IoTSim-Stream User Manual

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1 What is IoTSim-Stream

IoTSim-Stream is an IoT Simulator for Stream processing on the big data that offers an environment to model complex stream graph applications in Multicloud environment, where the large-scale simulation-based studies can be conducted to evaluate and analyse these applications. It leverages the features of CloudSim and integrating real-time processing model with workflow scheduling and execution to execute the modelled stream graph application in Multicloud environment.

IoTSim-Stream supports the modelling of different patterns/structures of stream workflow applications, which are linear (a multi-stage application where each stage processes input stream generated by the previous stage and produces the output stream to the following stage), branching (an application with limited precedence constraints that splits data stream to perform different parallel processing and then combining the results for further analysing) and hybrid (a mix of linear and branching patterns).

For technical detail about IoTSim-Stream, please refer to our paper entitled "IoTSim-Stream: Modelling stream graph application in cloud simulation" that has been published in Future Generation Computer Systems, Volume 99, October 2019, Pages 86-105.

2 Unique Features

- Support modelling data incentive IoT-based applications using stream processing model (aka stream graph applications).
- Support modelling Multicloud environment as an execution environment for stream graph application.
- Support user-defined resource provisioning and scheduling policies.

3 Getting Started

3.1 System and Software Requirements

- Operating System: Windows, Linux or Mac OS.
- CPU: 1-GHz processor or equivalent (Minimum).
- RAM: 2 GB (Minimum).
- Hard Disk Space: 1 GB (Minimum).
- Java Platform: JDK version 11+ (recommended)
- Any IDE for Java programming language such as NetBeans or Eclipse

3.2 Download IoTSim-Stream

The simulation toolkit (IoTSim-Stream) can be downloaded from the below link. After downloading a zip file, you need to unzip IoTSim-Stream files.

https://github.com/mutazb999/IoTSim-Stream

3.3 Directory Structure of IoTSim-Stream

The structure of IoTSim-Stream package is as follows:

- IoTSim-Stream/
  - dependency.repository -- Jar dependencies (i.e. jar file for Cloudsim)
  - Sample_Stream_Workflows -- sample stream graphs with different sizes
  - src/main/java/examples/ -- Some examples of stream graph applications
  - src/main/java/iotsimstream/ -- The source code of IoTSim-Stream
  - src/main/java/resources/ -- The simulation properties file of IoTSim-Stream

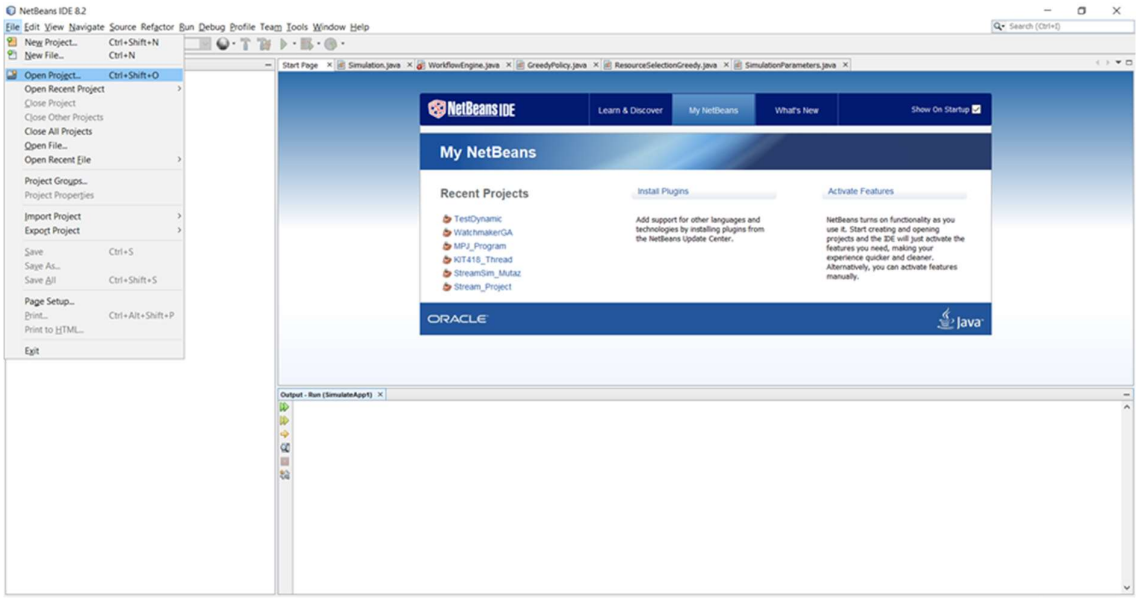
3.4 Setup IoTSim-Stream

Prior to use and work with IoTSim-Stream, you need to import and configure this project in the chosen IDE.

