# INTRODUCTION

In this project, we analyze the basic scheduling mechanism as provided by the VxWorks Real-Time Operating System (RTOS) and get acquainted with the VxWorks in the Tornado environment. We implement the Earliest Deadline First (EDF) scheduler by creating various task set.

A brief overview of VxWorks

VxWorks is a Real-Time Operating System developed by Wind River, with support for multi-tasking, mutual exclusion, easy to use inter-task communication, and two types of scheduling namely (Rate Monotonic Scheduling) RMS and EDF. For development purposes, the Tornado environment is used with VxWorks. VxWorks applications work at the Operating System (OS) layer. Applications can make system calls to the VxWorks kernel through an API in order to interface with the board's hardware. The Xilinx hardware API is also available for writing application code, but VxWorks handles interfacing with this API for the most part.
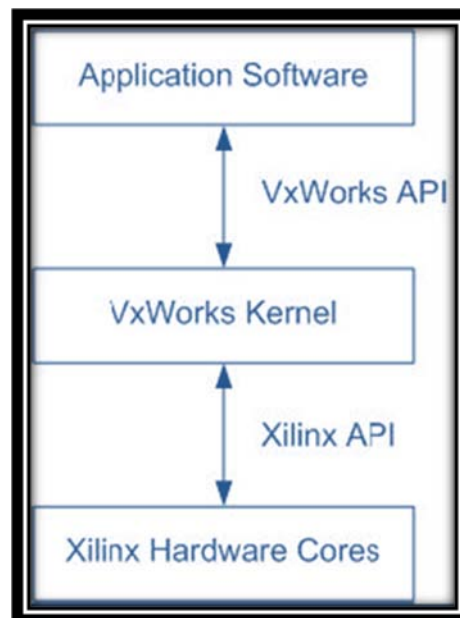
VxWorks uses the tick as its timing unit. A tick is a certain number of Central Processing Unit (CPU) cycles, defined at the kernel level. We need to set up local Wind Registry on our computer in order to keep track of all the target servers running in a given environment. A shell interface is provided by the VxWorks in the Tornado Environment which can be used for spawning the tasks, killing the tasks, determining the status of various tasks and various functions can also be called directly.

sp <function_name>: Spawn a task, starting at the beginning of function_name.
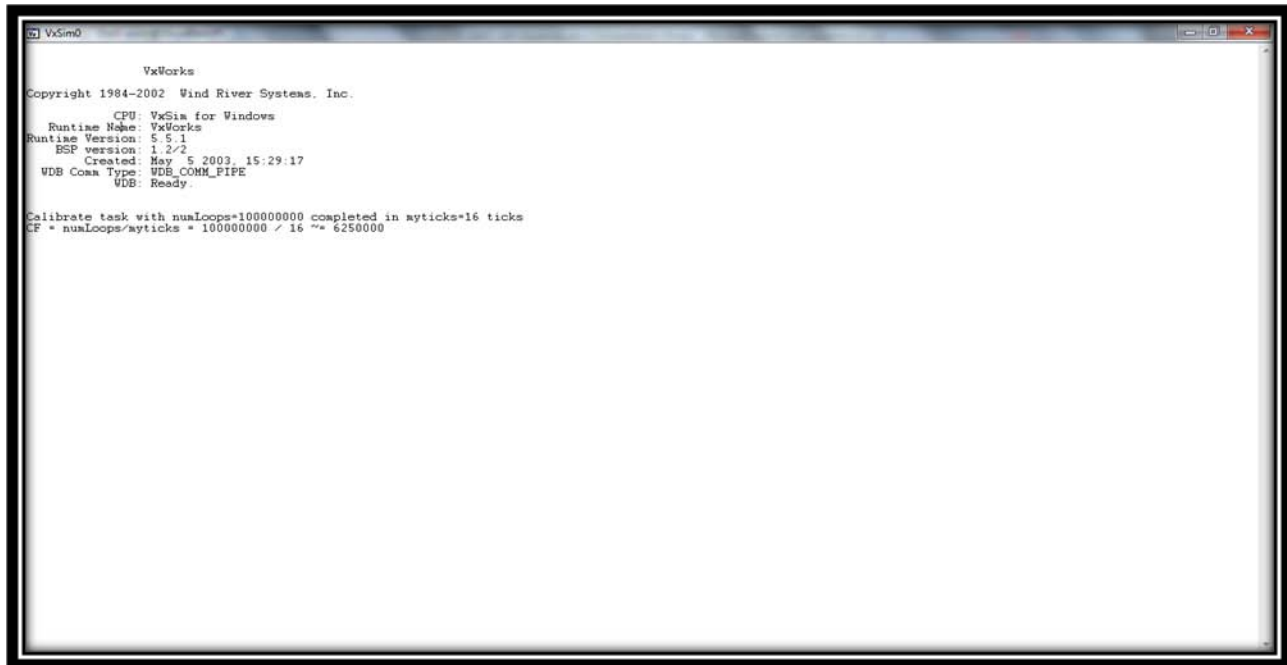
Tasks in VxWorks

