Simulating DAG Scheduling Algorithms with SimDAG

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About this Presentation

Presentation Goals and Contents

- Scientific Context of SimDAG: Studying DAG scheduling algorithms
- History of SimDag: Revival of the original API of SimGrid
- Learning by the example: Step by step introduction to the main features

The SimGrid 101 Serie

- This is part of a serie of presentations introducing various aspects of SimGrid
- SimGrid 101. Introduction to the SimGrid Scientific Project
- SimGrid User 101. Practical introduction to SimGrid and MSG
- SimGrid User::Platform 101. Defining platforms and experiments in SimGrid
- SimGrid User::SimDag 101. Practical introduction to the use of SimDag
- SimGrid User::Visualization 101. Visualization of SimGrid simulation results
- SimGrid User::SMPI 101. Simulation MPI applications in practice
- SimGrid User::Model-checking 101. Formal Verification of SimGrid programs
- SimGrid Internal::Models. The Platform Models underlying SimGrid
- SimGrid Internal::Kernel. Under the Hood of SimGrid
- Retrieve them from `http://simgrid.gforge.inria.fr/101`

Agenda

- Introduction
  - History
  - Context
  - To know before starting
- DAGs in SimDag
- Experimental Environment
- Scheduling Tasks on Resources
- Running the Simulation
- A Complete Scheduling Simulator Example
- Conclusion

SimDAG's History

SimGrid v1

- Started in 1999 by H. Casanova and A. Legrand
- study of"centralized" scheduling
  - off-line DAG scheduling on heterogeneous compute nodes
  - API very close to that of SimDAG

SimGrid v2

- Arnaud studies "decentralized" scheduling heuristics
  - MSG becomes the new default API in 2003
- The original API remained alive up to v2.18.5
  - And totally disappeared with the raise of SURF in v2.90 (02/2005)

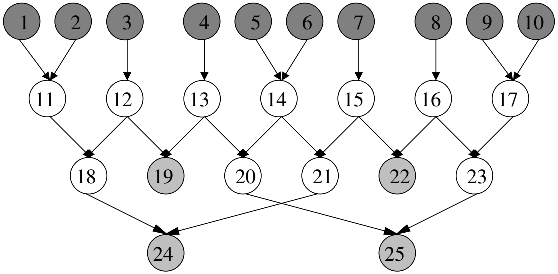
SimGrid v3

- Some people liked the lost SG API
- C. Thierry ports back the original API on top of SURF
  - SimDAG is born (again) in v3.1 (07/2006)

Definition of a DAG

Directed Acyclic Graph $\mathcal{G} = (\mathcal{V}, \mathcal{E})$

- $\mathcal{V} = \{v_i \mid i = 1, \ldots, V\}$
  - A set of vertices representing tasks
- $\mathcal{E} = \{e_{i,j} \mid (i,j) \in \{1, \ldots, V\} \times \{1, \ldots, V\}\}$
  - A set of edges representing precedence constraints between tasks



Definition of DAG Scheduling

Basic principle

- For each task
  - Assign a (set of) resource(s) for execution
  - Define an execution order
- Respect the precedence constraints
  - A task cannot start before all its predecessors have completed

Types of scheduling

- Offline
  - Take all decisions beforehand and then simulate
- Online
  - Take the decisions as the simulation goes

Fundamental Data Types

Link — SD_link_t

- A network resource with a bandwidth and a latency
- A route between two hosts is a list of links

Workstation — SD_workstation_t

- A place to execute some computation
- Has some computing capabilities
- Encompasses an host and one or more links

Task — SD_task_t

- A sequential or parallel computation
- Represented by some computing amount to execute

Dependency — SD_dependency_t

- Expresses an execution order between two tasks

SimDag Code Sample

Before starting to code anything

- `#include "simdag/simdag.h"` is mandatory

```
int main(int argc, char **argv) {

  /* Insert your code here */

  return 0;
}
```

SimDag Code Sample

Before starting to code anything

- `#include "simdag/simdag.h"` is mandatory
- Start by initializing the SimDag stuff

```
int main(int argc, char **argv) {
  SD_init(&argc, argv);

  /* Insert your code here */



  return 0;
}
```

SimDag Code Sample

Before starting to code anything

- `#include "simdag/simdag.h"` is mandatory
- Start by initializing the SimDag stuff
- End by cleaning this stuff neatly

```
int main(int argc, char **argv) {
  SD_init(&argc, argv);

  /* Insert your code here */

  SD_exit();

  return 0;
}
```

Agenda

- Introduction
- DAGs in SimDag
  - Vertices/Tasks
  - Edges/Dependencies
  - Describing a Complete DAG
- Experimental Environment
- Scheduling Tasks on Resources
- Running the Simulation
- A Complete Scheduling Simulator Example
- Conclusion

How to Represent Vertices/Tasks

Sequential computation

- Use a task of type `SD_TASK_COMP_SEQ`
- Constructor: `SD_task_create_comp_seq(name, data, amount)`
  - `name`: the name of the task, as given by the user
  - `data`: some user data attached to the task
    - Useful for scheduling attributes
  - `amount`: the number of flops computed by this task
- Destructor: `SD_task_destroy(task)`
- Can be used with any model compound handled by SURF
  - see `--help-models` for details

Parallel computation

- No type (`SD_TASK_NOT_TYPED`), default kind of task
- Constructor: `SD_task_create(name, data, amount)`
  - `amount`: represents the sequential cost of the task
- Restricted to the `ptask_L07` model

SimDag Code Sample

Sequential computation task creation and destruction

```
int main(int argc, char **argv) {
  SD_task_t task;

  SD_init(&argc, argv);





  SD_exit();
  return 0;
}
```

SimDag Code Sample

Sequential computation task creation and destruction

- Create a task that computes 1 billion of floating operations

```
int main(int argc, char **argv) {
  SD_task_t task;

  SD_init(&argc, argv);

  task = SD_task_create_comp_seq("my_sequential_task", NULL, 1E9);



  SD_exit();
  return 0;
}
```

SimDag Code Sample

Sequential computation task creation and destruction

- Create a task that computes 1 billion of floating operations
- And destroy it

```
int main(int argc, char **argv) {
  SD_task_t task;

  SD_init(&argc, argv);

  task = SD_task_create_comp_seq("my_sequential_task", NULL, 1E9);

  SD_task_destroy(task);

  SD_exit();
  return 0;
}
```

SimDag Code Sample

Parallel computation task creation and destruction

```
int main(int argc, char **argv) {
  SD_task_t task;

  SD_init(&argc, argv);





  SD_exit();
  return 0;
}
```

SimDag Code Sample

Parallel computation task creation and destruction

- Create a task that computes 1 billion of floating operations

```
int main(int argc, char **argv) {
  SD_task_t task;

  SD_init(&argc, argv);

  task = SD_task_create("my_parallel_task", NULL, 1E9);



  SD_exit();
  return 0;
}
```