How to setup IoTSim-Stream project in Netbeans

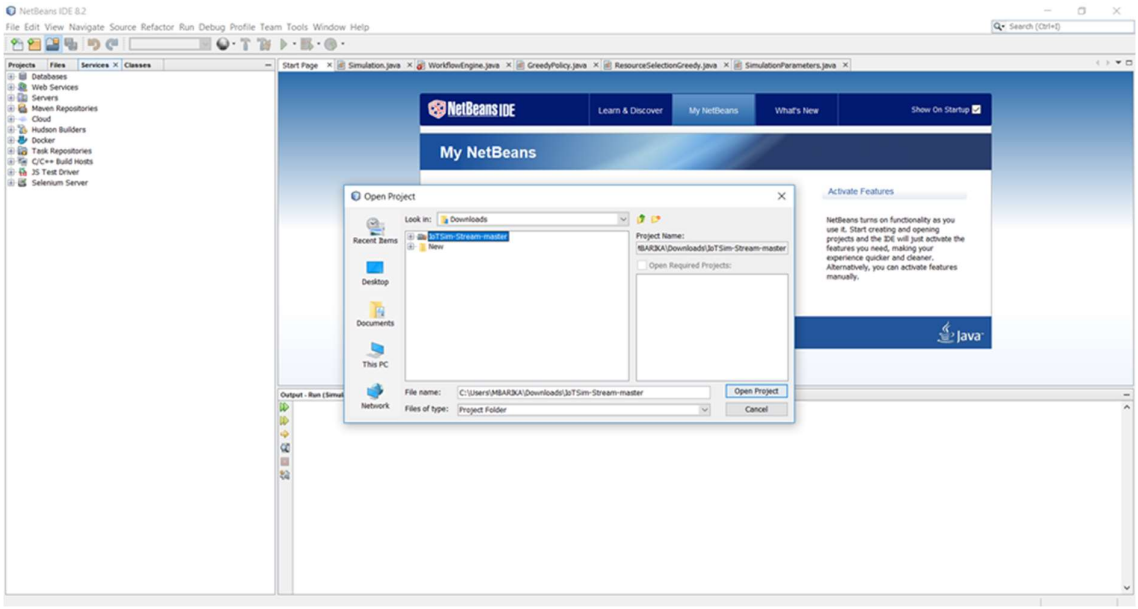
Step 1

Open NetBeans IDE -> File -> Open Project



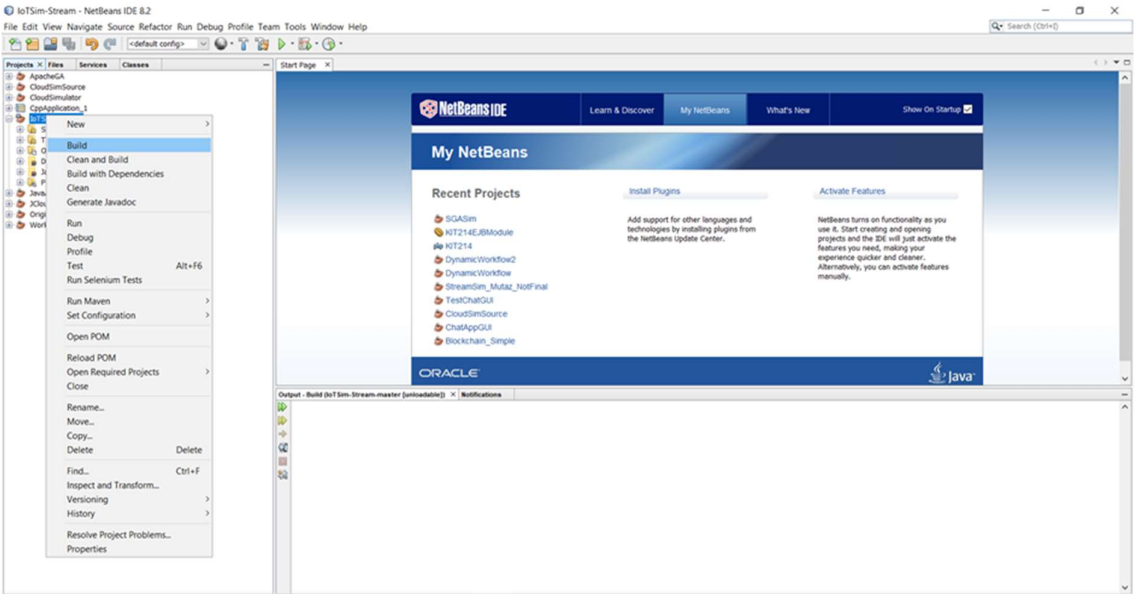
Step 2

Select the folder corresponding to IoTSim-Stream, then click on Open Project

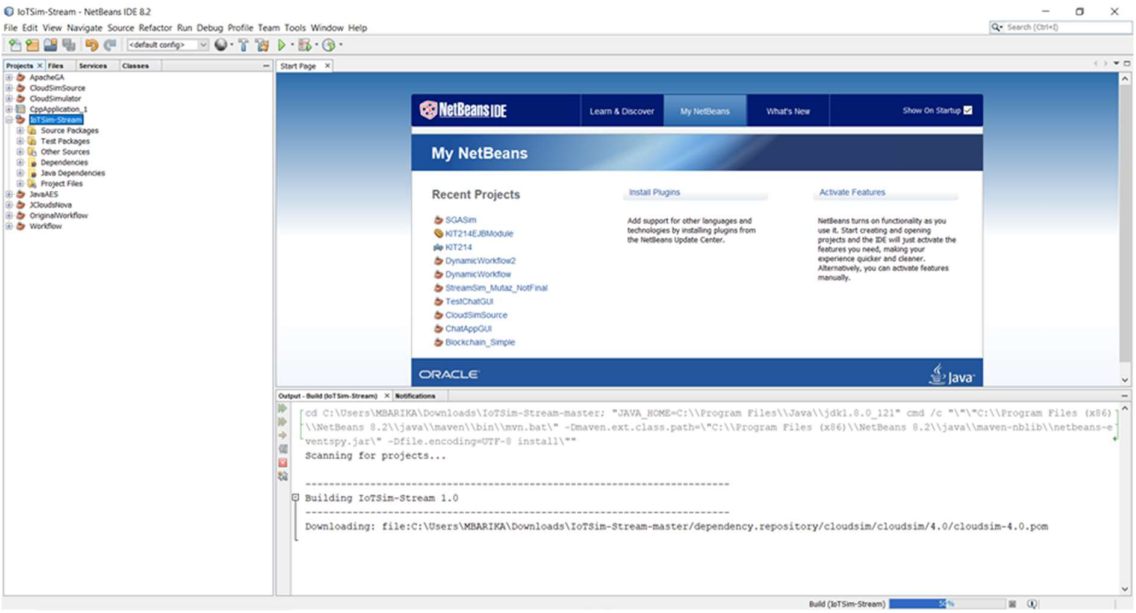


Step 3

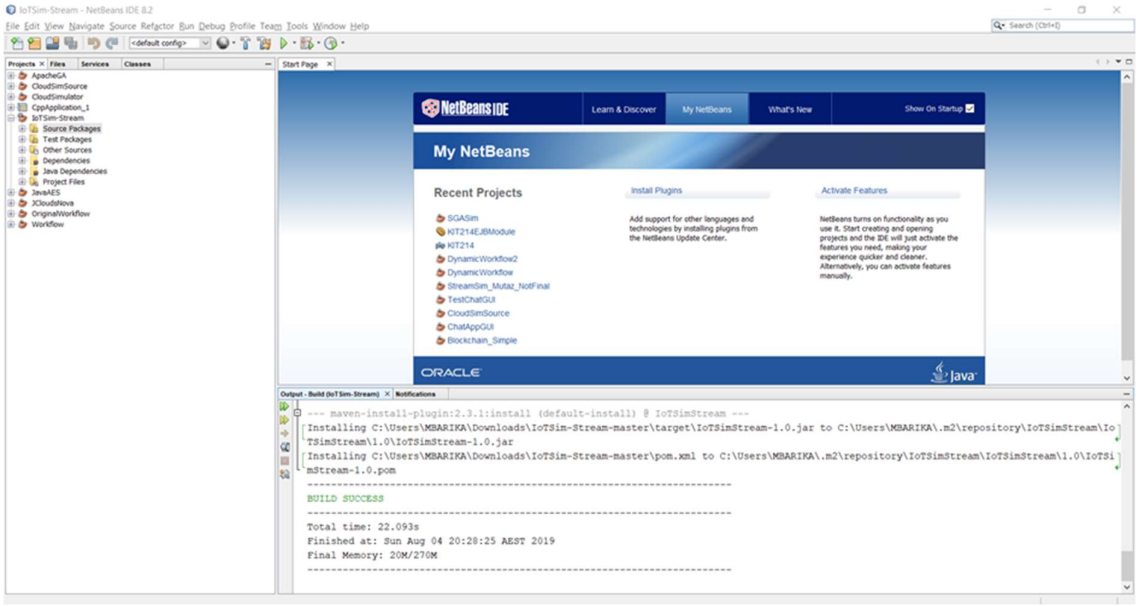
Right-click on IoTSim-Stream project and click on Build



Now, the build process is started. During this process, you will see some warnings that are highlighted with blue colour.