Tasks in VxWorks are essentially the same as processes in any operating system. They have a stack, memory space, and priority. They also have a task ID (denoted as TID), which corresponds to a process ID (denoted as PID) in other operating systems. Tasks may be in one or more of several states in VxWorks, including Pending, Ready, Running, and Suspended. Pending tasks either have not yet been scheduled or are waiting on some kind of inter-task communication. Ready tasks are ready to run, but have not currently been allocated processor time by the scheduler. Suspended tasks are never allocated processor time until they are resumed, but have not been deleted. The VxWorks libraries `taskLib` and `taskInfo` provide many useful functions for dealing with tasks. They are included by simply including `vxworks.h`.

Task Scheduling

In VxWorks, tasks are given a priority ranging from 0 to 255 corresponding to the highest to the lowest priority respectively (note the inverse relationship). The board support and system critical tasks fall within the priority range of 0-99. Application tasks fall in the range 100-255 and should never be higher priority than 100. The command `sp` defaults to priority 100.

VxWorks supports two scheduling algorithms: the Preemptive Priority Scheduling and the Round-Robin Scheduling with Priority. The default is the Preemptive Priority Scheduling.

In this scheduling algorithm, the highest-priority task is given the CPU all of the time until it blocks or completes. When a task of higher priority than the one currently running is spawned, the running task is preempted and the CPU is given over to the new task. Once this task completes, the previous task will resume execution, so long as there is not another task of higher priority waiting to run. The key defect with this scheduling algorithm arises with tasks of equal priority. When multiple tasks of equal priority are running, one may never be allocated processor time if another task of the same priority never blocks. Before proceeding with the task scheduling, we need to calibrate the dummy loops in order to have reasonably precise computation times for the tasks. We are interested in finding how much iteration corresponds to a time tick. The `calibrate()` method in the EDF implementation runs this task. In the Tornado shell, we should see a message similar to the following:

Our EDF Scheduler Implementation:

We implemented an EDF Scheduler in `EDFScheduler()` method. EDF is a dynamic priority scheduler that changes the priorities of the tasks dynamically at regular intervals. We write the `init ()` function to call `EDFScheduler()` method which in turn schedules the execution of three instances of `Ptask()` with different computation times and periods. The `EDFScheduler()` method must have priority over the `Ptask()` processes in order to be able to reprioritize them. We keep track of the changing absolute deadlines of the individual tasks adjusting their priorities as needed. A periodic scheduler task which regularly changes the task priorities based on the last updated deadline values.

STEPS FOR RUNNING THE EDF SCHEDULER IN TORNADO ENVIRONMENT:

Setting up the project:

a.   From the "Start" menu, "All Programs">"Tornado 2.2″>"Tornado"
b.   If the "Create Project in New/Existing Workspace" dialog is up, click on "New". If not, from the "File" menu select "New Project…"
c.   Click "Create downloadable application modules for VxWorks", click "OK"
d.   Enter the following parameters:
  ▪   "Name:", "RTS_Project"
  ▪   "Location:", "C:\Tornado2.2\target\proj\RTS_Project"