SimDag Code Sample

Parallel computation task creation and destruction

- Create a task that computes 1 billion of floating operations
- And destroy it

```
int main(int argc, char **argv) {
  SD_task_t task;

  SD_init(&argc, argv);

  task = SD_task_create("my_parallel_task", NULL, 1E9);

  SD_task_destroy(task);

  SD_exit();
  return 0;
}
```

How to Represent Edges

Control flow dependency

- a.k.a precedence constraint
- Goal: Force SimDAG to wait for the completion of ● to start ●
- Create a `SD_task_dependency`

How to Represent Edges

Control flow dependency

- a.k.a precedence constraint
- Goal: Force SimDAG to wait for the completion of ● to start ●
- Create a `SD_task_dependency`
  - `SD_task_dependency_add (name, data,●, ●)`

SimDag Code Sample

Addition of a control flow dependency

```
int main(int argc, char **argv) {
  SD_task_t taskA, taskB;
  SD_init(&argc, argv);









  SD_exit();
  return 0;
}
```

SimDag Code Sample

Addition of a control flow dependency

- Create two typed sequential tasks
  - Similar for parallel tasks

```
int main(int argc, char **argv) {
  SD_task_t taskA, taskB;
  SD_init(&argc, argv);

  taskA = SD_task_create_comp_seq("taskA", NULL, 1E9);
  taskB = SD_task_create_comp_seq("taskB", NULL, 1E9);

  SD_exit();
  return 0;
}
```

SimDag Code Sample

Addition of a control flow dependency

- Create two typed sequential tasks
  - Similar for parallel tasks
- Add the dependency

```
int main(int argc, char **argv) {
  SD_task_t taskA, taskB;
  SD_init(&argc, argv);

  taskA = SD_task_create_comp_seq("taskA", NULL, 1E9);
  taskB = SD_task_create_comp_seq("taskB", NULL, 1E9);

  SD_task_dependency_add ("my_dependency", NULL, taskA, taskB);




  SD_exit();
  return 0;
}
```

SimDag Code Sample

Addition of a control flow dependency

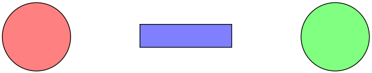
- Create two typed sequential tasks
  - Similar for parallel tasks
- Add the dependency
- Destroy the tasks
  - The dependency is automatically cleaned

```
int main(int argc, char **argv) {
  SD_task_t taskA, taskB;
  SD_init(&argc, argv);

  taskA = SD_task_create_comp_seq("taskA", NULL, 1E9);
  taskB = SD_task_create_comp_seq("taskB", NULL, 1E9);

  SD_task_dependency_add ("my_dependency", NULL, taskA, taskB);

  SD_task_destroy(taskA);
  SD_task_destroy(taskB);

  SD_exit();
  return 0;
}
```

How to Represent Edges

Data flow dependency

- a.k.a passing data from a task to another
- Need to create a transfer ■ task between ● and ●



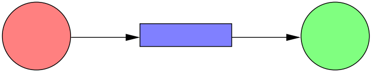
Question

- How to declare a transfer task?

How to Represent Edges

Data flow dependency

- a.k.a passing data from a task to another
- Need to create a transfer task between and
  - Add `SD_task_dependency` accordingly
  - `SD_task_dependency_add (name, data, , )`
  - `SD_task_dependency_add (name, data, , )`



Question

- How to declare a transfer task?

How to Represent Transfer Tasks

End-to-end communications

- If both source and destination are sequential tasks
- Use a task of type `SD_TASK_COMM_E2E`
- Constructor: `SD_task_create_comm_e2e(name, data, amount)`
  - `name`: the name of the task, as given by the user
  - `data`: some user data attached to the task
  - `amount`: the number of bytes transfered by this task

MxN data redistributions

- Same as for parallel computations
- No type (`SD_TASK_NOT_TYPED`)
- Constructor: `SD_task_create(name, data, amount)`
  - `amount`: represents the total number of bytes
  - Communication scheme defined at scheduling time
- Restricted to the `ptask_L07` model

SimDag Code Sample

End-to-End transfer task creation and destruction

```
int main(int argc, char **argv) {
  SD_task_t task;

  SD_init(&argc, argv);





  SD_exit();
  return 0;
}
```

SimDag Code Sample

End-to-End transfer task creation and destruction

- Create a task that moves 1 billion of bytes

```
int main(int argc, char **argv) {
  SD_task_t task;

  SD_init(&argc, argv);

  task = SD_task_create_comm_e2e("my_end-to-end_transfer", NULL, 1E9);



  SD_exit();
  return 0;
}
```

SimDag Code Sample

End-to-End transfer task creation and destruction

- Create a task that moves 1 billion of bytes
- And destroy it

```
int main(int argc, char **argv) {
  SD_task_t task;

  SD_init(&argc, argv);

  task = SD_task_create_comm_e2e("my_end-to-end_transfer", NULL, 1E9);

  SD_task_destroy(task);

  SD_exit();
  return 0;
}
```

SimDag Code Sample

$M \times N$ transfer task creation and destruction

```
int main(int argc, char **argv) {
  SD_task_t task;

  SD_init(&argc, argv);





  SD_exit();
  return 0;
}
```

SimDag Code Sample

$M \times N$ transfer task creation and destruction

- Create a task that moves 1 billion of bytes

```
int main(int argc, char **argv) {
  SD_task_t task;

  SD_init(&argc, argv);

  task = SD_task_create("my_m-x-n_transfer", NULL, 1E9);



  SD_exit();
  return 0;
}
```

SimDag Code Sample

$M \times N$ transfer task creation and destruction

- Create a task that moves 1 billion of bytes
- And destroy it

```
int main(int argc, char **argv) {
  SD_task_t task;

  SD_init(&argc, argv);

  task = SD_task_create("my_m-x-n_transfer", NULL, 1E9);

  SD_task_destroy(task);

  SD_exit();
  return 0;
}
```

SimDag Code Sample

Addition of a data flow dependency

```
int main(int argc, char **argv) {
  SD_task_t src, dest, comm;
  SD_init(&argc, argv);








  SD_exit();
  return 0;
}
```

SimDag Code Sample

Addition of a data flow dependency

- Create two computation tasks and one transfer task

```
int main(int argc, char **argv) {
  SD_task_t src, dest, comm;
  SD_init(&argc, argv);

  src = SD_task_create_comp_seq("src", NULL, 1E9);
  dest = SD_task_create_comp_seq("dest", NULL, 1E9);
  comm = SD_task_create_comm_e2e("comm", NULL, 1E9);









  SD_exit();
  return 0;
}
```

SimDag Code Sample

Addition of a data flow dependency

- Create two computation tasks and one transfer task
- Add the dependencies

```
int main(int argc, char **argv) {
  SD_task_t src, dest, comm;
  SD_init(&argc, argv);

  src = SD_task_create_comp_seq("src", NULL, 1E9);
  dest = SD_task_create_comp_seq("dest", NULL, 1E9);
  comm = SD_task_create_comm_e2e("comm", NULL, 1E9);

  SD_task_dependency_add ("src_comm", NULL, src, comm);
  SD_task_dependency_add ("comm_dest", NULL, comm, dest);





  SD_exit();
  return 0;
}
```