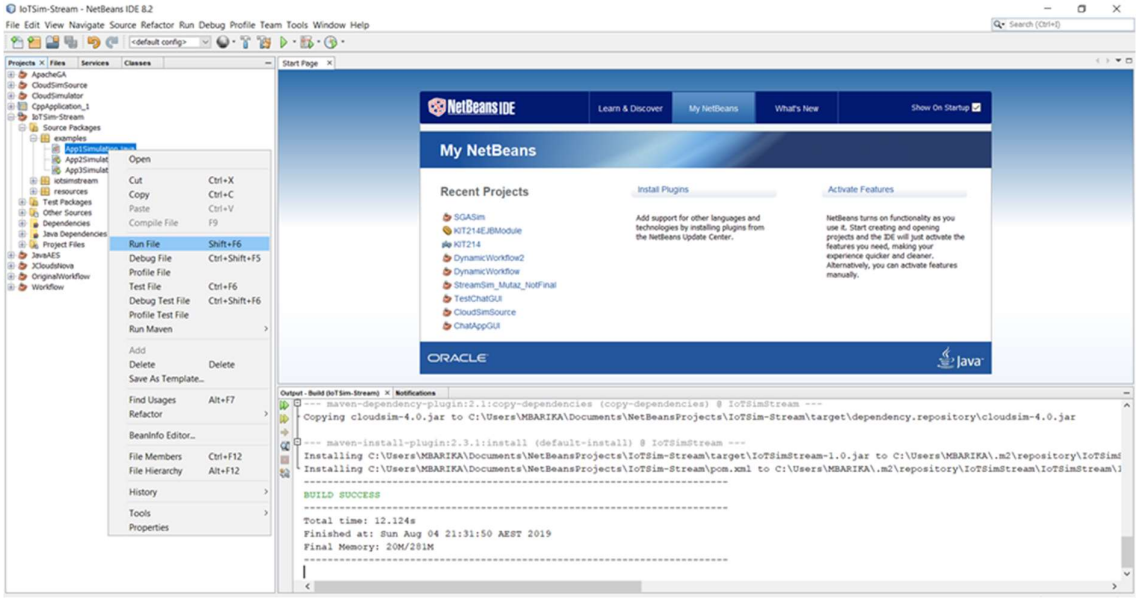


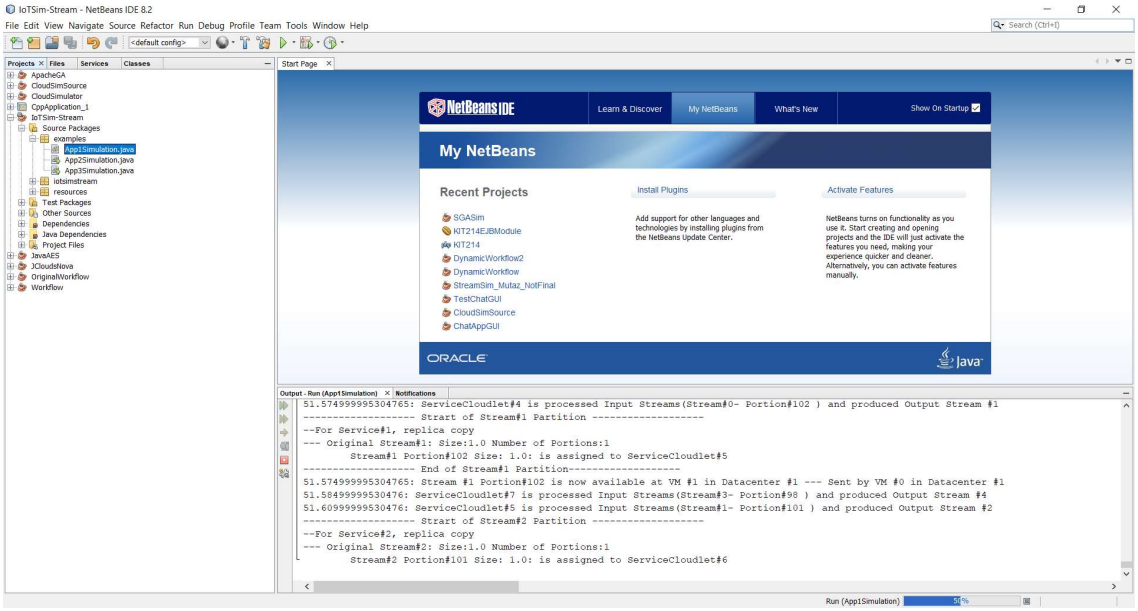
When the build process is completed, you will see “BUILD SUCCESS” as shown in the below screenshot. At this point, you successfully built and configured IoTSim-Stream.



Step 4

To run a simulation, you need to go to the examples package and run any example provided. For instance, if you would to simulate App1, expand the examples package, right-click on “App1Simulation” and select “Run file”. The simulation process will be initialized and the simulation of App1 will begin.