- ▪   "Add to a New or Existing Workspace",
  "C:\Tornado2.2\target\proj\Workspace0.wsp"
e.   Click "Next"
f.   Select the "A toolchain" option. Select "SIMNTgnu" to use the simulator. Otherwise, select the appropriate toolchain. Click "Next"
g.   Click "Finish"

Add a file for entering the Program:

h.   From the "File" menu, select "New…"
i.   Select the following parameters:
j.   From the left box, "C/C++ Source File"
k.   "Add to project:", "RTS_Project.wpj"
l.   "File name:", "EDF_Scheduler.c"
     "Location:", "C:\Tornado2.2\target\proj\RTS_Project"
m.   Click "OK"
n.   Enter the implemented code into EDF_Scheduler.c:
o.   Save the file.

Build the Project:
- **p.** From the "Build" menu, select "Build"
- **q.** Click "OK" to generate dependencies (i.e. include files).
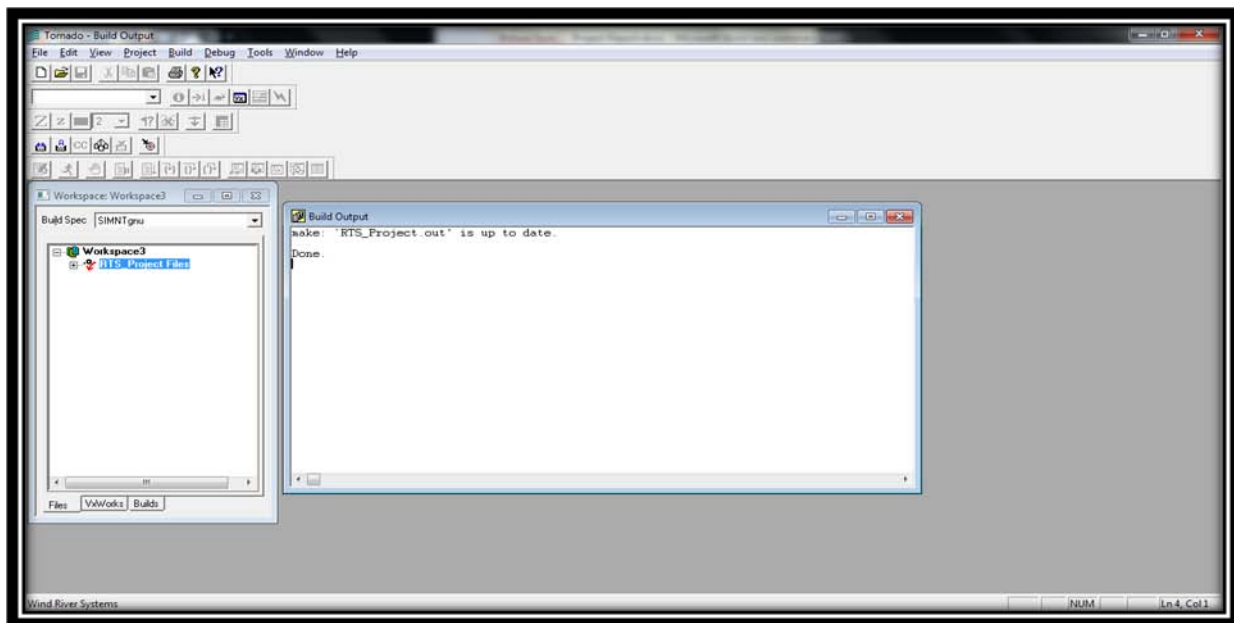