SimDag Code Sample

Addition of a data flow dependency

- Create two computation tasks and one transfer task
- Add the dependencies
- Destroy the tasks

```
int main(int argc, char **argv) {
  SD_task_t src, dest, comm;
  SD_init(&argc, argv);

  src = SD_task_create_comp_seq("src", NULL, 1E9);
  dest = SD_task_create_comp_seq("dest", NULL, 1E9);
  comm = SD_task_create_comm_e2e("comm", NULL, 1E9);

  SD_task_dependency_add ("src_comm", NULL, src, comm);
  SD_task_dependency_add ("comm_dest", NULL, comm, dest);

  SD_task_destroy(src);
  SD_task_destroy(dest);
  SD_task_destroy(comm);

  SD_exit();
  return 0;
}
```

Describing a Complete DAG

By hand

1. Create all computation tasks
2. Create all transfer tasks
3. Create all the control flow dependencies
4. Create all the data flow dependencies

Use a loader

- `SD_daxload(filename)`: loader for DAX files
  - Format of workflow used by Pegasus (`http://pegasus.isi.edu/`)
- `SD_dotload(filename)`: loader for DOT files
  - Well-known format of the `graphviz` tool suite
- Creates everything automatically
- Adds two special dummy tasks: `root` and `end`
- Returns a `xbt_dynar_t` of typed `SD_task_t`
  - `SD_TASK_COMP_SEQ` and `SD_TASK_COMM_E2E`

DAX File Sample (1/3)

Header

- Name space and schema declaration
  - From Pegasus
- Name of the DAX
- Number of jobs: `jobCount`
- Number of control dependencies: `childCount`

```
<?xml version="1.0" encoding="UTF-8"?>
<adag xmlns="http://pegasus.isi.edu/schema/DAX"
      xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
      xsi:schemaLocation="http://pegasus.isi.edu/schema/DAX
                          http://pegasus.isi.edu/schema/dax-2.1.xsd"
      version="2.1" count="1" index="0" name="smalldax"
      jobCount="3" fileCount="0" childCount="1">

<!-- Job and control dependencies go here -->

</adag>
```

DAX File Sample (2/3)

Job description

- Described by: id, name, runtime, input and output files
  - Only computations are described ($\texttt{amount} = \texttt{runtime} \times 4.2e9$)
  - Output of task1 is a input of task2 $\Rightarrow$ Transfer task + data flow dependency

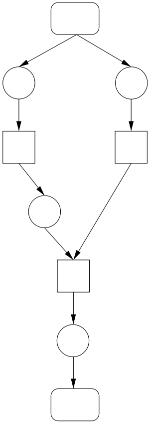
```
<adag ...">
  <job id="1" namespace="SG" name="task1" version="1.0" runtime="10">
    <uses file="i1" link="input" register="true" transfer="true"
          optional="false" type="data" size="1000000"/>
    <uses file="o1" link="output" register="true" transfer="true"
          optional="false" type="data" size="1000000"/>
  </job>
  <job id="2" namespace="SG" name="task2" version="1.0" runtime="10">
    <uses file="i2" link="input" register="true" transfer="true"
          optional="false" type="data" size="1000000"/>
  </job>
  <job id="3" namespace="SG" name="task3" version="1.0" runtime="10">
    <uses file="o1" link="input" register="true" transfer="true"
          optional="false" type="data" size="1000000"/>
    <uses file="o3" link="output" register="true" transfer="true"
          optional="false" type="data" size="1000000"/>
  </job>
<!-- Control-flow dependencies -->
</adag>
```

DAX File Sample (3/3)

Control flow dependencies

- task3 cannot start before the completion of task2
  - While there is no data flow dependency

```
<adag ...>

<!-- Job descriptions -->

  <child ref="3">
    <parent ref="2"/>
  </child>
</adag>
```

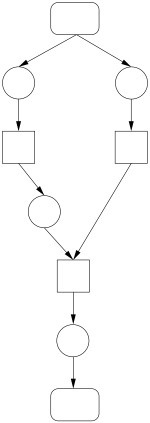


DOT File Sample

Task Description

- Described by an id and a size
  - The size correspond to the `amount` parameter of the task creator
  - Expressed in flops

```
digraph G {
# Tasks
1 [size="42000000000.00"];
2 [size="42000000000.00"];
3 [size="42000000000.00"];

}
```

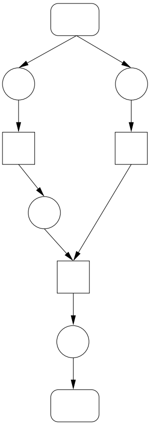


DOT File Sample

Task Description

- Described by an id and a size
  - The size correspond to the `amount` parameter of the task creator
  - Expressed in flops

```
digraph G {
# Tasks
1 [size="42000000000.00"];
2 [size="42000000000.00"];
3 [size="42000000000.00"];
# Dependencies
root->1 [size="1000000.00"];
root->2 [size="1000000.00"];
1->3    [size="1000000.00"];
2->3    [size="-1."]; # Control dependency
3->end  [size="1000000.00"];
}
```



Dependency Description

- Described by `src`→`dst` and a size
  - The size also corresponds to `amount`
  - Expressed in bytes

SimDag Code Sample

Using the DAX loader

```
int main(int argc, char **argv) {
  unsigned int cpt;
  SD_task_t task;
  xbt_dynar_t DAG;
  SD_init(&argc, argv);









  SD_exit();
  return 0;
}
```

SimDag Code Sample

Using the DAX loader

- Call the loader

```
int main(int argc, char **argv) {
  unsigned int cpt;
  SD_task_t task;
  xbt_dynar_t DAG;
  SD_init(&argc, argv);

  dag = SD_daxload(argv[1]);






  SD_exit();
  return 0;
}
```

SimDag Code Sample

Using the DAX loader

- Call the loader
- Destroy each task

```
int main(int argc, char **argv) {
  unsigned int cpt;
  SD_task_t task;
  xbt_dynar_t DAG;
  SD_init(&argc, argv);

  dag = SD_daxload(argv[1]);

  xbt_dynar_foreach(dag, cpt, task){
    SD_task_destroy(task);
  }

  SD_exit();
  return 0;
}
```

SimDag Code Sample

Using the DOT loader

```
int main(int argc, char **argv) {
  unsigned int cpt;
  SD_task_t task;
  xbt_dynar_t DAG;
  SD_init(&argc, argv);







  SD_exit();
  return 0;
}
```

SimDag Code Sample

Using the DOT loader

- Call the loader

```
int main(int argc, char **argv) {
  unsigned int cpt;
  SD_task_t task;
  xbt_dynar_t DAG;
  SD_init(&argc, argv);

  dag = SD_dotload(argv[1]);






  SD_exit();
  return 0;
}
```

