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EXCELENCIA SEVERO OCHOA

Programming Distributed Computing Platforms with COMPSs

Workflows & Distributed Computing Group

28-29/01/2020

Barcelona

Outline

Day 2

- Session 6 (9:30-11:00): Java & C++
  - Writing Java applications
  - Java Hands-on + debug
  - C++ Syntax
- Coffee break (11:00 – 11:30)
- Session 7 (11:30-13:00): COMPSs Advanced Features
  - Using binaries and MPI code, Fault Tolerance and Exception management, Numba
  - COMPSs execution environment
- Lunch break (13:00 – 14:30)
- Session 8 (14:30-16:30): Cluster Hands-on (MareNostrum)
- COMPSs Installation & Final Notes
- SLIDES
  - http://compss.bsc.es/releases/tutorials/tutorial-PATC_2020/

Java Syntax

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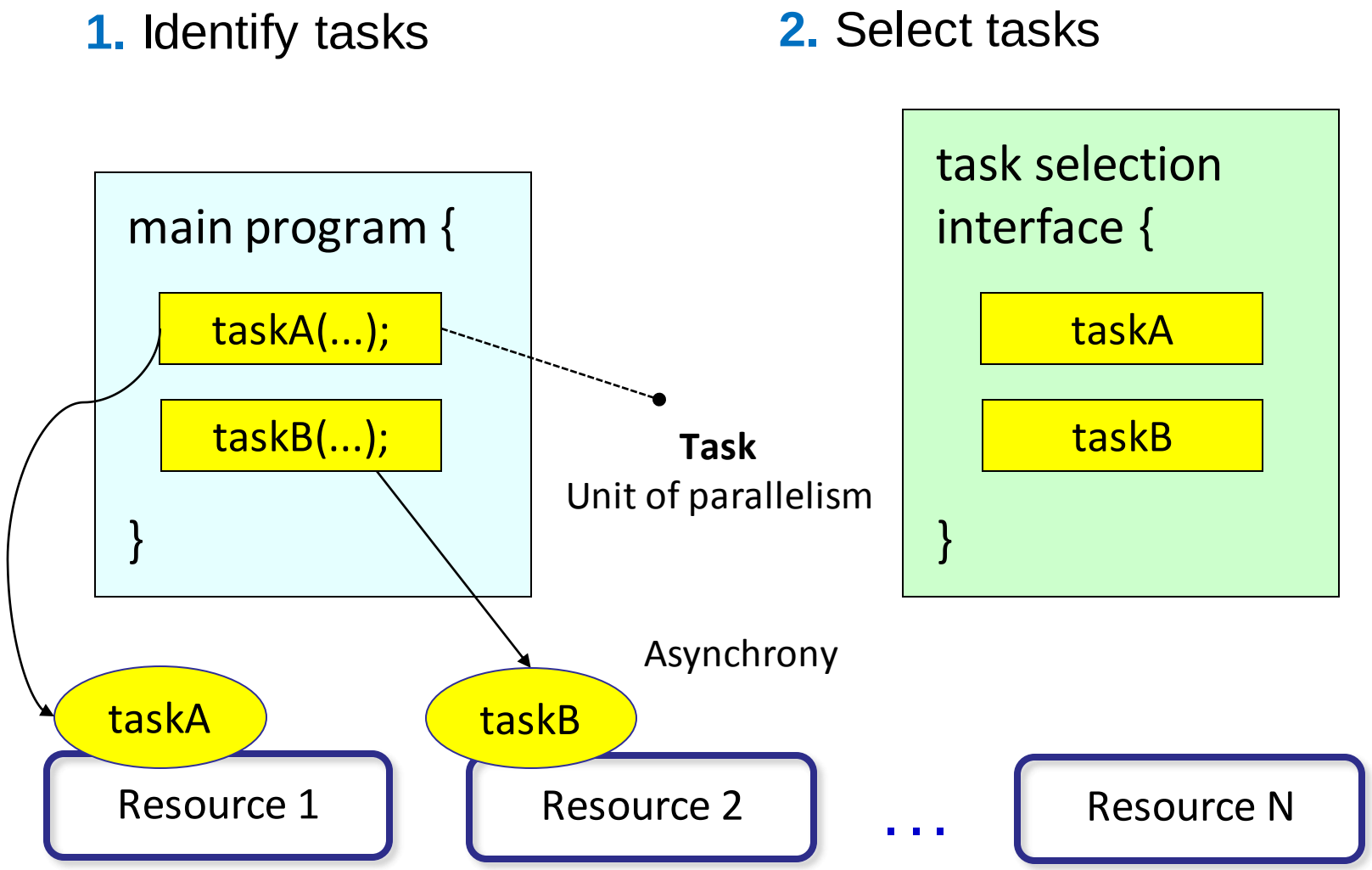
Programming Steps



