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EXCELENCIA SEVERO OCHOA

Programming Distributed Computing Platforms with COMPSs

Pol Alvarez, Javier Alvarez, Ramon Amela, Rosa M. Badia, Javier Conejero, Marc Dominguez, Jorge Ejarque, Daniele Lezzi, Francesc Lordan, Cristian Ramon-Cortes, Sergio Rodriguez

Workflows & Distributed Computing Group

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Barcelona

Outline

Day 2

- Session 6 (9:30-11:00): Java & C++
  - Writing Java applications
  - Java Hands-on
  - C++ Syntax
- Coffee break (11:00 – 11:30)
- Session 7 (11:30-12:30): COMPSs Advanced Features
  - Integration with OmpSs
  - Using binaries and MPI code
  - COMPSs execution environment
- Lunch break (13:30 – 14:30)
- Session 8 (14:30-15:30): Cluster Hands-on (MareNostrum)
- Session 9 (15:30 -16:30): Practical session (Bring your Own Code)
- COMPSs Installation & Final Notes
- SLIDES
  - http://compss.bsc.es/releases/tutorials/tutorial-PATC_2019/

Java Syntax

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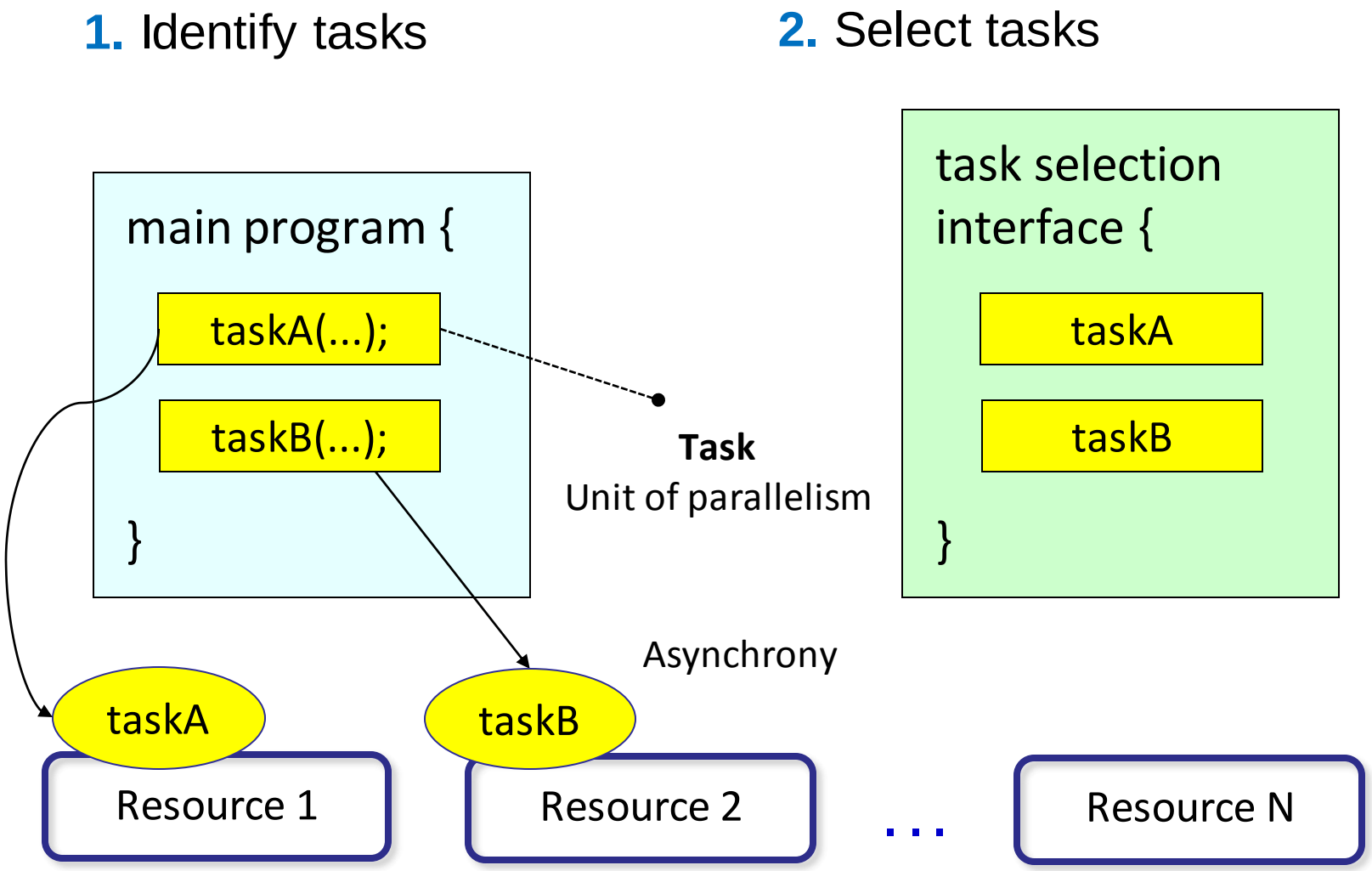
Programming Steps