SimDag Code Sample

Using the DOT loader

- Call the loader
- Destroy each task

```
int main(int argc, char **argv) {
  unsigned int cpt;
  SD_task_t task;
  xbt_dynar_t DAG;
  SD_init(&argc, argv);

  dag = SD_dotload(argv[1]);

  xbt_dynar_foreach(dag, cpt, task){
    SD_task_destroy(task);
  }

  SD_exit();
  return 0;
}
```

Retrieving Information About a Task

Parameters of the constructor

- `SD_task_get_name(task)`
  - Can also be modified with `SD_task_set_name(task, "new_name")`
- `SD_task_get_data(task)`
  - Returns a `(void*)`, has to be casted by the user
  - Data can be attached at any time: `SD_task_set_data(task, (void*) data)`
- `SD_task_get_amount(task)` (non modifiable)
- `SD_task_get_kind(task)` (non modifiable)

Dependencies of task `T`

- Tasks on which `T` depends: `SD_task_get_parents(T)`
- Tasks depending on `T`: `SD_task_get_children(T)`
- Both functions return a `xbt_dynar_t`

Retrieving everything

- `SD_task_dump(task)`

SimDag Code Sample

```
int main(int argc, char **argv) {
  SD_task_t task;
  SD_init(&argc, argv);

  task = SD_task_create_comp_seq("src", NULL, 1E9);

  SD_task_dump(task);

  SD_exit();
  return 0;
}
```

```
[0.000000] [sd_task/INFO] Displaying task src
[0.000000] [sd_task/INFO]   - state:    not runnable
[0.000000] [sd_task/INFO]   - kind: sequential computation
[0.000000] [sd_task/INFO]   - amount: 1000000000
[0.000000] [sd_task/INFO]   - Dependencies to satisfy: 0
[0.000000] [sd_task/INFO]   - pre-dependencies:
[0.000000] [sd_task/INFO]   - post-dependencies:
```

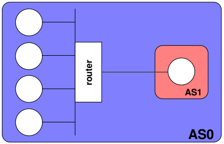
Agenda

- Introduction
- DAGs in SimDag
- Experimental Environment
  - Computing and Network Resources
  - Retrieving Information About Workstations
  - Retrieving Information About Network
- Scheduling Tasks on Resources
- Running the Simulation
- A Complete Scheduling Simulator Example
- Conclusion

How to Represent Resources

Types of resources

- Single Hosts: `id` and `power`
- Links: `id`, `latency` and `bandwidth`
- Clusters
  - `id` and name (`prefix radical suffix`)
  - `power`
  - private link latency (`lat`) and bandwidth (`bw`)
  - backbone latency (`bb_lat`) and bandwidth (`bb_bw`)
  - `router`



- routes: `src` and `dst`
- Resources grouped in Autonomous Systems (`AS`)
- Description in an XML platform file

Platform File Sample

cluster_and_one_host.xml

```
<?xml version='1.0'?>
<!DOCTYPE platform SYSTEM "http://simgrid.gforge.inria.fr/simgrid.dtd">
<platform version="3">
  <AS id="AS0" routing="Full">
    <cluster id="my_cluster_1" prefix="c-" suffix=".me" radical="0-4"
             power="1000000000" bw="125000000" lat="5E-5"
             bb_bw="2250000000" bb_lat="5E-4"
             router_id="router1"/>

    <AS id="AS1" routing="none">
      <host id="host1" power="1000000000"/>
    </AS>

    <link id="link1" bandwidth="100000" latency="0.01"/>

    <ASroute src="my_cluster_1" dst="AS1" gw_src="router1" gw_dst="host1">
      <link_ctn id="link1"/>
    </ASroute>
  </AS>
</platform>
```

Adding Extra Information on Resources

Properties

- Attach arbitrary data to any `host` or `link`
- Key/Value dictionaries
- User responsible of management (not simulated by SimGrid)

```
<host id="host1" power="1000000000"/>
  <prop key="memory" value="1000000000"/>
  <prop key="OS" value="Linux 2.6.22-14"/>
</host>
```

Dynamic availability traces

- Connects to a trace detailing the changing behavior of a resource
  - Availability (ON/OFF) and power for `host`
  - Availability, latency, and bandwidth for `link` and `route`

```
<host id="host1" power="1000000000"/>
<trace id="mytrace" file="host1.trace"/>
<trace:connect element="host1" kind="POWER" trace="mytrace"/>
```

SimDag Code Sample

Loading the platform file

```
int main(int argc, char **argv) {
  SD_init(&argc, argv);



  SD_exit();

  return 0;
}
```

SimDag Code Sample

Loading the platform file

- Use the SD_create_environment function
  - Takes a filename as input
  - Creates an array of SD_workstation_t
    - workstation: a compute host and a set of network links
  - No need for deployment file in SimDag

```
int main(int argc, char **argv) {
  SD_init(&argc, argv);

  SD_create_environment(argv[1]);

  SD_exit();

  return 0;
}
```

Retrieving Information About Workstations

Getting all the workstations

- `SD_workstation_get_number()`
  - Returns the number of workstations
- `SD_workstation_get_list()`
  - Returns the workstation list

Workstation specific information

- `SD_workstation_get_name(workstation)` (non modifiable)
- `SD_workstation_get_power(workstation)` (non modifiable)
- `SD_workstation_get_data(workstation)`
  - Returns a `(void*)`, has to be casted by the user
  - Data can be attached at any time
    `SD_task_set_data(workstation, (void*) data)`
- `SD_workstation_get_properties(workstation)`
  - Returns a `xbt_dict_t` will all the properties
- `SD_workstation_get_property_value (workstation, name)`
  - Returns the value stored for property called `name`

Retrieving Information About Network

Getting all the links

- `SD_link_get_number()` returns the number of links
- `SD_link_get_list()` returns the list of links

Link specific information

- `SD_link_get_name(link)` (non modifiable)
- `SD_link_get_data(workstation)`
  - Returns a `(void*)`, has to be casted by the user
  - Data can be attached at any time: `SD_link_set_data(link, (void*) data)`
- `SD_link_get_sharing_policy (link)`
  - May this link cause contention or not

Route specific information

- `SD_route_get_size (src_workstation, dst_workstation)`
  - Returns the number of links on the route between two workstations
- `SD_route_get_list (src_workstation, dst_workstation)`
  - Returns the list of links on the route between two workstations

Agenda

Scheduling Default Parallel Tasks

Issue: different semantics

- Creation
  - `task = SD_task_create(name, data, amount)`
  - Where `amount` is the compute work to do or data size to transfer
- Scheduling
  - `SD_task_schedule(task, workstation_nb, workstation_list, computation_amount, communication_amount, rate)`

Things to be done

- Determine
  - How many workstations to use
  - Which workstations
- Distribute
  - the work to compute (in an array)
  - the data to communicate (in a communication matrix)
- Can't schedule a transfer task before having scheduled its parent and child