Start the Simulator, download and run your program:
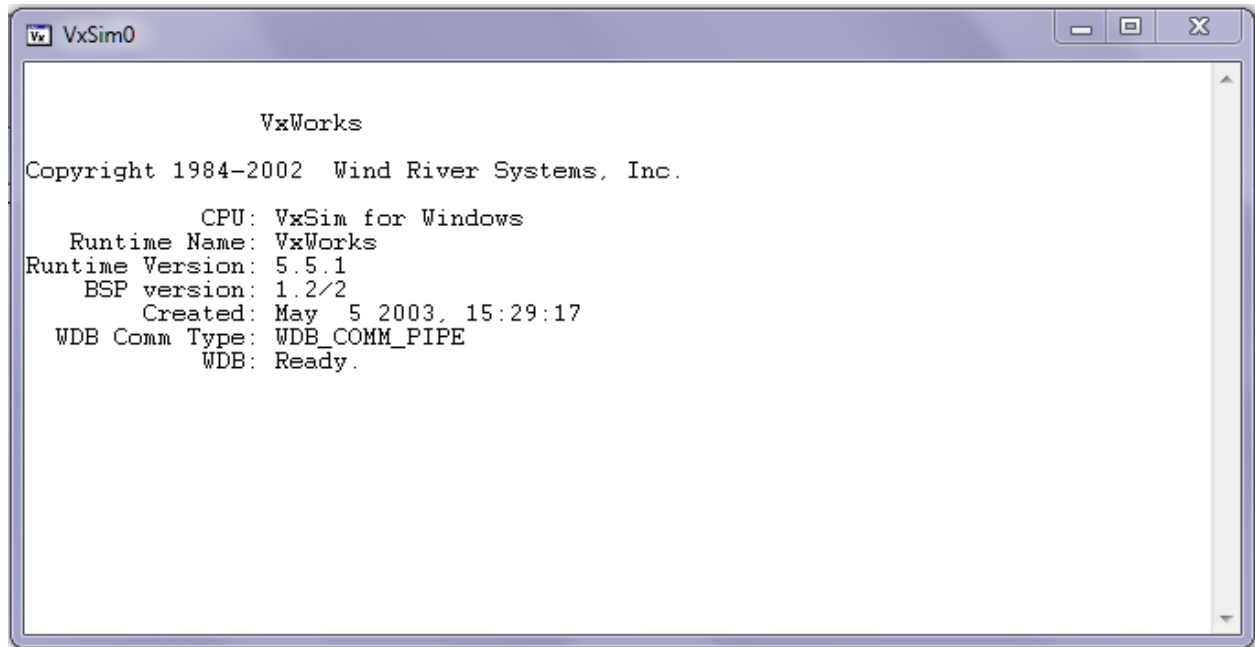
r.   From the "Tools" menu, select "Simulator…" (Or click the "Launch Simulator" button)
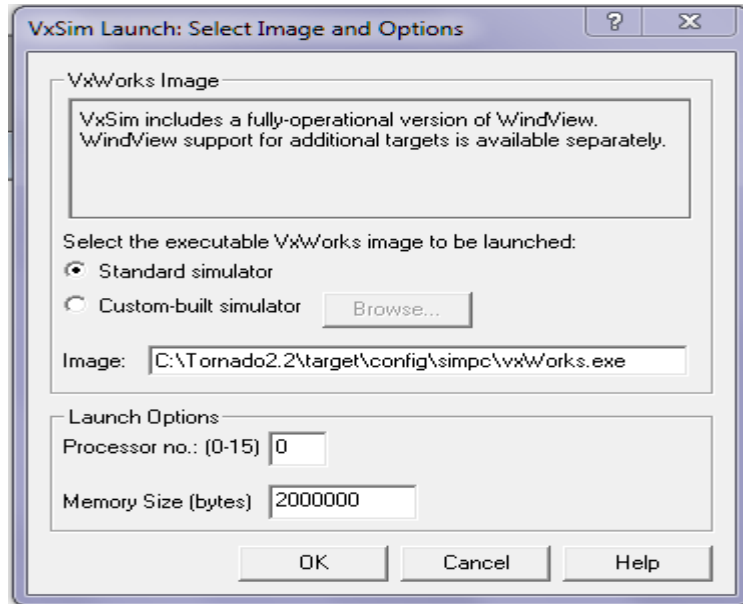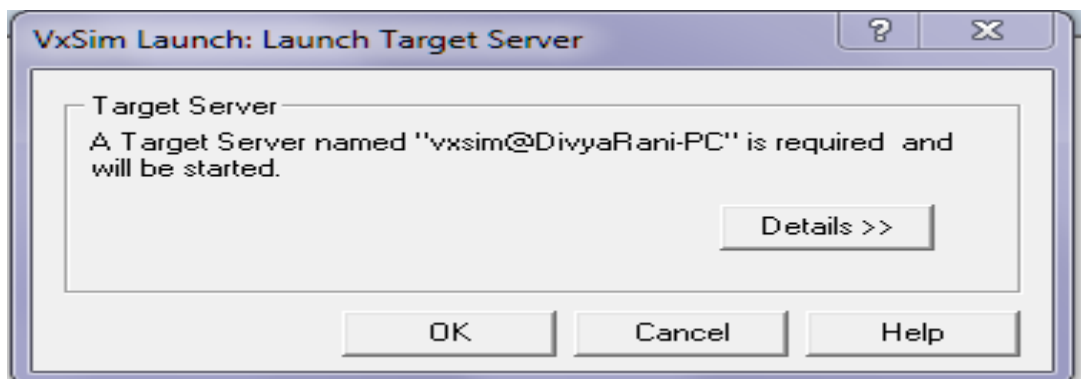
s.   Click "OK" to run the standard simulator

```
VxSim Launch: Select Image and Options          ?   X

  VxWorks Image
    VxSim includes a fully-operational version of WindView.
    WindView support for additional targets is available separately.

    Select the executable VxWorks image to be launched:
    ⊙ Standard simulator
    ○ Custom-built simulator    Browse...

    Image:  C:\Tornado2.2\target\config\simpc\vxWorks.exe

  Launch Options
    Processor no.: (0-15) 0

    Memory Size (bytes)  2000000

              OK          Cancel          Help
```