Task Selection Interface

```
public interface SampleItf {
   @Constraints(computingUnits = "1", memorySize = "0.5f")
   @Method(declaringClass = "compss.Example")
   void myMethod(
      @Parameter(direction = INOUT) Reply r,
       @Parameter(type = FILE, direction = OUT) String filename
    );

   @Service(namespace = "http://servicess.es/example",
            name = "SampleService",
            port = "SamplePort")
   Reply myServiceOp(
      @Parameter(direction = IN) Query q
    );
}
```

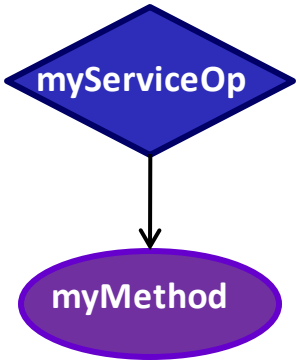
Main program

```
public class App {

   public static void main(String[] args) {
       Query query = new Query(…);

       Reply reply = myServiceOp(query);

       myMethod(reply, "out.txt");

       reply.printToLog();
   }
}
```

Service task call

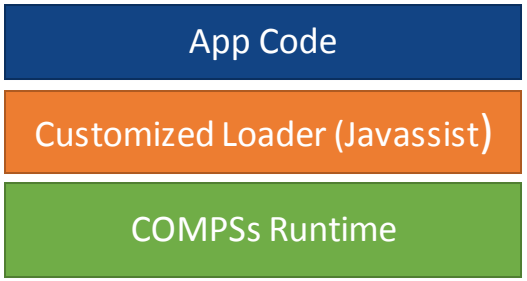
Method task call

Synchronization



Why we do not need to synchronize?

- Code instrumented with Javassist
  - Modified at loading time.




```
public class App {
  public static void main(String[] args) {
      COMPSsRuntime.start();
      Query query = new Query(…);
      Reply reply = myServiceOp(query); -> COMPSsRuntime.executeTask(…)
      myMethod(reply, "out.txt"); -> COMPSsRuntime.executeTask(…)
      COMPSsRuntime.getObject(reply);
      reply.printToLog();
      COMPSsRuntime.stop();
  }
}
```

Java example

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Sample Application

- Main Program

```
public static void main(String[] args) {
   String counter1 = args[0], counter2 = args[1], counter3 = args[2];

   initializeCounters(counter1, counter2, counter3);

   for (i = 0; i < 3; i++) {

      increment(counter1);
      increment(counter2);
      increment(counter3);

   }
}
```

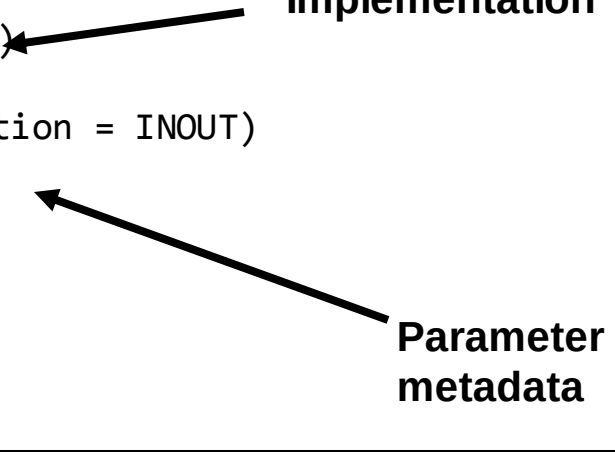
- Task Method

```
public static void increment(String counterFile) {
      int value = readCounter(counterFile);
      value++;
      writeCounter(counterFile, value);
}
```