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
    );
}
```

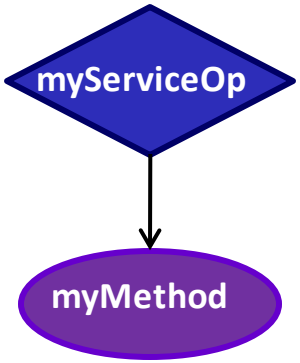
Main program

```
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

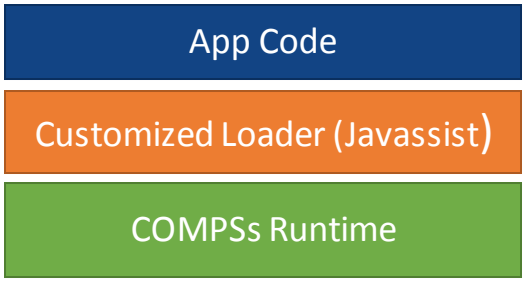
Method task call

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);

   }
}
```

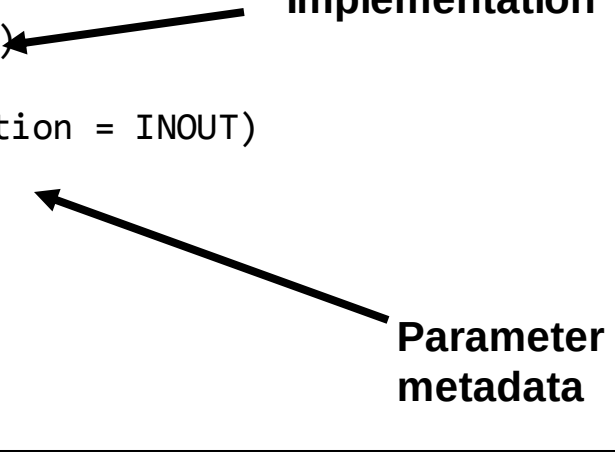
- Task Method

```
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)