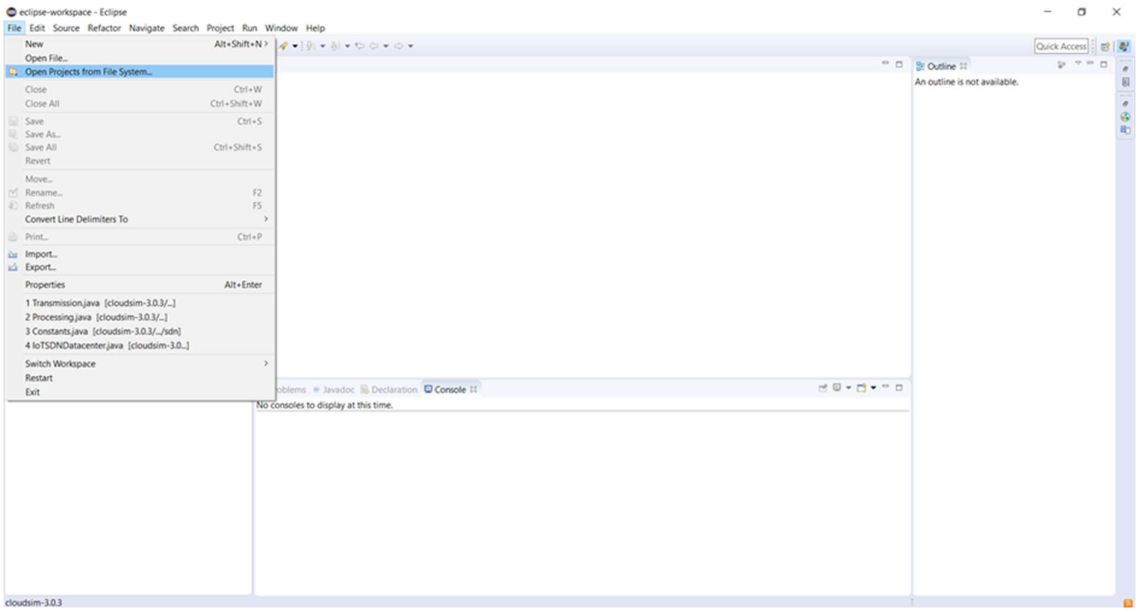




How to setup IoTSim-Stream project in Eclipse

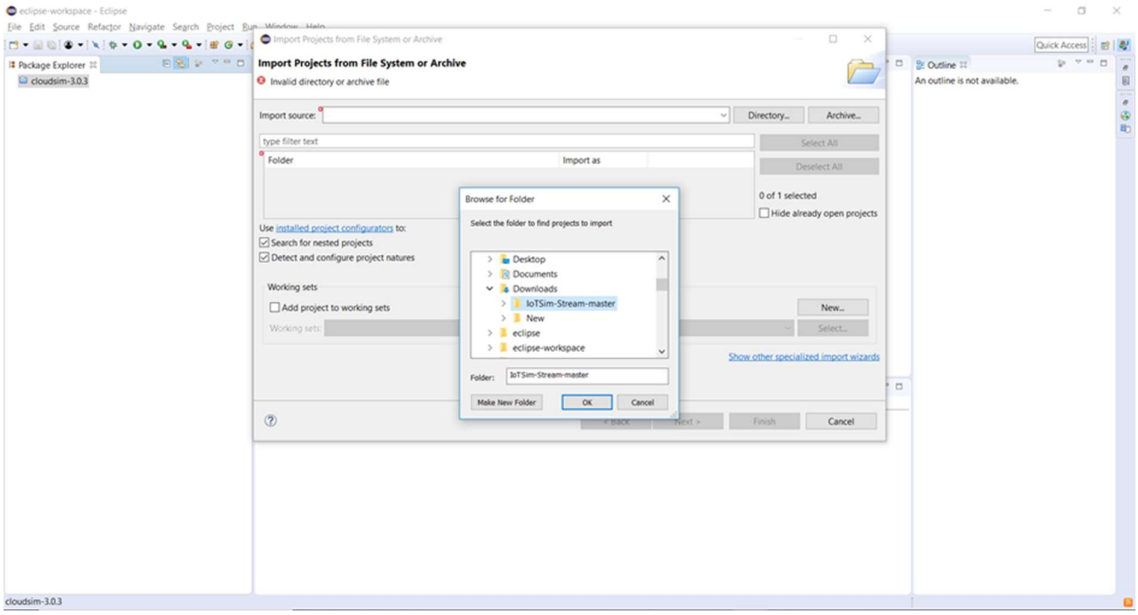
Step 1

Open Eclipse IDE -> File -> Open Projects From File System…

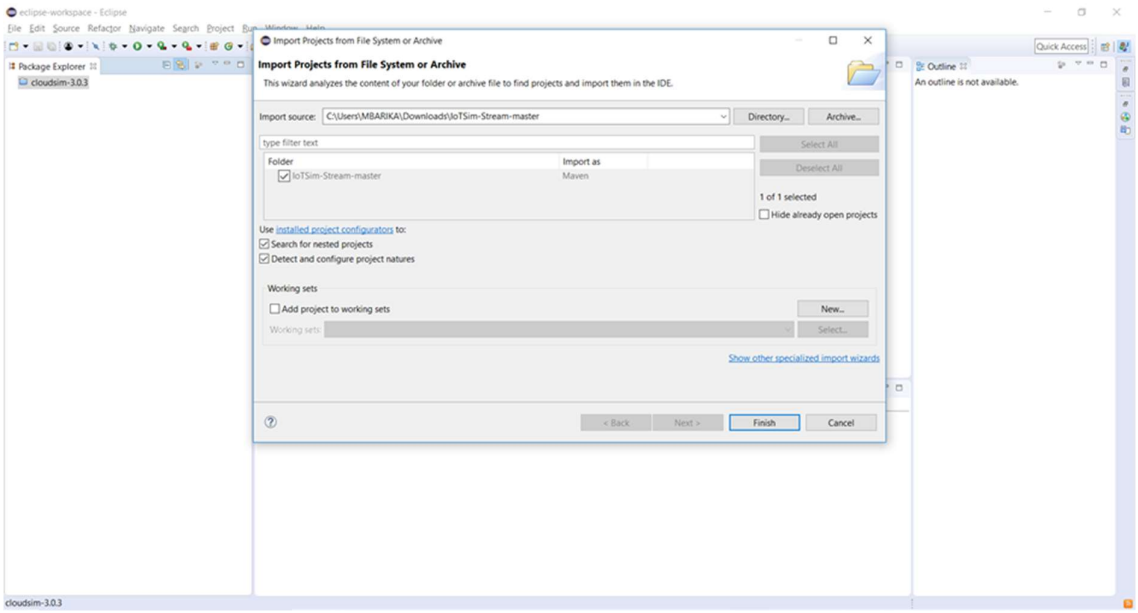


Step 2

Click on Directory and then select the folder corresponding to IoTSim-Stream. After that click on OK