Sample Application (Interface)

- Task Annotation Interface

```
public interface SimpleItf {

        @Method(declaringClass  = “SimpleImpl")
        void increment(
                @Parameter(type = FILE, direction = INOUT)
                String counterFile
        );

}
```



Sample Application (Main Program)

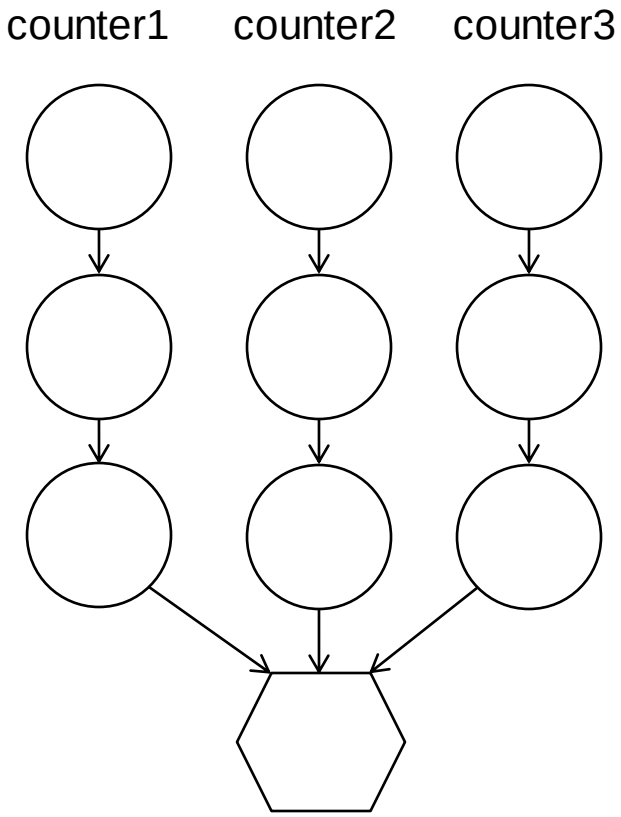
- Main program NO CHANGES!
- No need to synchronize data COMPSs is doing itself!

```
public static void main(String[] args) {
   String counter1 = args[0], counter2 = args[1], counter3 = args[2];

   initializeCounters(counter1, counter2, counter3);

   for (i = 0; i < 3; i++) {

      increment(counter1);
      increment(counter2);
      increment(counter3);

   }
   printCounters(counter1, counter2, counter3);
}
```

No need to synch

Programming Model: Task Graph

```
for (i = 0; i < 3; i++) {
      increment(counter1);
      increment(counter2);
      increment(counter3);
}
printCounters(counter1, counter2,
                counter3);
```



Other features

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Versioning

```
@Constraints(computingUnits = “1”, memorySize = “0.5f”)
@Method(declaringClass = “example.Sequential”)
@Method(declaringClass = “example.Threading”,
        constraints = @Constraints(computingUnits = "2"))
void myMethod(
      @Parameter(direction = INOUT)
      Reply r
    );
}
```

COMPSs API calls

- There are some calls that can not be inferred and the user can use calling the COMPSs API
  - Static class COMPSs
- Barrier: wait for all tasks to finish
  - COMPSs.barrier();
- Deregister object
  - As objects are registered in the runtime. It prevents the Java GC to delete the object.
  - COMPSs.deregisterObject(object);