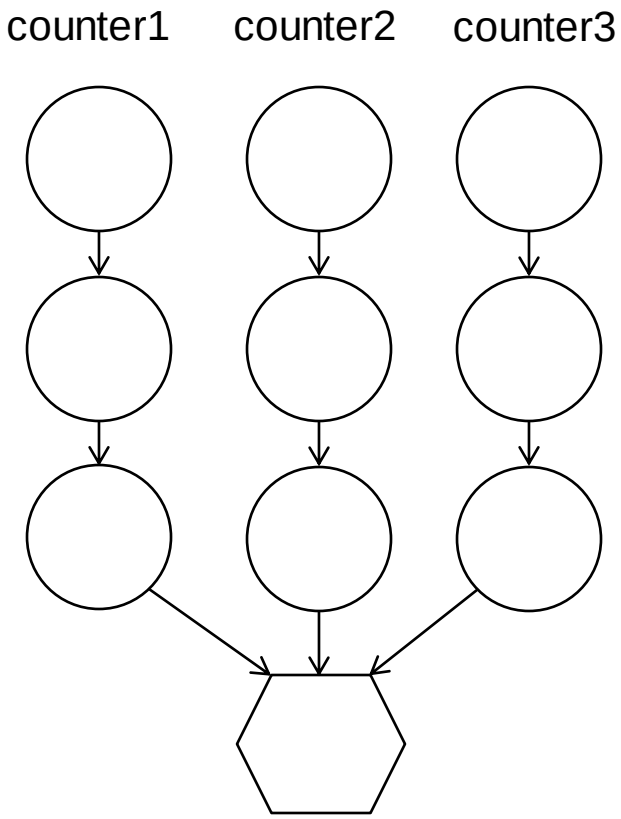
- Main program NO CHANGES!
- No need to synchronize data COMPSs is doing itself!

```
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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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);
- Synchronize a file without opening
  - COMPSs.**getFile**(filename);

Java Hands-on

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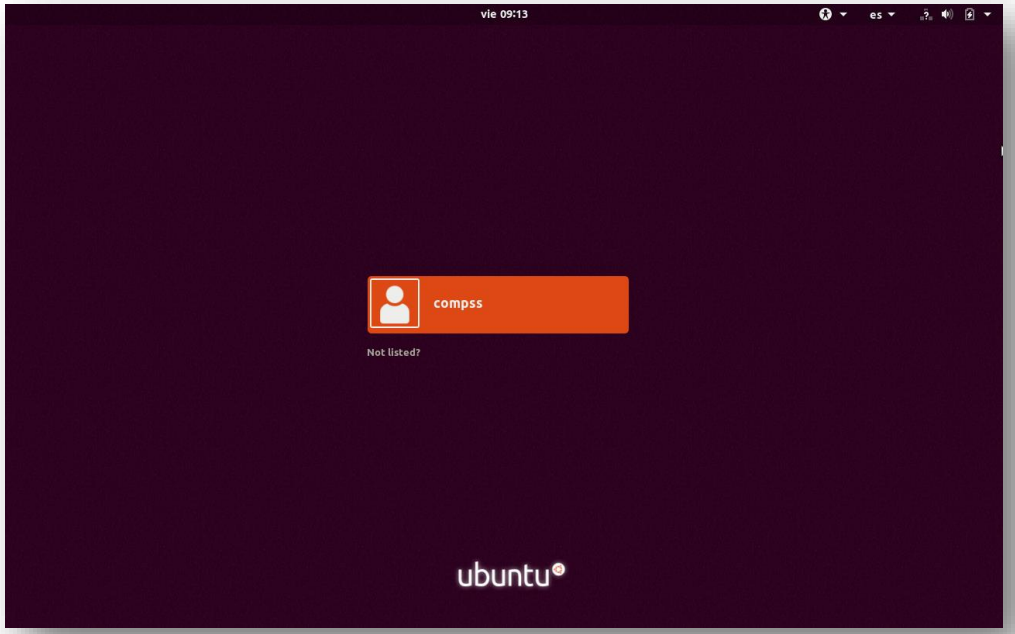
Hands-on environment

- Windows users: Start the Virtual Machine
  - User: **compss**
  - Password: **compss2019**

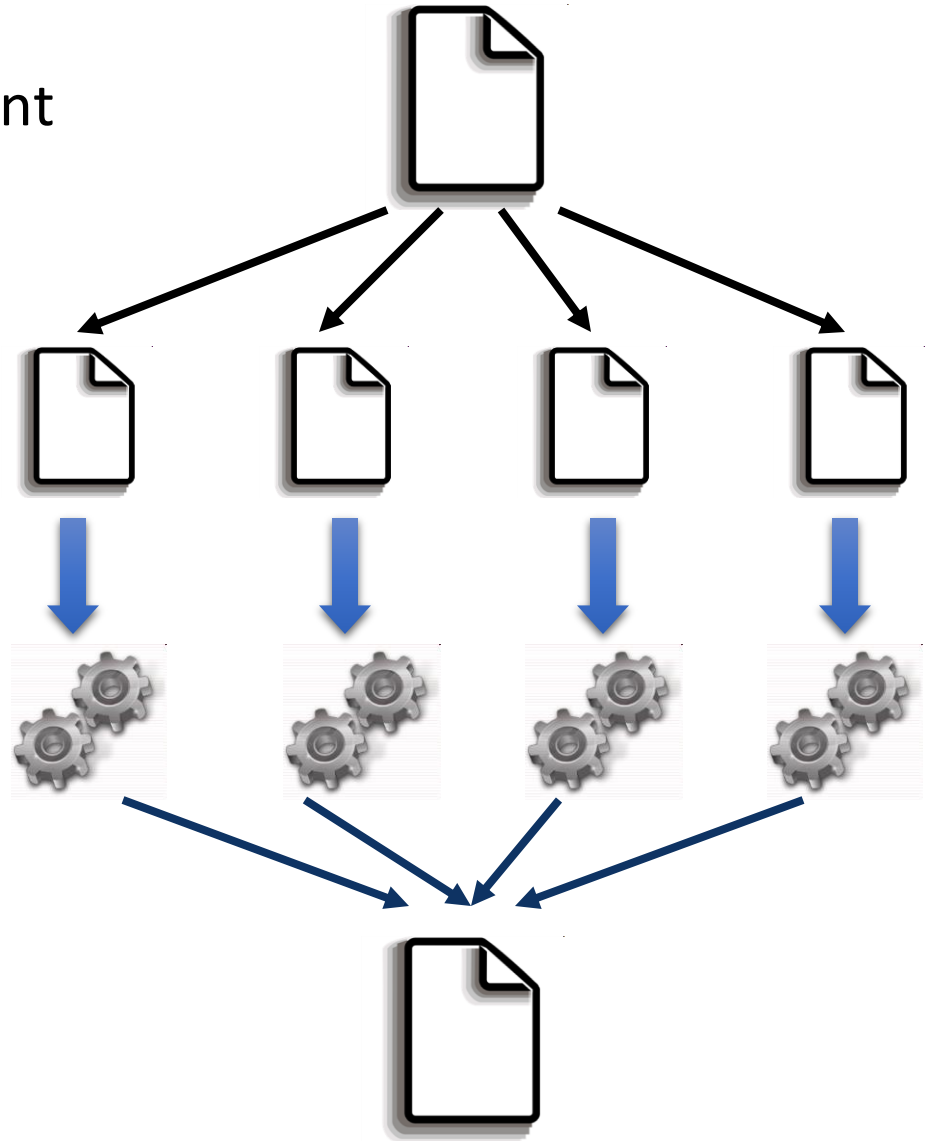
~/tutorial_apps/java

- Open eclipse



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*
- Init the docker testing environment
  - compss init -i compss/compss-tutorial:2.6
- Use compss command to run the application
  - compss run [options] < FQDN app. classname> <application args>

Note: *compss run* command is used for running the application in the Docker testing environments in production installations this command has to be substituted by *runcompss*

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

    wordcount.uniqueFile.Wordcount <data_file> <block_size>


