [ver=1, servers=1, clients=0, CPUs=4, heap=1.0GB]
[10:33:42] Topology snapshot [ver=2, servers=2, clients=0, CPUs=4, heap=2.0GB]
[10:33:51] Topology snapshot [ver=3, servers=3, clients=0, CPUs=4, heap=5.6GB]
Hello World!
[10:33:52] Topology snapshot [ver=4, servers=2, clients=0, CPUs=4, heap=2.0GB]
```

```
[10:33:42]
[10:33:42] Ignite node started OK (id=96552095)
[10:33:42] Topology snapshot [ver=2, servers=2, clients=0, CPUs=4, heap=2.0GB]
[10:33:51] Topology snapshot [ver=3, servers=3, clients=0, CPUs=4, heap=5.6GB]
Hello World!
[10:33:52] Topology snapshot [ver=4, servers=2, clients=0, CPUs=4, heap=2.0GB]
```

Demo!

Word Count Example

In this example we will stream text into Ignite and count each individual word. We will also issue periodic SQL queries into the stream to query top 10 most popular words.

The example will work as follows:

1. We will setup up a cache to hold the words and their counts.
2. We will setup a 5 second sliding window to keep the word counts only for last 5 seconds.
3. `StreamWords` program will stream text data into Ignite.
4. `QueryWords` program will query top 10 words out of the stream.

Cache Configuration

We define a `CacheConfig` class which will provide configuration to be used from both programs, `StreamWords` and `QueryWords`. The cache will use words as keys, and counts for words as values. Note that in this example we use a sliding window of 5 seconds for our cache. This means that words will disappear from cache after 5 seconds since they were first entered into cache.

```
public class CacheConfig {
  public static CacheConfiguration<String, Long> wordCache() {
    CacheConfiguration<String, Long> cfg = new CacheConfiguration<>("words");

    // Index the words and their counts,
    // so we can use them for fast SQL querying.
    cfg.setIndexedTypes(String.class, Long.class);

    // Sliding window of 5 seconds.
    cfg.setExpiryPolicyFactory(FactoryBuilder.factoryOf(
      new CreatedExpiryPolicy(new Duration(SECONDS, 5))));

    return cfg;
  }
}
```

StreamWords class

We define a `StreamWords` class which will be responsible to continuously read words form a local text file ("alice-in-wonderland.txt" in our case) and stream them into Ignite "words" cache.

1. We set `allowOverwrite` flag to `true` to make sure that existing counts can be updated.
2. We configure a `StreamTransformer` which takes currently cache count for a word and increments it by 1.

StreamWords class

```
public class StreamWords {
 public static void main(String[] args) throws Exception{
    // Mark this cluster member as client.
    Ignition.setClientMode(true);

    try (Ignite ignite = Ignition.start()) {
      IgniteCache<String, Long> stmCache =
        ignite.getOrCreateCache(CacheConfig.wordCache());

      // Create a streamer to stream words into
         the cache.
      try (IgniteDataStreamer<String, Long> stmr =
        ignite.dataStreamer(stmCache.getName())) {
        // Allow data updates.
        stmr.allowOverwrite(true);

        // Configure data transformation to count
           instances of the same word.
        stmr.receiver(StreamTransformer.from((e, arg) ->
{
          // Get current count.
          Long val = e.getValue();

          // Increment current count by 1.
          e.setValue(val == null ? 1L : val + 1);

          return null;
        }));
```

book.

```
        // Stream words from "alice-in-wonderland"

        while (true) {
           Path path =
      Paths.get(StreamWords.class.getResource("alice-
      in-wonderland.txt").toURI());

           // Read words from a text file.
           try (Stream<String> lines =
             Files.lines(path)) {
             lines.forEach(line -> {
               Stream<String> words =
                 Stream.of(line.split(" "));

               // Stream words into Ignite streamer.
               words.forEach(word -> {
                 if (!word.trim().isEmpty())
                   stmr.addData(word, 1L);
               });
             });
           }
         }
       }
     }
   }
```

QueryWords class

We define a `QueryWords` class which will periodically query word counts form the cache.

1. We use standard SQL to query the counts.
2. Ignite SQL treats Java classes as SQL tables. Since our counts are stored as simple `Long` type, the SQL query below queries `Long` table.
3. Ignite always stores cache keys and values as `_key` and `_val` fields, so we use this syntax in our SQL query.

QueryWords class

```
public class QueryWords {
  public static void main(String[] args) throws Exception {
    // Mark this cluster member as client.
    Ignition.setClientMode(true);

    try (Ignite ignite = Ignition.start()) {
      IgniteCache<String, Long> stmCache = ignite.getOrCreateCache(CacheConfig.wordCache());

      // Select top 10 words.
      SqlFieldsQuery top10Qry = new SqlFieldsQuery(
        "select _key, _val from Long order by _val desc limit 10");

      // Query top 10 popular words every 5 seconds.
      while (true) {
        // Execute queries.
        List<List<?>> top10 = stmCache.query(top10Qry).getAll();

        // Print top 10 words.
        ExamplesUtils.printQueryResults(top10);

        Thread.sleep(5000);
      }
    }
  }
}
```

Coursework Specification

- Find top ten most accessed Wikipedia pages from page access log files

- Part A: Sequential, non-distributed
  Using Ignite stream log files and process them in a cache, applying a 1-second sliding window

- Part B: Concurrently, distributed
  Using Ignite stream these log files, and process them concurrently. Determine global top ten most popular pages on Wikibooks

- Details in hand-out, which will be uploaded to the course website shortly

- **Submission date: 4pm on Thursday, November 17, 2016**