Java Hands-on

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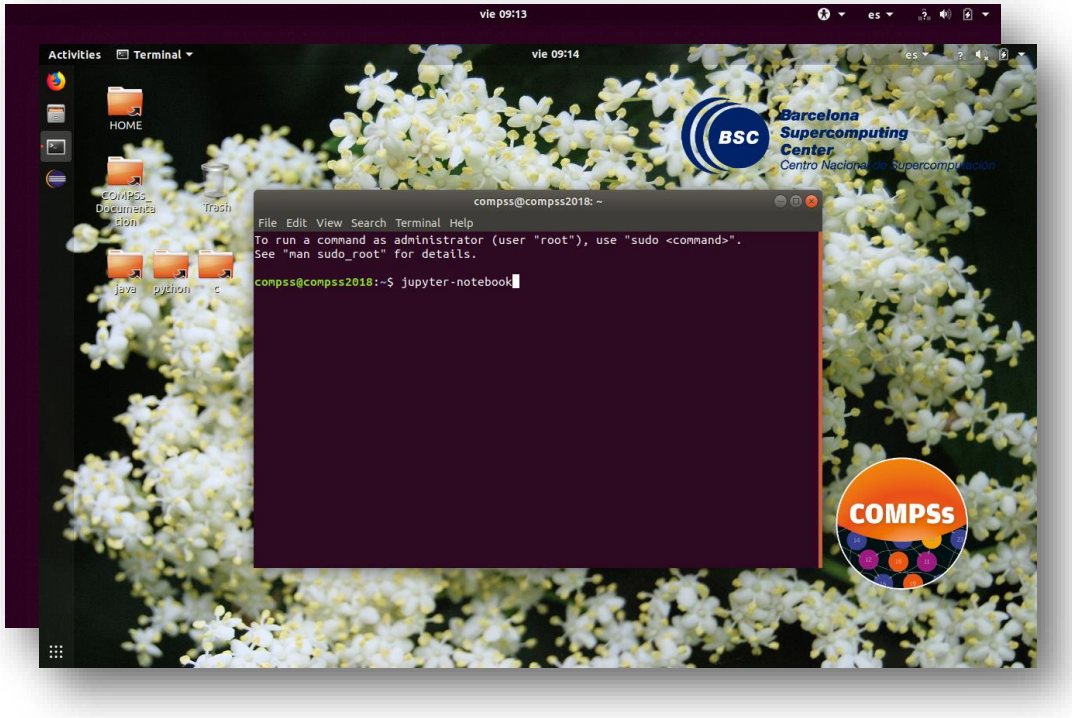
PyCOMPSs and Jupyter-Notebook in VM

- Start the Virtual Machine
  - User: **compss**
  - Password: **compss2018**
- Open eclipse

~/tutorial_apps/java



COMPSs in Docker

- In your machine
  - Install Eclipse IDE.
    - You can download from: https://www.eclipse.org/downloads/
  - Open Eclipse and install Maven for Eclipse plugin
  - Import maven tutorial_apps/java projects
- Run the compss-tutorial container (as root)

  $ *docker run –name mycompss -p 8080:8080 *
  *–v /path/to/tutorial_apps/:/home/compss/tutorial_apps *
  -itd compss/compss-tutorial:patc2019
  - NOTE: if docker daemon is not running: *sudo service docker start*
- Log into the container (as root)

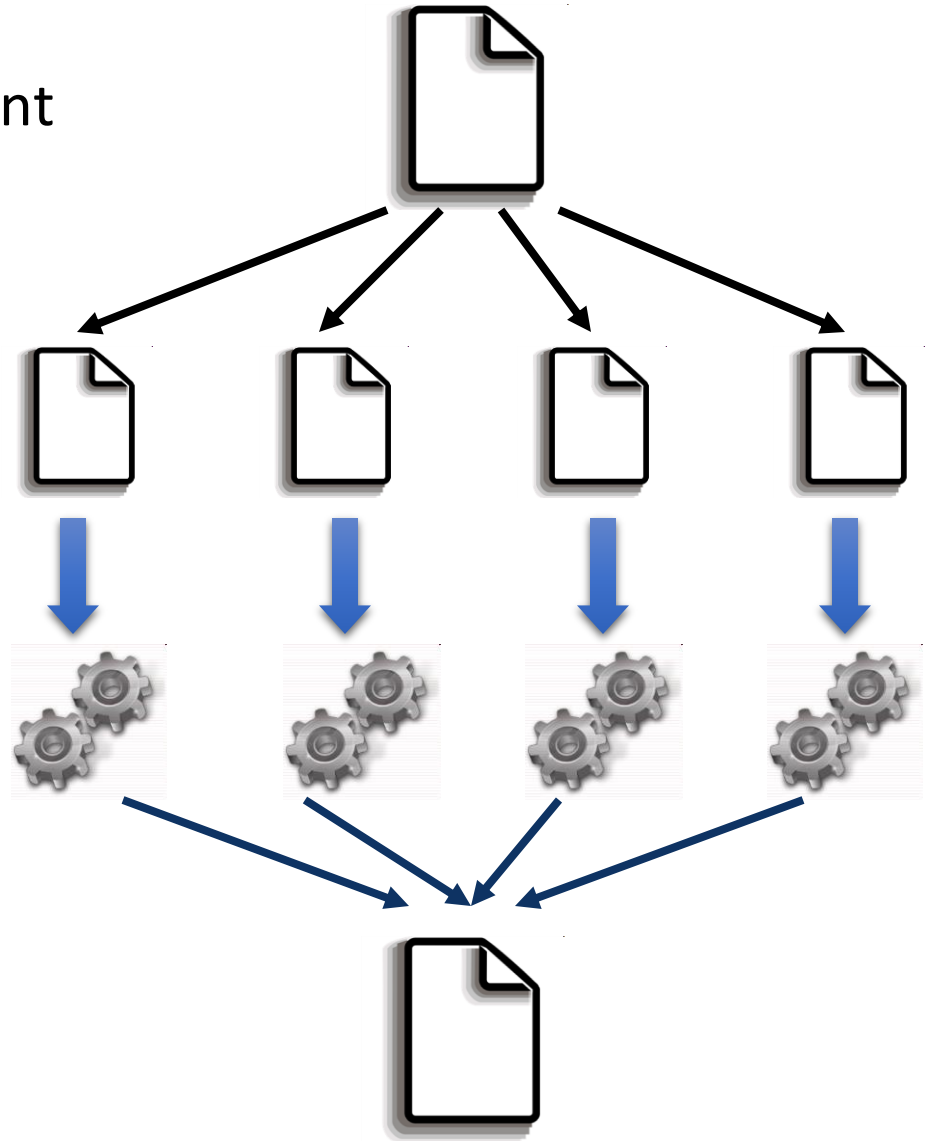
  $ *docker exec -it mycompss /bin/bash*