t.   If you get a 'A Target Server named "vxsim@XXXXXXX" is required and will be started.' dialog, click "OK". (Note: If you've been messing around with the full simulator, click "Details >>" and ensure the "Integrated simulator" option is selected.)

```
VxSim Launch: Launch Target Server          ?   X

  Target Server
   A Target Server named "vxsim@DivyaRani-PC" is required  and
   will be started.

                                   Details >>

              OK          Cancel          Help
```

u.   A "VxSim0" window should appear and the red target server icon should appear in your system tray.

```
Vx VxSim0                                                    _  □  X

                    VxWorks

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            CPU: VxSim for Windows
   Runtime Name: VxWorks
Runtime Version: 5.5.1
    BSP version: 1.2/2
        Created: May  5 2003, 15:29:17
  WDB Comm Type: WDB_COMM_PIPE
            WDB: Ready.
```

v.   Right-click on "RTS_Project Files" and select "Download RTS_Project.out".

w.   From the "Tools" menu, select "Shell…"; click "OK". (Or click the "Launch Shell"
        button).

x.   In the shell window, type "i" and hit ENTER to see the list of running tasks. You should
        get something like:

y.   `-> i`
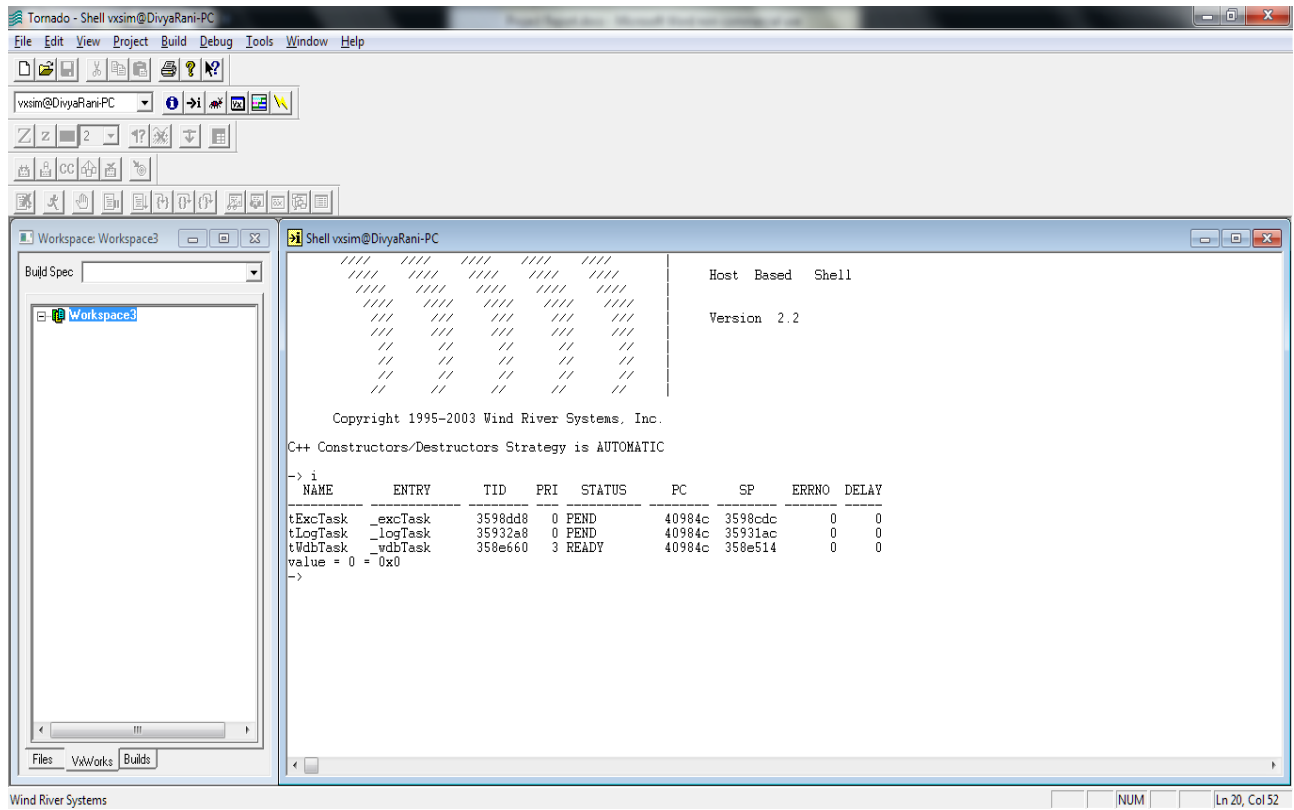
Type "`sp startit`" and hit <ENTER>. You should get the following output:
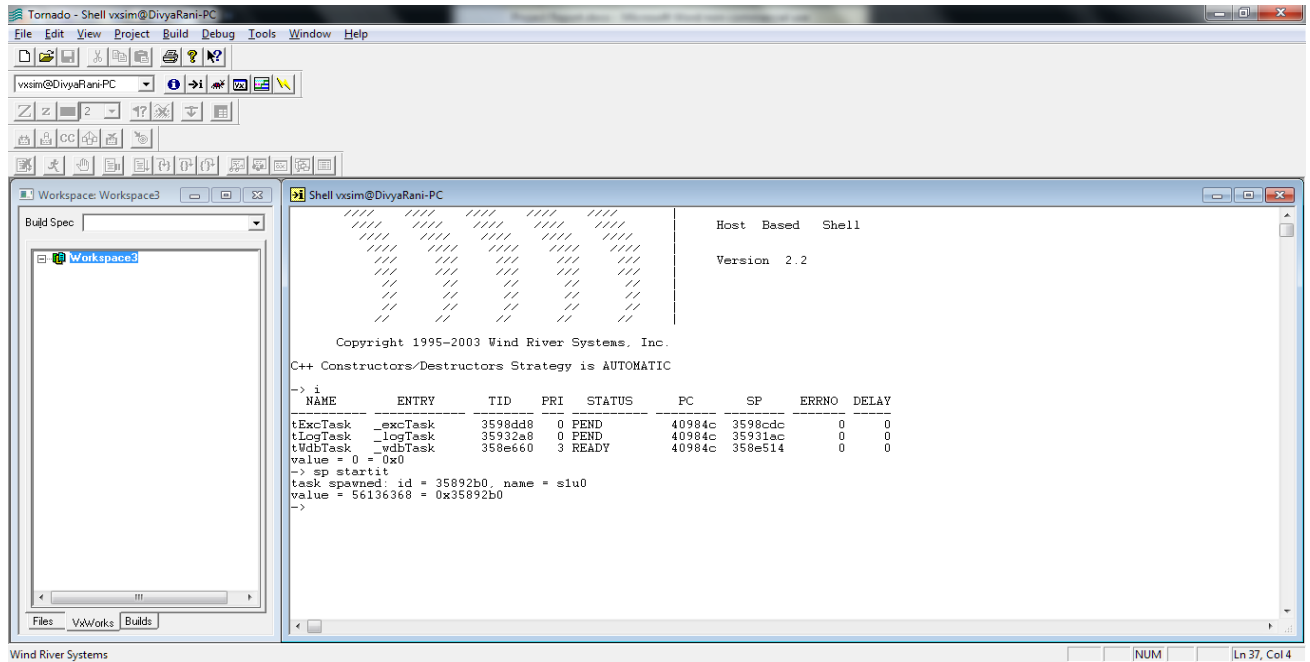
z.   The final output appears on the screen as:

```
VxSim0

New priority list is: 106      101     105     102     104     103
New priority list is: 106      101     105     102     104     103
New priority list is: 106      101     105     102     104     103
New priority list is: 106      101     105     102     104     103
New miss ratio error is 0.000000
Admitting task(1,50)
New priority list is: 107      101     105     102     104     103     106