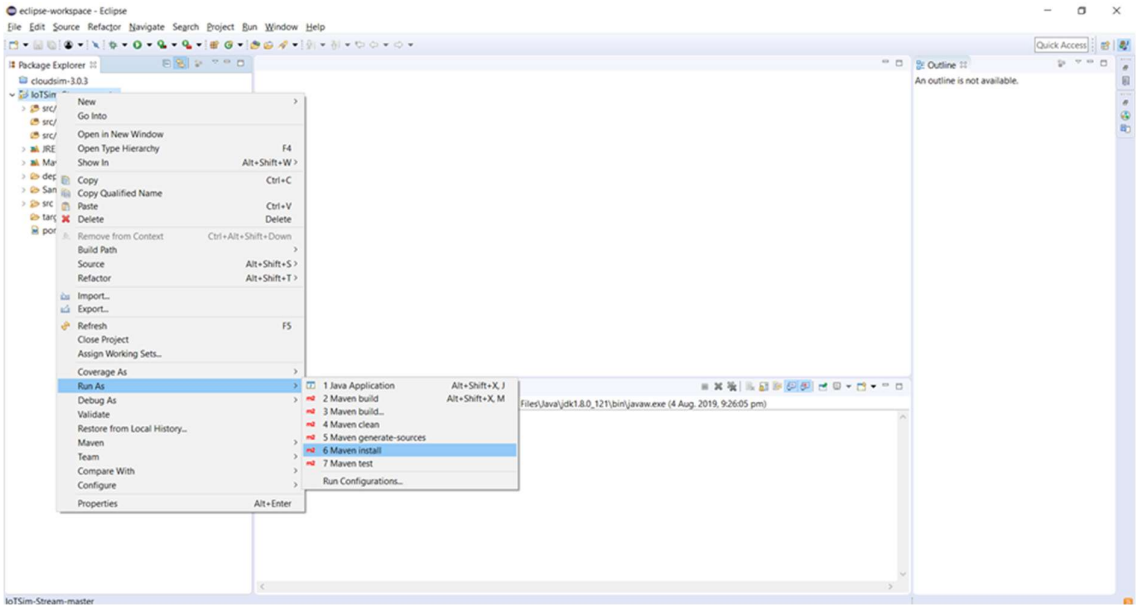


Now, click on Finish

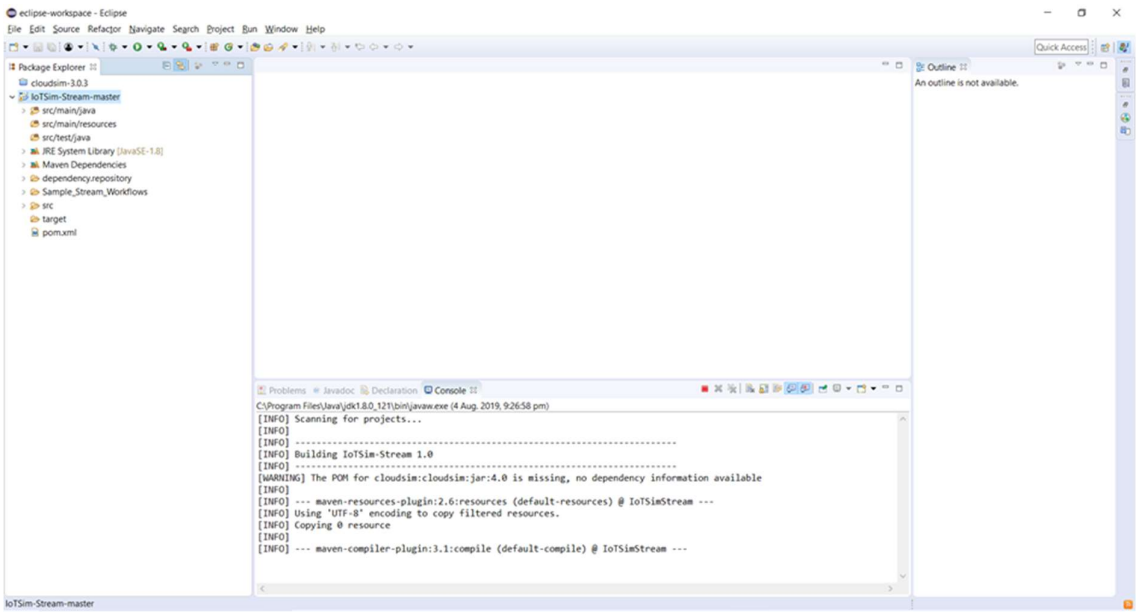


Step 3

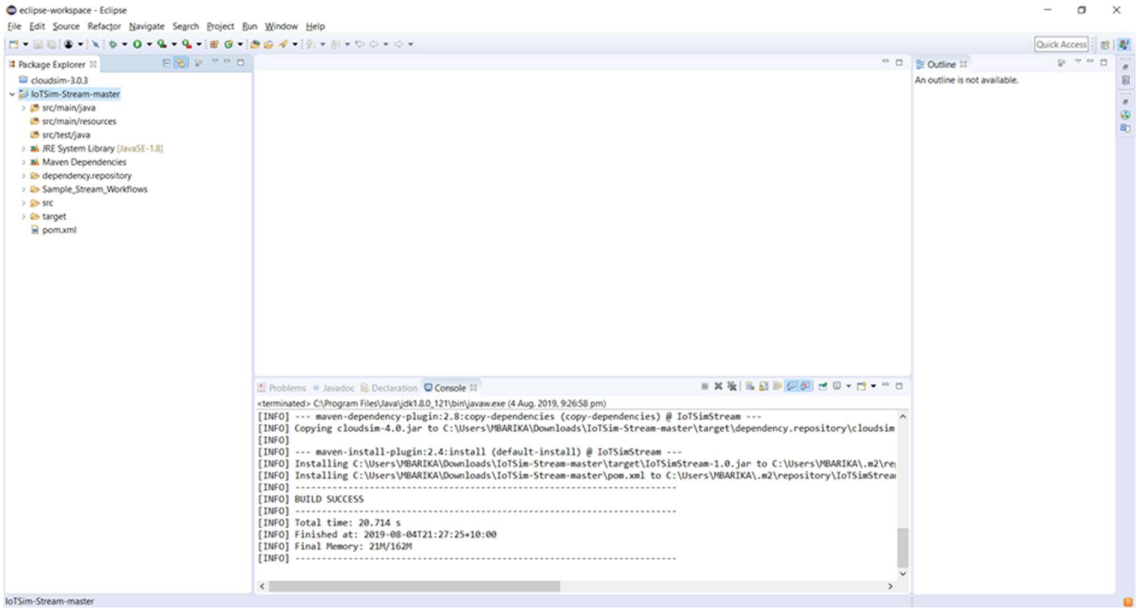
Right-click on IoTSim-Stream project and click on Maven install that found under Run As



Now, the installing project main artefact is started.

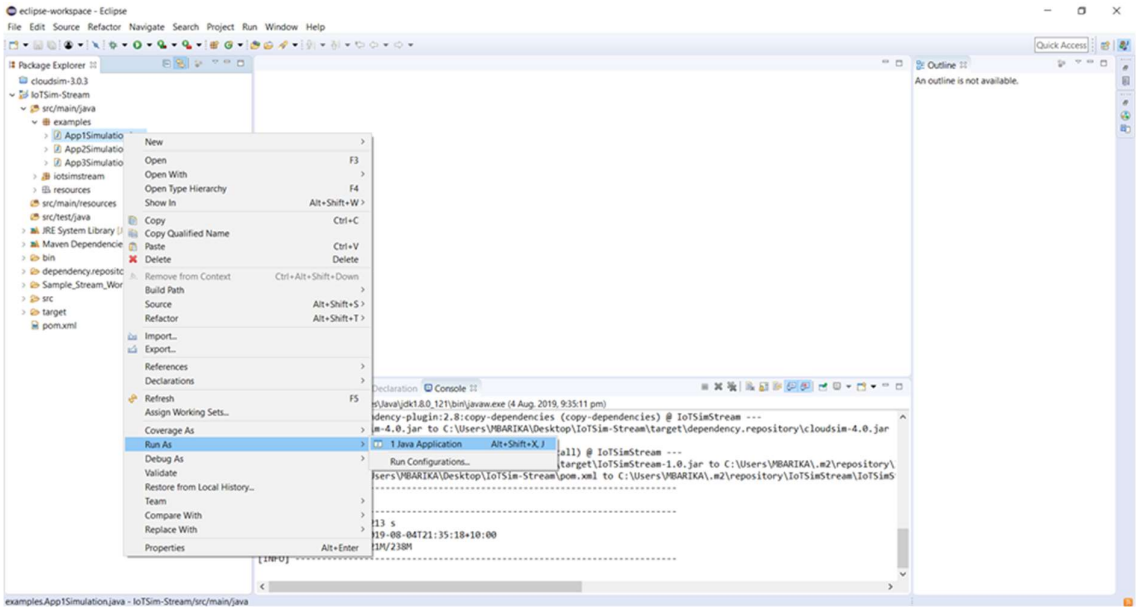


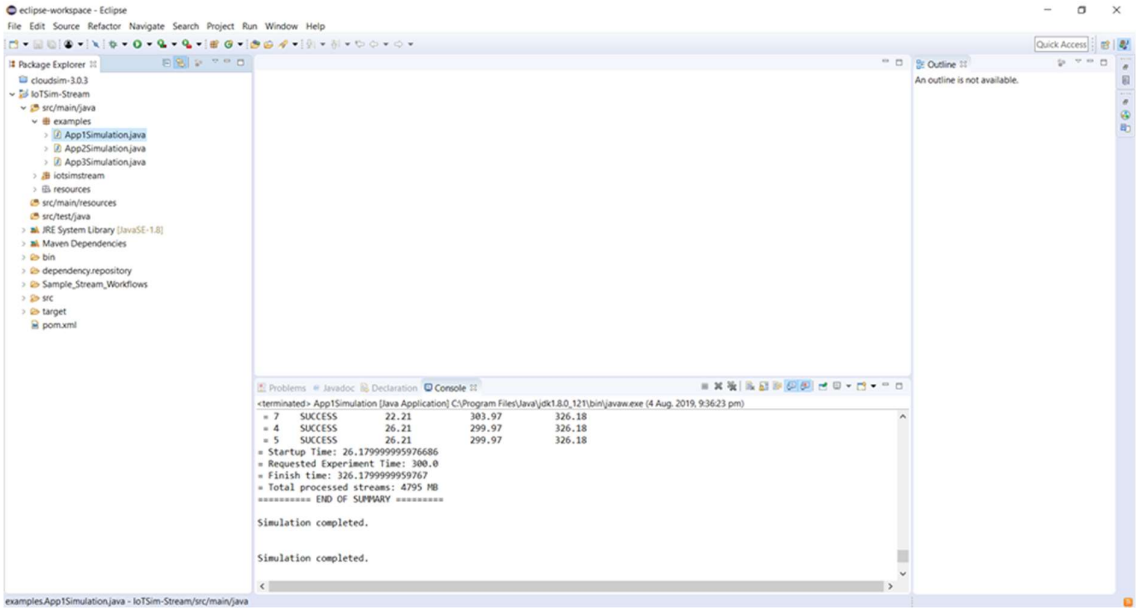
When this process is completed, you will see “BUILD SUCCESS” as shown in the below screenshot. At this point, you successfully built and configured IoTSim-Stream.



Step 4

To run a simulation, you need to go to the examples package and run any example provided. For instance, if you want to simulate App1, expand the examples package, right-click on “App1Simulation” and select “Run file”. The simulation process will be initialized and the simulation of App1 will begin.