Data files

- Download & Copy data files to tutorial_apps folder
  - *cd /path/to/tutorial_apps/java/wordcount/data*
  - wget http://compss.bsc.es/releases/tutorials/tutorial-PATC_2019/data/file_short.txt
  - wget http://compss.bsc.es/releases/tutorials/tutorial-PATC_2019/data/file_long.txt

Word count

- Counting words of a document
- Parallelization
  - Split documents in blocks
  - Count words of Blocks
  - Merge results



Java Hands On: Exercise

- Complete the Word Count parallelization with COMPSs
  - Level 0: No Java background
    - Look the implementation (wordcount project)
  - Level 1: Basic Java background
    - Define methods in the interface (wordcount_sequential)
  - Level 2: Java background
    - Define methods in the interface and complete the part of the main code with helper methods (wordcount_blanks)

Compilation and Simple Execution

- Compilation
  - Run *mvn clean install* in */home/compss/tutorial_apps/java/wordcount*
- Use runcompss command to run the application
  - runcompss [options] < FQDN app. classname> <application args>

- ***Exercise:*** Simple word count execution
  - Usage:

    wordcount.uniqueFile.Wordcount <data_file> <block_size>


```
$compss@bsc:~/> cd /home/compss/tutorial_apps/java/wordcount/jar
$compss@bsc:/home/compss/tutorial_apps/java/wordcount/jar/> runcompss wordcount.uniqueFile.Wordcount
    /home/compss/tutorial_apps/java/wordcount/data/file_short.txt 650
```

Java Hands On: Exercise Solution

- Main Code

```
private static void computeWordCount() {
        HashMap<String, Integer> result  = new HashMap<String, Integer>();
        int start = 0;
        for (int i = 0; i < NUM_BLOCKS; ++i) {
          HashMap<String, Integer> partialResult = wordCountBlock(DATA_FILE, start, BLOCK_SIZE);
          start = start + BLOCK_SIZE;
          result = mergeResults(result, partialResult);
        }
        System.out.println("[LOG] Counted Words is : " + result.keySet().size());
}
```

- Interface

```
public interface WordcountItf {
        @Method(declaringClass = "wordcount.uniqueFile.Wordcount")
        public HashMap<String, Integer> mergeResults(
          @Parameter HashMap<String, Integer> m1,
          @Parameter HashMap<String, Integer> m2
        );

        @Method(declaringClass = "wordcount.uniqueFile.Wordcount")
        HashMap<String, Integer> wordCountBlock(
          @Parameter(type = Type.FILE, direction = Direction.IN) String filePath,
          @Parameter int start,
          @Parameter int bsize
        );
}
```