SimDag Code Sample

Scenario

- Schedule 2 compute tasks and 1 transfer on `cluster_and_one_host.xml`
  - Compute task `t1` ⇒ on the cluster (parallel)
  - Compute task `t2` ⇒ on the host (sequential)
  - Data transfer `c1` from the cluster to the host

```
int main(int argc, char **argv) {

  [...]
}
```

SimDag Code Sample

Step 1

- Declare the needed data structures

```
int main(int argc, char **argv) {

  [...]
}
```

SimDag Code Sample

Step 1

- Declare the needed data structures
  - The task themselves

```
int main(int argc, char **argv) {
  int i;
  SD_task_t c1, c2, t1;











  [...]
}
```

SimDag Code Sample

Step 1

- Declare the needed data structures
  - The task themselves
  - Scheduling and complete lists of workstations

```
int main(int argc, char **argv) {
  int i;
  SD_task_t c1, c2, t1;
  SD_workstation_t *ws_list, *workstations;

  [...]
}
```

SimDag Code Sample

Step 1

- Declare the needed data structures
  - The task themselves
  - Scheduling and complete lists of workstations
  - Computation array and communication matrix

```
int main(int argc, char **argv) {
  int i;
  SD_task_t c1, c2, t1;
  SD_workstation_t *ws_list, *workstations;
  double *computation_amount, *communication_amount;

  [...]
}
```

SimDag Code Sample

Step 2

- Initialize SimDag

```
int main(int argc, char **argv) {
  int i;
  SD_task_t c1, c2, t1;
  SD_workstation_t *ws_list, *workstations;
  double *computation_amount, *communication_amount;

  SD_init(&argc, argv);

  [...]
}
```

SimDag Code Sample

Step 2

- Initialize SimDag
- Load the platform file to create resources
  - and get the complete list of workstations

```
int main(int argc, char **argv) {
  int i;
  SD_task_t c1, c2, t1;
  SD_workstation_t *ws_list, *workstations;
  double *computation_amount, *communication_amount;

  SD_init(&argc, argv);
  SD_create_environment("cluster_and_one_host.xml");
  workstations = SD_workstation_get_list();




  [...]
}
```

SimDag Code Sample

Step 3

- Creating the tasks
  - amount represents
    - The total number of flops to compute for c1 and c2

```
int main(int argc, char **argv) {
  int i;
  SD_task_t c1, c2, t1;
  SD_workstation_t *ws_list, *workstations;
  double *computation_amount, *communication_amount;

  SD_init(&argc, argv);
  SD_create_environment("cluster_and_one_host.xml");
  workstations = SD_workstation_get_list();

  c1 = SD_task_create("c1", NULL, 1e9); /* 1 billion flops */
  c2 = SD_task_create("c2", NULL, 1e9); /* 1 billion flops */

  [...]
}
```

SimDag Code Sample

Step 3

- Creating the tasks
  - `amount` represents
    - The total number of flops to compute for `c1` and `c2`
    - The total number of bytes to transfer for `t1`

```
int main(int argc, char **argv) {
  int i;
  SD_task_t c1, c2, t1;
  SD_workstation_t *ws_list, *workstations;
  double *computation_amount, *communication_amount;

  SD_init(&argc, argv);
  SD_create_environment("cluster_and_one_host.xml");
  workstations = SD_workstation_get_list();

  c1 = SD_task_create("c1", NULL, 1e9); /* 1 billion flops */
  c2 = SD_task_create("c2", NULL, 1e9); /* 1 billion flops */
  t1 = SD_task_create("t1", NULL, 1e9); /* 1 GB */
  [...]
}
```

SimDag Code Sample

Step 4

- Scheduling parallel compute task c1 on four hosts

```
int main(int argc, char **argv) {
  [...]
}
```

SimDag Code Sample

Step 4

- Scheduling parallel compute task `c1` on four hosts
  - Allocate `ws_list`, `computation_amount`, and `communication_amount`

```
int main(int argc, char **argv) {
  [...]
  ws_list = (SD_workstation_t*) calloc (4, sizeof(SD_workstation_t));
  computation_amount = (double*) calloc (4, sizeof(double));
  communication_amount = (double*) calloc (16, sizeof(double)); /* 4x4 matrix */
}
```

SimDag Code Sample

Step 4

- Scheduling parallel compute task c1 on four hosts
  - Allocate ws_list, computation_amount, and communication_amount
  - Fill these structures
    - Evenly distribute the amount of work among hosts
    - The communication matrix remains empty

```
int main(int argc, char **argv) {
  [...]
  ws_list = (SD_workstation_t*) calloc (4, sizeof(SD_workstation_t));
  computation_amount = (double*) calloc (4, sizeof(double));
  communication_amount = (double*) calloc (16, sizeof(double)); /* 4x4 matrix */

  for (i=0;i<4;i++){
    ws_list[i]=workstations[i];
    computation_amount[i] = SD_task_get_amount(c1)/4.;
  }

}
```

SimDag Code Sample

Step 4

- Scheduling parallel compute task c1 on four hosts
  - Allocate ws_list, computation_amount, and communication_amount
  - Fill these structures
    - Evenly distribute the amount of work among hosts
    - The communication matrix remains empty
  - Call SD_task_schedule

```
int main(int argc, char **argv) {
  [...]
  ws_list = (SD_workstation_t*) calloc (4, sizeof(SD_workstation_t));
  computation_amount = (double*) calloc (4, sizeof(double));
  communication_amount = (double*) calloc (16, sizeof(double)); /* 4x4 matrix */

  for (i=0;i<4;i++){
    ws_list[i]=workstations[i];
    computation_amount[i] = SD_task_get_amount(c1)/4.;
  }

  SD_task_schedule(c1,4,ws_list,computation_amount,communication_amount,-1);

  [...]
}
```

SimDag Code Sample

Step 5

- Scheduling parallel compute task c2 on one host

```
int main(int argc, char **argv) {
  [...]

  [...]
}
```

SimDag Code Sample

Step 5

- Scheduling parallel compute task c2 on one host
  - Reallocate computation_amount
    - Don't care about ws_list and communication_amount

```
int main(int argc, char **argv) {
  [...]
  computation_amount = (double*) realloc (computation_amount, sizeof(double));

  [...]
}
```

SimDag Code Sample

Step 5

- Scheduling parallel compute task c2 on one host
  - Reallocate computation_amount
    - Don't care about ws_list and communication_amount
  - Set computation_amount[0] to amount

```
int main(int argc, char **argv) {
  [...]
  computation_amount = (double*) realloc (computation_amount, sizeof(double));
  computation_amount[0] = SD_task_get_amount(c2);

  [...]
}
```

SimDag Code Sample

Step 5

- Scheduling parallel compute task c2 on one host
  - Reallocate computation_amount
    - Don't care about ws_list and communication_amount
  - Set computation_amount[0] to amount
  - Call SD_task_schedule
    - Direct mention of the host and no communication matrix

int main(int argc, char **argv) {

```
  [...]
  computation_amount = (double*) realloc (computation_amount, sizeof(double));
  computation_amount[0] = SD_task_get_amount(c2);
  SD_task_schedule(c2,1,&(workstations[5]),computation_amount,NULL,-1);
  [...]
}
```