3.5 Simulation Configuration: Stream processing system simulation

Prior to simulating stream graph applications, you need to configure the parameters of the stream processing system and define them in the simulation properties file (named simulation.properties). These parameters will be read by IoTSim-Stream during initialisation to prepare the simulation environment and then simulating a given stream graph application on this environment according to the specified configurations. The below table shows the simulation parameters that are included in this file with their descriptions.

Table 1: User-defined Simulation Parameters Configuration

Parameter	Description
simulation time	The requested simulation time in seconds
scheduling.policy	Provisioning and scheduling policy
dag.file	Path of XML file of stream graph application
cloud.datacenter	Number of Clouds, where each Cloud is represented by a datacenter
engine.network.bandwidth	Network bandwidth of GraphAppEngine
engine.network.latency	Network latency of GraphAppEngine
cloud.provider	Index of Cloud provider in execution environment (index starting from 0)
datacenter.hosts#index	number of hosts in datacenter (ex. datacenter.hosts#0)
vm.delay#index	Average delay of VM boot time
vm.o ers#index	Path of Java class for offerings of Cloud-based datacentre
host.cores#index	Number of cores (PEs) available for each host
host.memory#index	Amount of memory available for each host
host.storage#index	Amount of storage available for each host
core.mips#index	MIPS for each core or PE
internal.bandwidth#index	Internal network bandwidth available for each VM within Cloud-based datacentre
internal.latency#index	Network delay between VMs within Cloud-based datacentre
external.bandwidth#index	External network bandwidth available by Cloud-based datacentre for transferring data streams to other datacentres
external.latency#index	Network delay from Cloud-based datacentre to other dataentres

The below listing shows an example of simulation.properties file to configure the simulation environment with two datacenters (IaaS providers). This file is found in the IoTSim-Stream directory (src/main/java/resources). The VM offers provided by each datacentre can be found in the corresponding class (see VmOffersDatacenter1 and VmOffersDatacenter2).

Listing 1: An example of simulation.properties

```
simulation.time = 300
scheduling.policy = iotsimstream.SimpleSchedulingPolicy
dag.file =

cloud.datacenter = 2
engine.network.bandwidth =  250
engine.network.latency =  0.03

cloud.provider = 0
datacenter.hosts#0 = 1000
vm.delay#0 = 20
vm.offers#0 = iotsimstream.VmOffersDatacenter1
host.cores#0 = 64
host.memory#0 = 144000
host.storage#0 = 1400000
core.mips#0 = 1000
internal.bandwidth#0 = 770
internal.latency#0 = 0.00077
external.bandwidth#0 = 170
external.latency#0 = 0.028

cloud.provider = 1
datacenter.hosts#1 = 1000
vm.delay#1 = 20
vm.offers#1 = iotsimstream.VmOffersDatacenter2
host.cores#1 = 64
host.memory#1 = 176000
host.storage#1 = 1500000
core.mips#1 = 2000
internal.bandwidth#1 = 780
internal.latency#1 = 0.00075
external.bandwidth#1 = 180
external.latency#1 = 0.026
```

4 Simulating

The structure of the stream graph application involves heterogeneous services, multiple data sources, multiple input streams and multiple output streams. This structure can be expressed in DAG file by including all modelled services with their data processing requirements and performance constraints that defined by the owner of this application, and data dependencies among them. Moreover, IoTSim-Stream supports the modelling of different patterns/structures of stream workflow applications, which are linear, branching and hybrid. Linear workflow pattern (like App1) is a multi-stage application, where each stage processes the input stream generated by the previous stage and produces the output stream to the following stage. Branching workflow pattern (like App2) is an application with limited precedence constraints that splits data stream to perform different parallel processing and

then combining the results for further analysing. Hybrid workflow pattern (like App3) is a mix of linear and branching patterns. The DAG file will be parsed by the simulator to create stream graph application.

To simulate stream graph application, you need to describe stream graph application in XML structure in DAG file, and then given the path of such file to the simulator by writing it down as a value of dag.file property in simulation.properties.

4.1 Example of Linear Stream Graph Application

If your stream graph application is the one that is presented in the below figure, the XML structure of such application is depicted in the below listing.

SERVICE / EXTERNAL SOURCE	DATA PROCESSING REQUIREMENT	USER PERFORMANCE REQUIREMENT	INPUT	OUTPUT	OUTPUT STREAM TO SERVICE(S)
EX0	N/A	N/A	N/A	4 MB/s	4 MB/s to S0
S0	500 MI/MB	4 MB/s	4 MB/s	4 MB/s	4 MB/s to S1
S1	500 MI/MB	4 MB/s	4 MB/s	4 MB/s	4 MB/s to S2
S2	1000 MI/MB	4 MB/s	4 MB/s	4 MB/s	4 MB/s to S3
S3	1000 MI/MB	4 MB/s	4 MB/s	1 MB/s	None

Figure 1. Example of linear stream graph application with its parameter configurations

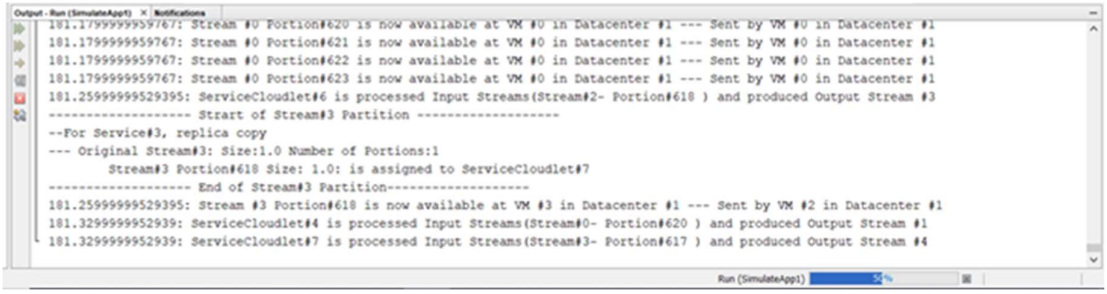
Listing 2: XML structure of linear stream graph application in DAG file

```
<?xml version="1.0" encoding="UTF-8" standalone="no"?><!-- generated: 2017-06-24T14:29:13-
07:00 --><!-- generated by: Mutaz[??] --><adag xmlns="http://pegasus.isi.edu/schema/DAX"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" childCount="3" name="App1"
serviceCount="4" version="2.1" xsi:schemaLocation="http://pegasus.isi.edu/schema/DAX
http://pegasus.isi.edu/schema/dax-2.1.xsd">
<!-- part 1: list of all referenced files (may be empty) -->
<!-- part 2: definition of all jobs (at least one) -->
  <externalsources>
          <exsource datarate="4" id="PID00000" name="Producer0" type="stream"/>
  </externalsources>
  <service dataprocessingreq="500" id="ID00000" name="TmpltBank" userreq="4">
    <uses link="input" producerref="PID00000" type="stream"/>
    <uses link="output" size="4" transfer="true" type="stream"/>
  </service>
  <service dataprocessingreq="500" id="ID00001" name="TmpltBank" userreq="4">
    <uses link="input" processingtype="replica" serviceref="ID00000" transfer="true"
type="stream"/>
    <uses link="output" size="4" transfer="true" type="stream"/>
  </service>
  <service dataprocessingreq="1000" id="ID00002" name="TmpBank" userreq="4">
    <uses link="input" processingtype="replica" serviceref="ID00001" type="stream"/>
    <uses link="output" size="4" type="stream"/>
  </service>
  <service dataprocessingreq="1000" id="ID00003" name="TmpBank" userreq="4">
    <uses link="input" processingtype="replica" serviceref="ID00002" type="stream"/>
    <uses link="output" size="1" type="stream"/>
  </service>
  <child ref="ID00001">
    <parent ref="ID00000"/>
  </child>
  <child ref="ID00002">
    <parent ref="ID00001"/>
  </child>
  <child ref="ID00003">
    <parent ref="ID00002"/>
  </child>
</adag>
```