Java Hands-on: Result

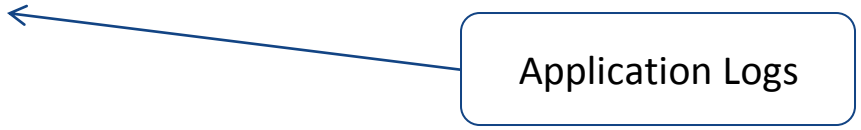
```
$compss@bsc:~/tutorial_apps/java/wordcount/jar/> runcompss wordcount.uniqueFile.Wordcount
    ~/tutorial_apps/java/wordcount/data/file_short.txt 650

Using default location for project file:
    /opt/COMPSs/Runtime/scripts/user/../../configuration/xml/projects/project.xml
Using default location for resources file:
    /opt/COMPSs/Runtime/scripts/user/../../configuration/xml/resources/resources.xml

----------------- Executing wordcount.uniqueFile.Wordcount -------------------------

WARNING: IT Properties file is null. Setting default values
[   API]  -  Deploying COMPSs Runtime v2.4 (build xxxx)
[   API]  -  Starting COMPSs Runtime v2.4 (build xxxx)
DATA_FILE parameter value = /home/compss/tutorial_apps/java/wordcount/data/file_short.txt
BLOCK_SIZE parameter value = 650
[LOG] Computing word count result
[LOG] Counted Words is : 250
[   API]  -  No more tasks for app 1
[   API]  -  Getting Result Files 1
[   API]  -  Execution Finished

------------------------------------------------------------
```



Java Hands-on: Configuration

- Project.xml: /opt/COMPSs/Runtime/configuration/xml/projects/default_project.xml

```
<?xml version="1.0" encoding="UTF-8"?>
<Project>
      <MasterNode>
      <ComputeNode Name="localhost">
            <InstallDir>/opt/COMPSs/</InstallDir>
        <WorkingDir>/tmp/COMPSsWorker</WorkingDir>
       </ComputeNode>
</Project>
```

  - Other optional parameters
    - User, AppDir, LibraryPath

Java Hands-On: Configuration

- Resources.xml: /opt/COMPSs/Runtime/configuration/xml/resources/default_resources.xml

```
<?xml version="1.0" encoding="UTF-8"?>
<ResourceList>
    <!--Description for any physical node-->
    <ComputeNode Name="localhost">
      <Processor Name="Main">
                <ComputingUnits>4</Computingnits>
            </Processor>
            <Memory>
            <size>8</size>
      </Memory>
       <Storage>
            <size>50</size>
      </Storage>
            <Adaptors>
           <Adaptor Name="integratedtoolkit.nio.master.NIOAdaptor">
             ...
          <Adaptor Name="integratedtoolkit.gat.master.GATAdaptor">
            ...
            </Adaptors>
    </ComputeNode>
<ResourceList>
```

Affects to application parallelism

Java Hands-On: Monitoring

- The runtime of COMPSs provides real-time monitoring
  - http://localhost:8080/compss-monitor/
  - If not started run as **root**:
    - /etc/init.d/compss-monitor start
- The user can log-in and follow the progress of the executions
  - Running tasks, resources usage, execution time per task, real-time execution graph, etc.
- Activate monitoring with a runcompss flag
  - Setting a monitoring interval
    - runcompss **--monitoring=<int>**
  - With a default monitoring interval
    - runcompss **–m** (or) runcompss **--monitoring**
- ***Exercise:*** run wordcount enabling monitoring


```
$compss@bsc:~/> cd /home/compss/tutorial_apps/java/wordcount/jar
$compss@bsc:/home/compss/tutorial_apps/java/wordcount/jar/> runcompss –m wordcount.uniqueFile.Wordcount
    /home/compss/tutorial_apps/java/wordcount/data/file_long.txt 250000
```

Java Hands-on: Debugging

- Different log levels activated as runcompss options
  - runcompss **--log_level**=<level>
    (**off**: for performance | **info**: basic logging | **debug**: detect errors)
  - runcompss **–debug** or runcompss **-d**
- The output/errors of the main code of the application are shown in the console
- Other logging files are stored in:
  - $HOME/.COMPSs/<APP_NAME>_XX
- Inside this folder, the user can check the following:
  - The output/error of a task # N : ***/jobs/jobN.[out|err]***
  - Messages from the COMPSs : ***runtime.log***
  - Task to resources allocation: ***resources.log***
- ***Exercise:*** run wordcount with debugging


```
$compss@bsc:~/> cd /home/compss/tutorial_apps/java/wordcount/jar
$compss@bsc:/home/compss/tutorial_apps/java/wordcount/jar/> runcompss –d wordcount.uniqueFile.Wordcount
    /home/compss/workspace_java/wordcount/data/file_short.txt 650
```