SimDag Code Sample

Step 6

- Scheduling data transfer task t1 from cluster to host

```
int main(int argc, char **argv) {
  [...]
  computation_amount = (double*) realloc (computation_amount, sizeof(double));
  computation_amount[0] = SD_task_get_amount(c2);
  SD_task_schedule(c2,1,&(workstations[5]),computation_amount,NULL,-1);








  [...]
}
```

SimDag Code Sample

Step 6

- Scheduling data transfer task `t1` from cluster to host
  - Reallocate `computation_amount` and `communication_amount`
    - `computation_amount` is actually useless

```
int main(int argc, char **argv) {
  [...]
  computation_amount = (double*) realloc (computation_amount, sizeof(double));
  computation_amount[0] = SD_task_get_amount(c2);
  SD_task_schedule(c2,1,&(workstations[5]),computation_amount,NULL,-1);

  computation_amount = (double*) realloc (computation_amount, 5*sizeof(double));
  communication_amount = (double*) realloc (communication_amount, 25*sizeof(double));






  [...]
}
```

SimDag Code Sample

Step 6

- Scheduling data transfer task t1 from cluster to host
  - Reallocate computation_amount and communication_amount
    - computation_amount is actually useless
  - Fill communication_amount

```
int main(int argc, char **argv) {
  [...]
  computation_amount = (double*) realloc (computation_amount, sizeof(double));
  computation_amount[0] = SD_task_get_amount(c2);
  SD_task_schedule(c2,1,&(workstations[5]),computation_amount,NULL,-1);

  computation_amount = (double*) realloc (computation_amount, 5*sizeof(double));
  communication_amount = (double*) realloc (communication_amount, 25*sizeof(double));

  for(i=0; i<4;i++)
    communication_amount[i*5+4]=SD_task_get_amount(t1)/4.;


  [...]
}
```

SimDag Code Sample

Step 6

- Scheduling data transfer task t1 from cluster to host
  - Reallocate computation_amount and communication_amount
    - computation_amount is actually useless
  - Fill communication_amount
  - Call SD_task_schedule
    - Use workstations directly as all hosts are involved

```
int main(int argc, char **argv) {
  [...]
  computation_amount = (double*) realloc (computation_amount, sizeof(double));
  computation_amount[0] = SD_task_get_amount(c2);
  SD_task_schedule(c2,1,&(workstations[5]),computation_amount,NULL,-1);

  computation_amount = (double*) realloc (computation_amount, 5*sizeof(double));
  communication_amount = (double*) realloc (communication_amount, 25*sizeof(double));

  for(i=0; i<4;i++)
    communication_amount[i*5+4]=SD_task_get_amount(t1)/4.;

  SD_task_schedule(t1,5,workstations,computation_amount,communication_amount,-1);
  [...]
}
```

SimDag Code Sample

Step 7

- Unschedule the tasks

```
int main(int argc, char **argv) {
  [...]

  SD_task_unschedule(c1);
  SD_task_unschedule(c2);
  SD_task_unschedule(t1);

}
```

SimDag Code Sample

Step 7

- Unschedule the tasks
- Clean stuff

```
int main(int argc, char **argv) {
  [...]

  SD_task_unschedule(c1);
  SD_task_unschedule(c2);
  SD_task_unschedule(t1);

  free(computation_amount);
  free(communication_amount);
  free(ws_list);

  SD_exit();

  return 0;
}
```

SimDag Code Sample

Step 7

- Unschedule the tasks
- Clean stuff
- Remark: The simulation itself is not implemented in this example

```
int main(int argc, char **argv) {
  [...]

  SD_task_unschedule(c1);
  SD_task_unschedule(c2);
  SD_task_unschedule(t1);

  free(computation_amount);
  free(communication_amount);
  free(ws_list);

  SD_exit();

  return 0;
}
```

Auto-Scheduling Typed Tasks

- When scheduling DAGs
  - Compute tasks run on one host only
  - Data transfers are point-to-point communications

⇒ Get rid off all the useless complexity of parallel tasks
  - Thanks to typed tasks
- Creation
  - `compute_task = SD_task_create_comp_seq(name, data, amount)`
  - `transfer_task = SD_task_create_comm_e2e(name, data, amount)`
- Scheduling
  - `SD_task_schedulev(task, workstation_nb, workstation_list)`
  - `SD_task_schedulel(task, workstation_nb, ...)`
  - `amount` will be directly used
- Transfers can be auto-scheduled

SimDag Code Sample

Scenario

- Schedule 2 compute tasks and 1 transfer on `cluster_and_one_host.xml`
  - Compute task t1 ⇒ on one host of the cluster (sequential)
  - Compute task t2 ⇒ on the host (sequential)
  - Point-to-point data transfer c1 from the cluster to the host

```
int main(int argc, char **argv) {

  [...]
}
```

SimDag Code Sample

Step 1

```
int main(int argc, char **argv) {

  [...]
}
```

SimDag Code Sample

Step 1

- Declare the tasks

```
int main(int argc, char **argv) {
  SD_task_t c1, c2, t1;









  [...]
}
```

SimDag Code Sample

Step 1

- Declare the tasks
- Declare the list of workstations

```
int main(int argc, char **argv) {
  SD_task_t c1, c2, t1;
  SD_workstation_t *workstations;









  [...]
}
```

SimDag Code Sample

Step 1

- Declare the tasks
- Declare the list of workstations
- Initialize SimDag

```
int main(int argc, char **argv) {
  SD_task_t c1, c2, t1;
  SD_workstation_t *workstations;

  SD_init(&argc, argv);

  [...]
}
```

SimDag Code Sample

Step 1

- Declare the tasks
- Declare the list of workstations
- Initialize SimDag
- Load the platform file to create resources
  - and get the complete list of workstations

```
int main(int argc, char **argv) {
  SD_task_t c1, c2, t1;
  SD_workstation_t *workstations;

  SD_init(&argc, argv);

  SD_create_environment("cluster_and_one_host.xml");
  workstations = SD_workstation_get_list();





  [...]
}
```

SimDag Code Sample

Step 2

- Create the tasks
  - `amount` represents
    - The total number of flops to compute for `c1` and `c2`

```
int main(int argc, char **argv) {
  SD_task_t c1, c2, t1;
  SD_workstation_t *workstations;

  SD_init(&argc, argv);

  SD_create_environment("cluster_and_one_host.xml");
  workstations = SD_workstation_get_list();

  c1 = SD_task_create_comp_seq("c1", NULL, 1e9); /* 1 billion flops */
  c2 = SD_task_create_comp_seq("c2", NULL, 1e9); /* 1 billion flops */


  [...]
}
```