New priority list is: 107      101     105     102     104     103     106
New priority list is: 107      101     105     102     104     103     106
New priority list is: 107      101     105     102     104     103     106
New priority list is: 107      101     105     102     104     103     106
Admitting task(4,199)
New priority list is: 108      101     105     102     104     103     106     107
New priority list is: 108      101     105     102     104     103     106     107
New priority list is: 108      101     105     102     104     103     106     107
New priority list is: 108      101     105     102     104     103     106     107
New priority list is: 108      101     105     102     104     103     106     107
New miss ratio error is -0.010000
Admitting task(4,199)
New priority list is: 109      101     105     102     104     103     106     107     108
New priority list is: 109      101     105     102     104     103     106     107     108
New priority list is: 109      101     105     102     104     103     106     107     108
New priority list is: 109      101     105     102     104     103     106     107     108
New priority list is: 109      101     105     102     104     103     106     107     108
Admitting task(4,199)
New priority list is: 110      101     105     102     104     103     106     107     108     109
New priority list is: 110      101     105     102     104     103     106     107     108     109
New priority list is: 110      101     105     102     104     103     106     107     108     109
New priority list is: 110      101     105     102     104     103     106     107     108     109
New priority list is: 110      105     102     104     103     106     101     107     108     109
New miss ratio error is -0.010000
Admitting task(4,199)
New priority list is: 111      104     103     106     101     105     102     107     108     109     110