Java Hands-on: Graph generation

- To generate the graph of an application, it must be run with the monitor or graph flags activated
  - runcompss **-m** (or) runcompss **–graph** (or) runcompss **-g**
- The graph will be stored in:
  - $HOME/.COMPSs/<APP_NAME>_XX/monitor/complete_graph.dot
- To convert the graph to a PDF format use gengraph command
  - Usage: gengraph <dot_file>
- **Exercise:** generate the graph for the wordcount application


```
$compss@bsc:~/> cd /home/compss/tutorial_apps/java/wordcount/jar
$compss@bsc:/home/compss/tutorial_apps/java/wordcount/jar/> runcompss –g wordcount.uniqueFile.Wordcount
      /home/compss/tutorial_apps/java/wordcount/data/file_short.txt 650

… application execution …

$compss@bsc:/home/compss/tutorial_apps/java/wordcount/jar/> cd ~/.COMPSs/wordcount.uniqueFile.Wordcount_04/monitor
$~/.COMPSs/wordcount.uniqueFile.Wordcount_04/monitor> gengraph complete_graph.dot
Output file: complete_graph.pdf
$~/.COMPSs/wordcount.uniqueFile.Wordcount_04/monitor> evince complete_graph.pdf
```

C Syntax

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COMPSs C++ Binding

- Application Structure
- C Binding API
- Task definition /Supported data
- Compilation & Execution

Application Structure

- Main Code
  - <AppName>.cc
- Task definition interface
  - <AppName>.idl
- Task Implementation
  - <AppName>-functions.cc
- Auxiliary classes and methods
  - src folder

C++-Binding API

- Similar to the Python Binding
- Start/stop
  - compss_on() /compss_off()
- Synchronize and delete Objects
  - template <class T> void compss_wait_on(T* &obj);
  - template <class T> T compss_wait_on(T &obj);
  - template <class T> int compss_delete_object(T* &obj);
- Synchronize and delete files
  - void compss_ifstream(char * filename, ifstream& ifs);
  - void compss_ofstream(char * filename, ofstream& ofs);
  - void compss_delete_file(char * filename);
  - FILE* compss_fopen(char * filename, char * mode);
- Barrier
  - void compss_barrier();

Task definition

- Task definition interface (IDL-like interface)
  - Task definition
    - [return_type|void] [static][class_name::]method_name(params…);
  - Param definition
    - [in|out|inout] data_type name
  - Supported Data types for Dependencies
    - Files: *file*, objects: *Class_name*, 1D Arrays: *type[#elems]*
    - Primitive data types only IN direction: char*(string), int, double, float,…

```
interface example {
  @Constraints(ComputingUnits=2)
  void method(in f_in, out file f_out);
   //Expected C++ method: void method(char* f_in, char* f_out)

  ObjectEx ObjectEx:objectMethod(in inout ObjectEx accum,);
  //Expected C++ method: ObjectEx* ObjectEx:objectMethod(ObjectEx* accum)

  double[20] normal_method(in int n, in double[n] in_array);
  //Expected C++ method: double* normal_method(int n, double*)
}
```

Compilation & Execution

- Compilation
  - Generate master/worker stubs (C++ do not support reflection)
  - Command:
    - compss_build_app <appName>
- Execution
  - Same as Python/Java (runcompss command)
    - runcompss master/<appName> [app_args]
  - Require to set the AppDir
    - In the project.xml
    - Homogeneous cluster:
      - runcompss –appdir

```
<Project>
  <MasterNode/>
  <ComputeNode Name="localhost">
     <InstallDir>/opt/COMPSs/</InstallDir>
     <WorkingDir>/tmp/WorkerLocalhost/</WorkingDir>
     <Application>
        <AppDir>/home/tutorial_apps/c/matmul_objects/</AppDir>
     </Application>
  </ComputeNode>
</Project>
```

Exercise

- Matrix Multiplication with c-binding
  - <tutorial_apps>/c/matmul_object
- Compile:
  - compss_build_app Matmul
- Execute:
  - Edit xml/project.xml to set appdir
  - Runcompss –project=xml/project.xml master/Matmul <N> <M> <Value>


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