SimDag Code Sample

Step 2

- Create the tasks
  - `amount` represents
    - The total number of flops to compute for `c1` and `c2`
    - The total number of bytes to transfer for `t1`

```
int main(int argc, char **argv) {
  SD_task_t c1, c2, t1;
  SD_workstation_t *workstations;

  SD_init(&argc, argv);

  SD_create_environment("cluster_and_one_host.xml");
  workstations = SD_workstation_get_list();

  c1 = SD_task_create_comp_seq("c1", NULL, 1e9); /* 1 billion flops */
  c2 = SD_task_create_comp_seq("c2", NULL, 1e9); /* 1 billion flops */

  t1 = SD_task_create_comm_e2e("t1", NULL, 1e9); /* 1 GB */
  [...]
}
```

SimDag Code Sample

Step 3

- Scheduling the tasks
  - c1 goes on the first host in the cluster

```
int main(int argc, char **argv) {
  [...]

  SD_task_schedulel(c1, 1, workstations[0]);

}
```

SimDag Code Sample

Step 3

- Scheduling the tasks
  - c1 goes on the first host in the cluster
  - c2 goes on the host

```
int main(int argc, char **argv) {
  [...]

  SD_task_schedulel(c1, 1, workstations[0]);
  SD_task_schedulel(c2, 1, workstations[5]);

}
```

SimDag Code Sample

Step 3

- Scheduling the tasks
  - c1 goes on the first host in the cluster
  - c2 goes on the host
  - And ... that's all!
    - t1 is automatically scheduled between these two workstations

```
int main(int argc, char **argv) {
  [...]

  SD_task_schedulel(c1, 1, workstations[0]);
  SD_task_schedulel(c2, 1, workstations[5]);

}
```

SimDag Code Sample

Step 4

- Unschedule the tasks
  - t1 has to be explicitly unscheduled

```
int main(int argc, char **argv) {
  [...]

  SD_task_schedulel(c1, 1, workstations[0]);
  SD_task_schedulel(c2, 1, workstations[5]);

  SD_task_unschedule(c1);
  SD_task_unschedule(c2);

  SD_task_unschedule(t1);

}
```

SimDag Code Sample

Step 4

- Unschedule the tasks
  - t1 has to be explicitly unscheduled
- Clean stuff

```
int main(int argc, char **argv) {
  [...]

  SD_task_schedulel(c1, 1, workstations[0]);
  SD_task_schedulel(c2, 1, workstations[5]);

  SD_task_unschedule(c1);
  SD_task_unschedule(c2);

  SD_task_unschedule(t1);

  SD_exit();

  return 0;
}
```

SimDag Code Sample

Step 4

- Unschedule the tasks
  - t1 has to be explicitly unscheduled
- Clean stuff
- Remark: The simulation itself is still not implemented in this example

int main(int argc, char **argv) {

```
  [...]

  SD_task_schedulel(c1, 1, workstations[0]);
  SD_task_schedulel(c2, 1, workstations[5]);

  SD_task_unschedule(c1);
  SD_task_unschedule(c2);

  SD_task_unschedule(t1);

  SD_exit();

  return 0;
}
```

Some Useful Prediction Functions

Default Parallel Tasks

- `SD_task_get_execution_time`
  - Workstation list
  - Array of computation amounts
  - Communication matrix
- `SD_task_get_remaining_amount`
  - The simulation is hold, how much computation remains for this task?

Sequential Computation and End-to-End Communications

- `SD_workstation_get_computation_time (workstation, amount)`
- `SD_route_get_communication_time (src, dst, amount)`
- These functions do not take concurrent executions into account

Routes and workstations

- `SD_route_get_current_bandwidth (src, dest)`
- `SD_route_get_current_latency (src, dest)`
- `SD_workstation_get_available_power(workstation)`

Running the Simulation

Static Schedules

- Build the complete schedule before running the simulation
  - Call a `SD_task_schedule*` function for each task
- Then call `SD_simulate(-1.)`
  - It will stop when all the work has been done
  - Or if no more tasks are reachable

Dynamic Schedules

- Build the schedule during the simulation
- Two options
  - Hold the simulation every X seconds to take more decisions: `SD_simulate(X)`
  - Add watchpoints on the state of tasks
    - `SD_task_watch (task, state)`
    - The simulation will be hold each time a watch point is reached
    - For in time when a task goes from `SD_TASK_RUNNING` to `SD_TASK_DONE`
- This requires to add an outer loop
- Dynamic rescheduling is possible with `SD_task_unschedule`

What You Can Get After the Simulation

- When the task did actually start
  - `SD_task_get_start_time (task)`
- When the task did actually finish
  - `SD_task_get_finish_time (task)`
- How many workstation were used to execute a task
  - `SD_task_get_workstation_count (task)`
- And which ones
  - `SD_task_get_workstation_list (task)`
- Now you can plot your Gantt chart and analyze your performance metrics
  - Using either Jedule or Pajé built-in instrumentation

Agenda

A Complete Scheduling Simulator Example

The Min-Min List Scheduling Algorithm

- For each ready task
  - get the workstation that minimizes the completion time
- select the task that has the minimum completion time on its best workstation
  - And schedule it there
- Full code available at `$SIMGRID_HOME/examples/simdag/scheduling/minmin_test.c`

What follows in the code sample

- Some management functions to attach attributes to workstations
  - Availability time
  - Last task scheduled on the workstation
- Functions to
  - Find the workstation that minimizes the completion time
  - Get the list of ready tasks
- The main scheduling function

SimDag Code Sample

```
typedef struct _WorkstationAttribute {
  double available_at;
  SD_task_t last_scheduled_task;
} *WorkstationAttribute;

static void SD_workstation_allocate_attribute(SD_workstation_t ws){
  void *data = calloc(1, sizeof(struct _WorkstationAttribute));
  SD_workstation_set_data(ws, data);
}
static void SD_workstation_free_attribute(SD_workstation_t ws) {
  free(SD_workstation_get_data(ws));  SD_workstation_set_data(ws, NULL);
}
static double SD_workstation_get_available_at(SD_workstation_t ws) {
  WorkstationAttribute attr = (WorkstationAttribute) SD_workstation_get_data(ws);
  return attr->available_at;
}
static void SD_workstation_set_available_at(SD_workstation_t ws, double time){
  WorkstationAttribute attr = (WorkstationAttribute) SD_workstation_get_data(ws);
  attr->available_at = time;  SD_workstation_set_data(ws, attr);
}
static SD_task_t SD_workstation_get_last_scheduled_task( SD_workstation_t ws){
  WorkstationAttribute attr = (WorkstationAttribute) SD_workstation_get_data(ws);
  return attr->last_scheduled_task;
}
static void SD_workstation_set_last_scheduled_task(SD_workstation_t ws, SD_task_t task){
  WorkstationAttribute attr = (WorkstationAttribute) SD_workstation_get_data(ws);
  attr->last_scheduled_task=task;  SD_workstation_set_data(ws, attr);
}
```