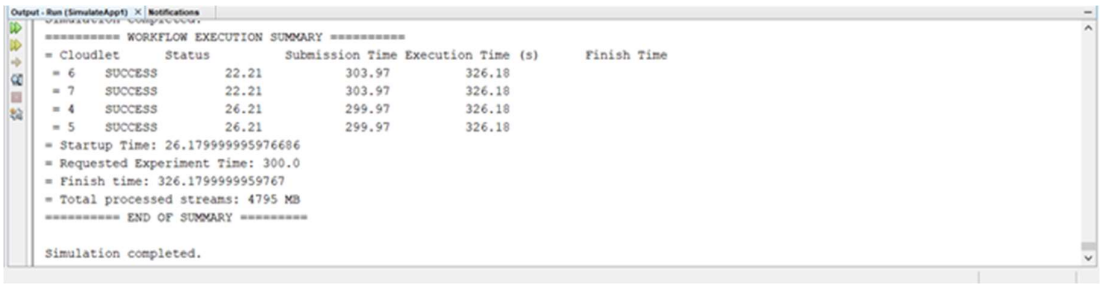
The above XML file for this stream graph application is named with “App1” and can be found in the IoTSim-Stream directory under Sample_Stream_Workflows.

Now, you can simply start the simulation by clicking Run File “App1Simulation”.

During the simulation, you will see the detailed execution of a given stream graph application in output toolbar/pane, where IoTSim-Stream logs each event. Some of those details are scheduling plan, stream transfer from source SVM to destination SVM(s), stream replica or partition and stream scheduling on SVMs.

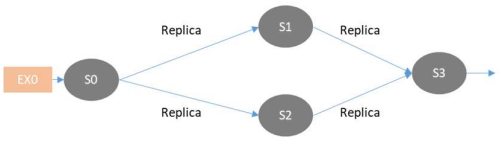


At the end of the simulation, you will see the summary of workflow execution like the below



4.2 Example of Branching Stream Graph Applications (App2)

If your stream graph application is the one that is presented in the below figure, the XML structure of such application is depicted in the below listing.



SERVICE / EXTERNAL SOURCE	DATA PROCESSING REQUIREMENT	USER PERFORMANCE REQUIREMENT	INPUT	OUTPUT	OUTPUT STREAM TO SERVICE(S)
EX0	N/A	N/A	N/A	4 MB/s	4 MB/s to S0
S0	500 MI/MB	4 MB/s	4 MB/s	4 MB/s	4 MB/s to S1 4 MB/s to S2
S1	500 MI/MB	4 MB/s	4 MB/s	4 MB/s	4 MB/s to S3
S2	1000 MI/MB	4 MB/s	4 MB/s	4 MB/s	4 MB/s to S3
S3	1000 MI/MB	8 MB/s	8 MB/s	1 MB/s	None

Figure 2. Example of branching stream graph application with its parameter configurations

Listing 3: XML structure of branching stream graph application in DAG file

```
<?xml version=”1.0” encoding=”UTF-8” standalone=”no”?><!-- generated: 2017-06-24T14:29:13-07:00 --><!-- generated by: Mutaz[??] -
-><adag xmlns="http://pegasus.isi.edu/schema/DAX" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" childCount="3"
name="App2" serviceCount="4" version="2.1" xsi:schemaLocation="http://pegasus.isi.edu/schema/DAX
http://pegasus.isi.edu/schema/dax-2.1.xsd">
<!-- part 1: list of all referenced files (may be empty) -->
<!-- part 2: definition of all jobs (at least one) -->
 <externalsources>
            <exsource datarate="4" id="PID00000" name="Producer0" type="stream"/>
 </externalsources>
 <service dataprocessingreq="500" id="ID00000" name="TmpltBank" userreq="4">
  <uses link="input" producerref="PID00000" type="stream"/>
  <uses link="output" size="4" transfer="true" type="stream"/>
 </service>
 <service dataprocessingreq="500" id="ID00001" name="TmpltBank" userreq="4">
  <uses link="input" processingtype="replica" serviceref="ID00000" type="stream"/>
  <uses link="output" size="4" transfer="true" type="stream"/>
 </service>
 <service dataprocessingreq="1000" id="ID00002" name="TmpBank" userreq="4">
  <uses link="input" processingtype="replica" serviceref="ID00000" type="stream"/>
  <uses link="output" size="4" type="stream"/>
 </service>
 <service dataprocessingreq="1000" id="ID00003" name="TmpBank" userreq="8">
  <uses link="input" processingtype="replica" serviceref="ID00001" type="stream"/>
  <uses link="input" processingtype="replica" serviceref="ID00002" type="stream"/>
  <uses link="output" size="1" type="stream"/>
 </service>
 <child ref="ID00001">
  <parent ref="ID00000"/>
 </child>
 <child ref="ID00002">
  <parent ref="ID00000"/>
 </child>
 <child ref="ID00003">
  <parent ref="ID00001"/>
  <parent ref="ID00002"/>
 </child>
</adag>
```

The above XML file for this stream graph application is named with “App2” and can be found in the IoTSim-Stream directory under Sample_Stream_Workflows.

Now, you can simply start the simulation by clicking Run File “App2Simulation”.

During the simulation, you will see the detailed execution of a given stream graph application in output toolbar/pane, where IoTSim-Stream logs each event. Some of those details are scheduling plan, stream transfer from source SVM to destination SVM(s), stream replica or partition and stream scheduling on SVMs.

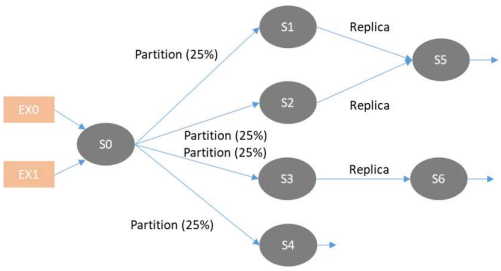
At the end of simulation, you will see the summary of workflow execution like the below

```
Output - Run (SimulateApp2) | Notifications
Simulation completed.
========== WORKFLOW EXECUTION SUMMARY ==========
= Cloudlet      Status          Submission Time Execution Time (s)      Finish Time
 = 6     SUCCESS          22.21           303.97          326.18
 = 7     SUCCESS          22.21           303.97          326.18
 = 4     SUCCESS          26.21           299.97          326.18
 = 5     SUCCESS          26.21           299.97          326.18
= Startup Time: 26.179999995976686
= Requested Experiment Time: 300.0
= Finish time: 326.1799999959767
= Total processed streams: 5993 MB
========== END OF SUMMARY ==========

Simulation completed.
```

4.3 Example of Hybrid Stream Graph Applications (App3)

If your stream graph application is the one that presented in the below figure, the XML structure of such an application is depicted in the below listing.