```
$compss@bsc:~/> cd /home/compss/tutorial_apps/java/wordcount
$compss@bsc:/home/compss/tutorial_apps/java/wordcount/> compss run -classpath=jar/wordcount.jar
    wordcount.uniqueFile.Wordcount data-set/file_small.txt 650
```

Java Hands On: Exercise Solution

- Main Code

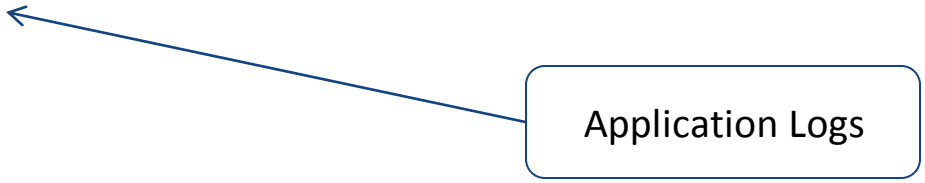
```
private static void computeWordCount() {
        HashMap<String, Integer> result  = new HashMap<String, Integer>();
        int start = 0;
        for (int i = 0; i < NUM_BLOCKS; ++i) {
          HashMap<String, Integer> partialResult = wordCountBlock(DATA_FILE, start, BLOCK_SIZE);
          start = 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/> compss run –classpath=jar/wordcount.jar
    wordcount.uniqueFile.Wordcount data-set/file_small.txt 650

Executing  cmd: runcompss –-project=/project.xml --resources=/resources.xml …

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

WARNING: COMPSs Properties file is null. Setting default values

[   API]  -  Starting COMPSs Runtime v2.6 (build xxxx)
DATA_FILE parameter value = data-set/file_small.txt
BLOCK_SIZE parameter value = 650
[LOG] Computing word count result
[LOG] Counted Words is : 247
[   API]  -  No more tasks for app 1
[   API]  -  Getting Result Files 1
[   API]  -  Execution Finished

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



Java Hands-on: Configuration

- Project.xml:
  - compss exec cat /project.xml

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

  - Other optional parameters
    - User, AppDir, LibraryPath

Java Hands-On: Configuration

- Resources.xml:
  - compss exec cat /resources.xml

```
<?xml version="1.0" encoding="UTF-8"?>
<ResourceList>
    <!--Description for any physical node-->
    <ComputeNode Name="localhost">
      <Processor Name="MainProcessor">
                <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

Simulating several workers

- Add workers:

```
$compss@bsc:/home/compss/tutorial_apps/java/wordcount/> compss components add worker 2
```

- Check project and resources