SimDag Code Sample

double finish_on_at(SD_task_t task, SD_workstation_t workstation){

```
double result, data_available = 0., last_data_available, redist_time = 0;
unsigned int i;
SD_task_t parent, grand_parent;
xbt_dynar_t parents, grand_parents;

SD_workstation_t *grand_parent_workstation_list;

parents = SD_task_get_parents(task);

if (!xbt_dynar_is_empty(parents)) {
  /* compute last_data_available */
  last_data_available = -1.0;
  xbt_dynar_foreach(parents, i, parent) {
    if (SD_task_get_kind(parent) == SD_TASK_COMM_E2E) {      /* normal case */
      grand_parents = SD_task_get_parents(parent);

      xbt_dynar_get_cpy(grand_parents, 0, &grand_parent);
      grand_parent_workstation_list = SD_task_get_workstation_list(grand_parent);

      /* Estimate the redistribution time from this parent */
      redist_time = SD_route_get_communication_time(grand_parent_workstation_list[0],
                                                     workstation, SD_task_get_amount(parent));
      data_available = SD_task_get_finish_time(grand_parent) + redist_time;

      xbt_dynar_free_container(&grand_parents);
    }
```

SimDag Code Sample

double finish_on_at(SD_task_t task, SD_workstation_t workstation){

```
    if (SD_task_get_kind(parent) == SD_TASK_COMP_SEQ) { /* no transfer, control dependency */
      data_available = SD_task_get_finish_time(parent);
    }

    if (last_data_available < data_available)
      last_data_available = data_available;
  }

  xbt_dynar_free_container(&parents);

  result = MAX(SD_workstation_get_available_at(workstation), last_data_available) +
      SD_workstation_get_computation_time(workstation, SD_task_get_amount(task));
 } else {
  xbt_dynar_free_container(&parents);

  result = SD_workstation_get_available_at(workstation) +
      SD_workstation_get_computation_time(workstation, SD_task_get_amount(task));
 }
 return result;
}
```

SimDag Code Sample

```
SD_workstation_t SD_task_get_best_workstation(SD_task_t task) {
  int i, nworkstations = SD_workstation_get_number();
  double EFT, min_EFT = -1.0;
  const SD_workstation_t *workstations = SD_workstation_get_list();
  SD_workstation_t best_workstation;

  best_workstation = workstations[0];
  min_EFT = finish_on_at(task, workstations[0]);

  for (i = 1; i < nworkstations; i++) {
    EFT = finish_on_at(task, workstations[i]);
    if (EFT < min_EFT) {
      min_EFT = EFT;  best_workstation = workstations[i];
    }
  }
  return best_workstation;
}
xbt_dynar_t get_ready_tasks(xbt_dynar_t dax) {
  unsigned int i;
  xbt_dynar_t ready_tasks = xbt_dynar_new(sizeof(SD_task_t), NULL);
  SD_task_t task;

  xbt_dynar_foreach(dax, i, task)
    if (SD_task_get_kind(task)==SD_TASK_COMP_SEQ && SD_task_get_state(task)==SD_SCHEDULABLE)
      xbt_dynar_push(ready_tasks, &task);

  return ready_tasks;
}
```

SimDag Code Sample

```
int main(int argc, char **argv) {

  unsigned int cursor;
  double finish_time, min_finish_time = -1.0;
  SD_task_t task, selected_task = NULL, last_scheduled_task;
  xbt_dynar_t ready_tasks;
  SD_workstation_t workstation, selected_workstation = NULL;
  int total_nworkstations = 0;
  const SD_workstation_t *workstations = NULL;
  xbt_dynar_t dax, changed;

  SD_init(&argc, argv); /* initialization of SD */

  SD_create_environment(argv[1]);  /* creation of the environment */

  /*  Allocating the workstation attribute */
  total_nworkstations = SD_workstation_get_number();
  workstations = SD_workstation_get_list();

  for (cursor = 0; cursor < total_nworkstations; cursor++)
    SD_workstation_allocate_attribute(workstations[cursor]);

  dax = SD_daxload(argv[2]);   /* load the DAX file */

  xbt_dynar_foreach(dax, cursor, task) /* add watchpoint on task completion */
    SD_task_watch(task, SD_DONE);
  [...]
}
```

SimDag Code Sample

```
int main(int argc, char **argv) {

  /* Schedule the DAX root first */
  xbt_dynar_get_cpy(dax, 0, &task);
  workstation = SD_task_get_best_workstation(task);
  SD_task_schedulel(task, 1, workstation);

  while (!xbt_dynar_is_empty((changed = SD_simulate(-1.0)))) {
    /* Get the set of ready tasks */
    ready_tasks = get_ready_tasks(dax);
    if (xbt_dynar_is_empty(ready_tasks)) {
      xbt_dynar_free_container(&ready_tasks);
      xbt_dynar_free_container(&changed);
      continue;  /* there is no ready task, let advance the simulation */
    }
    xbt_dynar_foreach(ready_tasks, cursor, task) {
      workstation = SD_task_get_best_workstation(task);
      finish_time = finish_on_at(task, workstation);
      if (min_finish_time == -1. || finish_time < min_finish_time) {
        min_finish_time = finish_time;
        selected_task = task;
        selected_workstation = workstation;
      }
    }

    SD_task_schedulel(selected_task, 1, selected_workstation);
  [...]
}
```

SimDag Code Sample

```
int main(int argc, char **argv) {
    /* Manage resource dependencies */
    last_scheduled_task =  SD_workstation_get_last_scheduled_task(selected_workstation);
    if (last_scheduled_task && (SD_task_get_state(last_scheduled_task) != SD_DONE) &&
        (SD_task_get_state(last_scheduled_task) != SD_FAILED) &&
        !SD_task_dependency_exists(SD_workstation_get_last_scheduled_task(
                                   selected_workstation), selected_task))
      SD_task_dependency_add("resource", NULL, last_scheduled_task, selected_task);

    SD_workstation_set_last_scheduled_task(selected_workstation, selected_task);
    SD_workstation_set_available_at(selected_workstation, min_finish_time);

    xbt_dynar_free_container(&ready_tasks);
    xbt_dynar_free_container(&changed);
    min_finish_time = -1.;     /* reset the min_finish_time for the next round */
  }
  xbt_dynar_foreach(dax, cursor, task)
    SD_task_destroy(task);
  xbt_dynar_free_container(&dax);
  xbt_dynar_free_container(&changed);

  for (cursor = 0; cursor < total_nworkstations; cursor++)
    SD_workstation_free_attribute(workstations[cursor]);

  SD_exit();
  return 0;

}
```

Conclusion

- This 101 tutorial gives examples of the basic usage of most SimDag function
  - You should be able to code your own simulator now!
- Where to find more information on SimDag
  - in `$SIMGRID_HOME/examples/simdag`
  - in the contrib section of SimGrid
    - A set of implementations of classical DAG scheduling algorithms
    - `svn co svn://scm.gforge.inria.fr/svn/simgrid/contrib/trunk/DAGSched`
- Feel free to contribute to SimDag and the contrib section
  - And to ask questions on `simgrid-user@lists.gforge.inria.fr`