SERVICE / EXTERNAL SOURCE	DATA PROCESSING REQUIREMENT	USER PERFORMANCE REQUIREMENT	INPUT	OUTPUT	OUTPUT STREAM TO SERVICE(S)
EX0	N/A	N/A	N/A	2 MB/s	2 MB/s to S0
EX1	N/A	N/A	N/A	2 MB/s	2 MB/s to S0
S0	2000 MI/MB	4 MB/s	4 MB/s	16 MB/s	4 MB/s to S1 4 MB/s to S2 4 MB/s to S3 4 MB/s to S4
S1	1000 MI/MB	4 MB/s	4 MB/s	4 MB/s	4 MB/s to S5
S2	2000 MI/MB	4 MB/s	4 MB/s	4 MB/s	4 MB/s to S5
S3	1000 MI/MB	4 MB/s	4 MB/s	4 MB/s	4 MB/s to S6
S4	4000 MI/MB	4 MB/s	4 MB/s	1 MB/s	None
S5	4000 MI/MB	8 MB/s	8 MB/s	2 MB/s	None
S6	4000 MI/MB	4 MB/s	4 MB/s	1 MB/s	None

Figure 3. Example of hybrid stream graph application with its parameter configurations

Listing 4: XML structure of hybrid sample stream graph application in DAG file

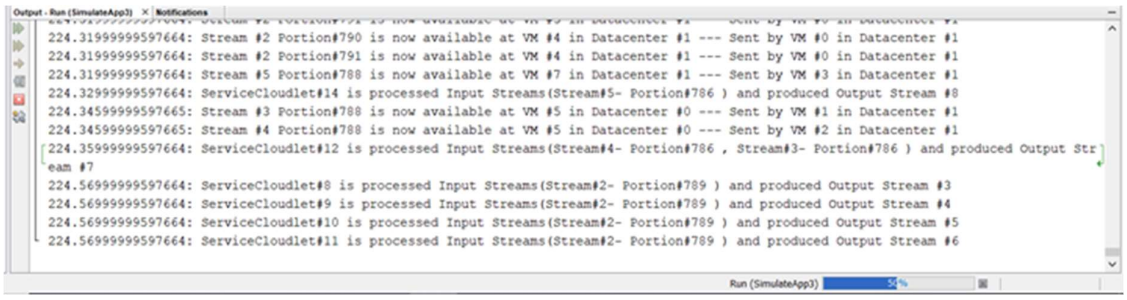
```
<?xml version="1.0" encoding="UTF-8"?>
<!-- generated: 2018-02-27:11:00 -->
<!-- generated by: Mutaz -->
<adag  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" version="1.0" count="6" name="SampleStreamGraphhApplication"
serviceCount="6" childCount="5">
<!-- part 1: list of all referenced outputs of services (may be empty) -->
<!-- part 2: definition of all services (at least one) -->
        <externalsources>
                <exsource id="PID00000" name="Producer0" type="stream" datarate="10"/>
                <exsource id="PID00001" name="Producer1" type="stream" datarate="10"/>
                <exsource id="PID00002" name="Producer2" type="stream" datarate="5"/>
                <exsource id="PID00003" name="Producer3" type="stream" datarate="5"/>
                <exsource id="PID00004" name="Producer4" type="stream" datarate="5"/>
        </externalsources>
        <service id="ID00000" dataprocessingreq="400" userreq="10" namespace="Sample"       name="BigService0" version="1.0">
                <uses link="input" type="stream" producerref="PID00000"/>
                <uses link="output" type="stream" size="5"/>
        </service>
        <service id="ID00001" dataprocessingreq="1000" userreq="5" namespace="Sample" name="BigService1" version="1.0">
                <uses link="input" type="stream" processingtype="replica" serviceref="ID00000"/>
                <uses link="output" type="stream" size="10"/>
        </service>
        <service id="ID00002" dataprocessingreq="500" userreq="8" namespace="Sample" name="BigService2" version="1.0">
                <uses link="input" type="stream" processingtype="replica" serviceref="ID00000"/>
                <uses link="input" type="stream" processingtype="partition" partitionprecentage="30" serviceref="ID00001"/>
                <uses link="output" type="stream" size="8"/>
```

```
        </service>
        <service id="ID00003" dataprocessingreq="2000" userreq="7" namespace="Sample" name="BigService3" version="1.0">
                <uses link="input" type="stream" processingtype="partition" partitionprecentage="70" serviceref="ID00001"/>
                <uses link="output" type="stream" size="1"/>
        </service>
        <service id="ID00004" dataprocessingreq="3000" userreq="8" namespace="Sample" name="BigService4" version="1.0">
                <uses link="input" type="stream" processingtype="replica" serviceref="ID00002"/>
                <uses link="output" type="stream" size="2"/>
        </service>
        <service id="ID00005" dataprocessingreq="1500" userreq="38" namespace="Sample" name="BigService5" version="1.0">
                <uses link="input" type="stream" producerref="PID00000"/>
                <uses link="input" type="stream" producerref="PID00001"/>
                <uses link="input" type="stream" producerref="PID00002"/>
                <uses link="input" type="stream" producerref="PID00003"/>
                <uses link="input" type="stream" producerref="PID00004"/>
                <uses link="input" type="stream" processingtype="replica" serviceref="ID00003"/>
                <uses link="input" type="stream" processingtype="replica" serviceref="ID00004"/>
                <uses link="output" type="stream" size="4"/>
        </service>
        <!-- part 3: list of control-flow dependencies (may be empty) -->
        <child ref="ID00001">
                <parent ref="ID00000"/>
        </child>
        <child ref="ID00002">
                <parent ref="ID00000"/>
                <parent ref="ID00001"/>
        </child>
        <child ref="ID00003">
                <parent ref="ID00001"/>
        </child>
        <child ref="ID00004">
                <parent ref="ID00002"/>
        </child>
        <child ref="ID00005">
                <parent ref="ID00003"/>
                <parent ref="ID00004"/>
        </child>
</adag>
```

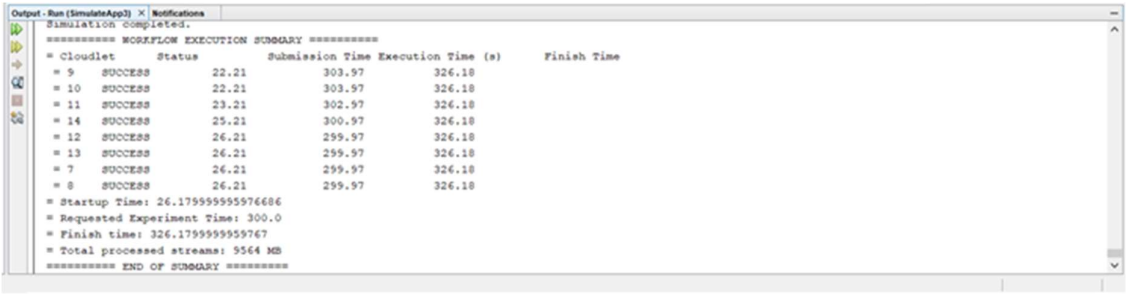
The above XML file for this stream graph application is named with “App3” and can be found in the IoTSim-Stream directory under Sample_Stream_Workflows.

Now, you can simply start the simulation by clicking Run File “App3Simulation”.

During the simulation, you will see the detailed execution of a given stream graph application in output toolbar/pane, where IoTSim-Stream logs each event. Some of those details are scheduling plan, stream transfer from source SVM to destination SVM(s), stream replica or partition and stream scheduling on SVMs.



At the end of the simulation, you will see the summary of workflow execution like the below



Note that: to simulate your stream graph application using IoTSim-Stream, you need to provide the actual path of the application. To do this, go to an any example provided and set the value of dag.file property in runSimulation() method to the actual path of this application.