```
$compss@bsc:/home/compss/tutorial_apps/java/wordcount/> compss exec cat /project.xml

$compss@bsc:/home/compss/tutorial_apps/java/wordcount/> compss exec cat /resources.xml
```

- Execute again

```
$compss@bsc:/home/compss/tutorial_apps/java/wordcount/> compss run -classpath=jar/wordcount.jar
    wordcount.uniqueFile.Wordcount data-set/file_small.txt 650
```

Java Hands-On: Monitoring

- The runtime of COMPSs provides real-time monitoring to follow the progress of the executions
  - Running tasks, resources usage, execution time per task, real-time execution graph, etc.
- Start monitor and open browser
  - **compss monitor start**
  - http://localhost:8080/compss-monitor/

Note: in production installations */etc/init.d/compss-monitor start*

- Activate monitoring with a runcompss/ compss run flag
  - Setting a monitoring interval
    - **compss run --monitoring=<int>**
  - With a default monitoring interval
    - **compss run –m** (or) **compss run --monitoring**

Note: *compss run* command is used for running the application in the Docker testing environments in production installations this command has to be substituted by *runcompss*

- ***Exercise:*** run wordcount enabling monitoring

```
$compss@bsc:/home/compss/tutorial_apps/java/wordcount/jar/> compss run -m -classpath=jar/wordcount.jar
    wordcount.uniqueFile.Wordcount   data-set/file_long.txt 350000
```

Java Hands-on: Graph generation

- To generate the graph of an application, it must be run with the monitor or graph flags activated
  - **compss run -m | –graph | –g**
- The graph will be stored in:
  - .COMPSs/<APP_NAME>_<EX#>/monitor/complete_graph.dot
- To convert the graph to a PDF format:
  - compss gengraph <dot_file>
- **Exercise:** generate the graph for the wordcount application

Remember: *compss run* command environments in production installations this command has to be substituted by *runcompss*

```
$compss@bsc:~/tutorial_apps/java/wordcount> compss run -g -classpath=jar/wordcount.jar wordcount.uniqueFile.Wordcount
data-set/file_small.txt 650

     … application execution …


$compss@bsc:~/tutorial_apps/java/wordcount>compss gengraph .COMPSs/wordcount.uniqueFile.Wordcount_04/monitor/complete_graph.dot

     Output file: .COMPSs/wordcount.uniqueFile.Wordcount_04/monitor/complete_graph.pdf