New priority list is: 111      106     101     105     103     104     103     107     108     109     110
New priority list is: 111      106     101     105     102     104     103     107     108     109     110
New priority list is: 111      106     101     105     102     104     103     107     108     109     110
New priority list is: 111      106     101     105     102     104     103     107     108     109     110
New priority list is: 111      106     101     105     102     104     103     107     108     109     110
New priority list is: 111      106     101     105     102     104     103     107     108     109     110
New priority list is: 111      106     101     105     102     104     103     107     108     109     110
New priority list is: 111      106     101     105     102     104     103     107     108     109     110
New miss ratio error is -0.010000
Admitting task(4,199)
New priority list is: 112      106     101     105     102     104     103     107     108     109     110     111
New priority list is: 112      106     101     105     102     104     103     107     108     109     110     111
New priority list is: 112      106     101     105     102     104     103     107     108     109     110     111
New priority list is: 112      106     101     105     102     104     103     107     108     109     110     111
New priority list is: 112      106     101     105     102     104     103     107     108     109     110     111
New priority list is: 112      106     101     105     102     104     103     107     108     109     110     111
New priority list is: 112      106     101     105     102     104     103     107     108     109     110     111
New priority list is: 112      106     101     105     102     104     103     107     108     109     110     111
New priority list is: 112      106     101     105     102     104     103     107     108     109     110     111
```