$compss@bsc:~/tutorial_apps/java/wordcount> evince .COMPSs/wordcount.uniqueFile.Wordcount_04/monitor/complete_graph.pdf
```


Java Hands-on: Debugging

- Different log levels activated as options
  - **--log_level**=<level>
    (**off**: for performance | **info**: basic logging | **debug**: detect errors)
  - **–debug** or **-d**
- The output/errors of the main code of the application are shown in the console
- Logging files are stored by default in:
  - $HOME/.COMPSs/<APP_NAME>_XX
  - Customizable with flag **–base_log_dir=<**path>
- Inside this folder, the user can check :
  - The output/error of a task # N : ***jobs/jobN.[out|err]***
  - Messages from the COMPSs : ***runtime.log***
  - Worker: ***$HOME/.COMPSs/<app_name_XX>/workers***
    or during the execution at ***/<working_dir>/<uuid>/<node_name>/logs***
- ***Exercise:*** run wordcount with debugging

Note: By default in production installations the log folder is in *$HOME/.COMPSs*. In the Docker environment, it is set to appear in *$PWD/.COMPS*. In this case, when using Jupyter the log dir flag is not set and you have to do *pycompss exec cp /root/.COMPSs to see the logs*

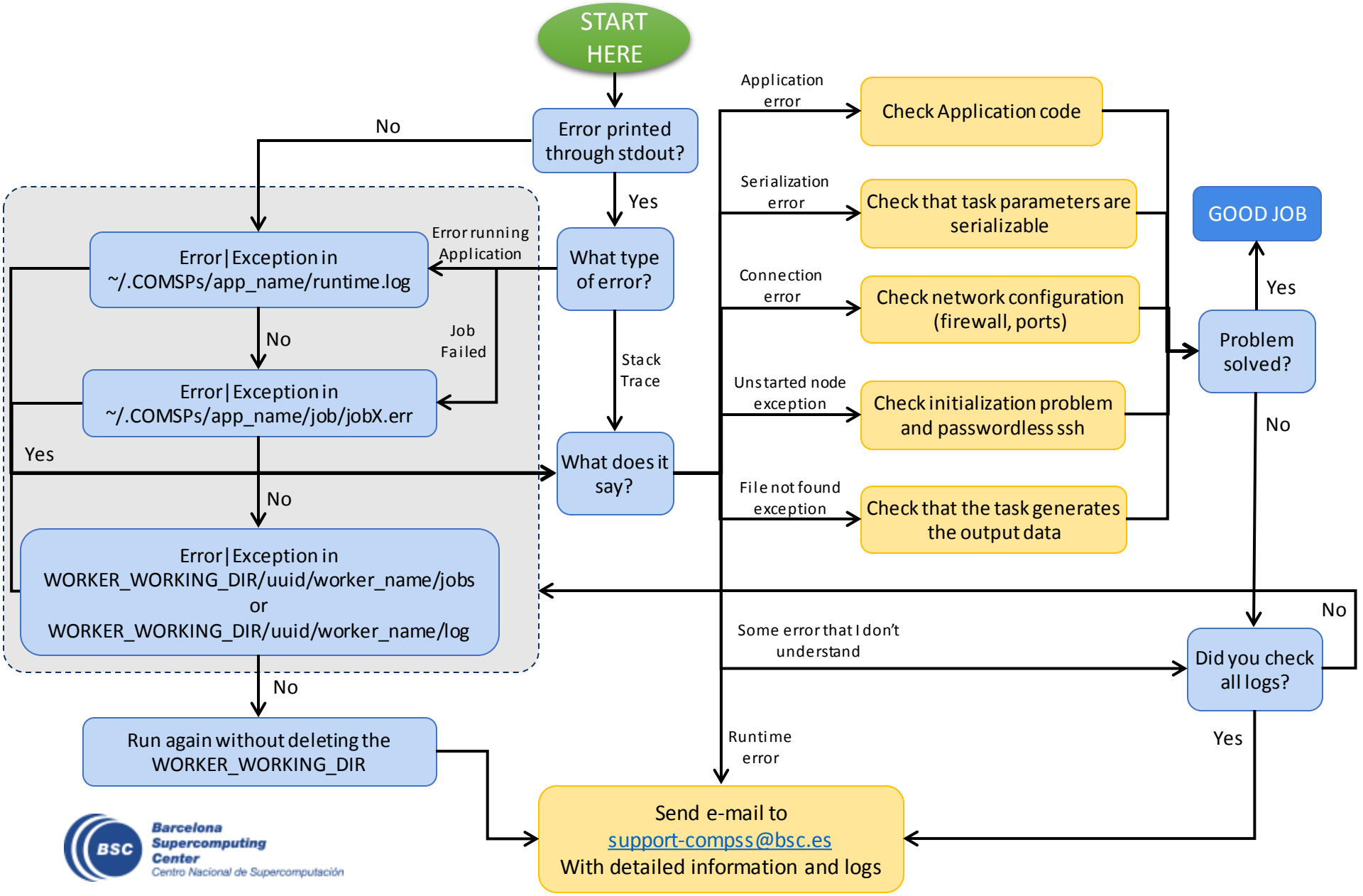
```
$$compss@bsc:/home/compss/tutorial_apps/java/wordcount/jar/> compss run -d -classpath=jar/wordcount.jar
    wordcount.uniqueFile.Wordcount /home/compss/workspace_java/wordcount/data/file_small.txt 650
```

Demo

- Common errors:
  - Exceptions
    - In main code
    - Within a task
  - Usage of non-serializable objects
    - As a parameters
    - As a return
  - Connectivity problems
    - The master can not connect to the worker
    - The worker can not connect to the master

Debugging process

Default log locations:
MASTER LOGS: ~/.COMPSs
WORKER_WORKING_DIR = /tmp/COMPSsWorker/



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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);
  - FILE* **compss_fopen**(char * filename, char * mode);
  - void **compss_wait_on_file**(char * filename);
  - void **compss_delete_file**(char * filename);
- 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
  - cd ~/tutorial_apps/c/matmul_object
- Compile:
  - compss exec compss_build_app Matmul
- Execute:
  - compss –appdir=/home/user/ master/Matmul 4 4 2.0


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