Modeling and Analysis Suite for Real Time Applications (MAST 1.3.8)

Description of the MAST Results

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1. MAST Output Files

The MAST tools produce several output files:

- *Console output*: Describes the work carried out by the tools, and any possible errors, in free format. If the verbose option is set, the tools provide a more detailed output. The last line in the file contains the string "`Final analysis status: code`", where code is a single word that is either "DONE", or some error indication.
- *Source destination file*: Describes the source of the MAST model of the analyzed system, including any elements introduced by the analysis tools into the system such as priorities, or priority ceilings. It follows the file format used for the MAST model. This file is only produced if the corresponding option is set.
- *Results file*: Describes the results of the analysis tools. If a filename is not provided for the results, they are written to the standard output, together with the Console Output. See Section 4 for a description of its format.

2. Type definitions

The following types are used in the definitions of the components of the MAST File and the MAST Results File:

- *Identifier*. String of characters following the rules described in the following section.
- *Priority*. Positive integer of implementation-defined range, defining the scheduling priority of tasks.
- *Interrupt_Priority*. Positive integer of implementation defined range, defining the scheduling priority of interrupt service routines.
- *Any_Priority*. Positive integer that is either in the *Priority* range or in the *Interrupt_Priority* range.
- *Normalized_Execution_Time*. Represents the execution time of an operation, as executed by a normalized processing resource of speed factor equal to one. It is obtained by multiplying the real execution time by the processing resource's speed factor.
- *Time*. Time interval in unspecified time units.

- *Absolute_Time*. Absolute time measured from and arbitrary time origin, in unspecified units.
- *Float*. It represents any float type.
- *Positive*. Integer positive number (excluding zero).
- *Natural*. Integer number that is greater than or equal to zero.
- *Percentage*. A floating point number representing a percentage, and followed by a "`%`" character. In some cases (slacks) the notation "`>=num%`" may be used to indicate that the actual result is greater than the specified number.
- *"Text"*: String of arbitrary characters, excluding the double quote character, and delimited within double quotes.
- *Date-Time*: String representing a date and time (hours, minutes and seconds) in the extended ISO 8601 format with no time zone:
  YYYY-MM-DDThh:mm:ss (e.g., 1997-07-16T19:20:30).
- *Pathname*: String representing a pathname of a file.

3. Writing the MAST File

The rules for writing the file with a real-time system according to the defined real-time system model are the following:

- Each object has the format:
  object_name (arguments);
- Most objects have a type and/or a name argument. In those cases, they are mandatory arguments, and they have to be defined as the first and second argument, respectively. All other arguments can go in any order, and are mostly optional.
- Blank spaces, tabs and new lines are ignored.
- Identifiers or names follow the Ada rules for composite identifiers: begin with a letter, followed by letters, digits, underscores ('_') or periods ('.').
- Identifiers or names can be expressed with or without quotes. A quoted name can be the same as one of the reserved words (appearing in bold face below).
- Each name that is referenced must have been defined earlier in the file.
- Float types without fractional part can be expressed without the decimal point.
- Comments are like in Ada: they begin with two dashes ("--"), anywhere in a line, and end at the end of the line.
- The description is not case-sensitive.

4. Results File Format

The results of the analysis are stored in the *results file* and are attached to different elements of the MAST model:

- the overall system:

  - slacks
  - traces
- transactions:
  - timing results: for each output event global response times (worst, best average) and maximum output jitter
  - transaction-specific slack
- processing resources:
  - slack
  - utilization or detailed utilization
  - scheduler queue size
- operations:
  - slack
- scheduling servers:
  - priorities
- shared resources:
  - priority ceilings
  - queue size

The format of the results file is described next. The *results file* is in text format and follows the same rules as the MAST model file (see Section 6, “Writing the MAST file”). The *results file* contains objects of the following types, without any particular ordering imposed:

4.1 Real-Time Situation

The overall system results are relative to a real-time situation that has been analyzed, and contain a set of results (described below) and the following attributes:

- *Model_Name*: Name of the analyzed real-time situation model.
- *Model_Date*: Date of last modification of the analyses real-time situation model, in the ISO 8601 format `YYYY-MM-DDThh:mm:ss`.
- *Tool_Generator*: Quoted text representing the name of the tool that generated the results.
- *Generation_Profile*: Quoted text representing the command and options used to invoke the tool for the generation of the results.
- *Generation_Date*: Date of generation of results, in the ISO 8601 format `YYYY-MM-DDThh:mm:ss`.

```
Real_Time_Situation (
     Model_Name                          => Identifier,
     Model_Date                          => YYYY-MM-DDThh:mm:ss,
     Generator_Tool                      => "Text",
```


```
     Generation_Profile                 => "Text",
     Generation_Date                    => YYYY-MM-DDThh:mm:ss,
     Results                            => (
                                        Result 1,
                                        Result 2,
                                        ...));
```

The specific results that may refer to a real-time situation are:

- *Slack*: If positive, it is the percentage by which all the execution times of all the operations in the real-time situation may be increased while still keeping the system schedulable. If negative, it is the percentage by which all the execution times of all the operations in the real-time situation have to be decreased to make the system schedulable. If zero, it means that the system is just schedulable.

```
Result = (
     Type                               => Slack,
     Value                              => Percentage)
```

- *Trace*: It describes the name of a file where trace information on the simulation of a MAST real-time situation can be found.

```
Result = (
     Type                               => Trace,
     Pathname                           => Pathname)
```

4.2 Transaction

The transaction results are relative to a transaction in the system that has been analyzed, and contain the name of the transaction and a set of results (described below) , using the following format:

```
Transaction (
     Name                               => Identifier,
     Results                            => (
                                        Result 1,
                                        Result 2,
                                        ...));
```

The specific results that may refer to a real-time situation are:

- *Slack*: If positive, it is the percentage by which all the execution times of all the operations used by the transaction may be increased while still keeping the system schedulable. If negative, it is the percentage by which all the execution times of all the operations used by the transaction have to be decreased to make the system schedulable. If zero, it means that the transaction is just schedulable.

```
Result = (
     Type                               => Slack,
     Value                              => Percentage)
```

- *Timing_Result*: Represents the timing results of a relevant event of the transaction and obtainable by a schedulability analysis tool. Its attributes are:
  - *Event_Name*: Name of event. The timing results always corresponds to the activity or activities that generated the event represented by this name.
  - *Worst_Local_Response_Time*: Worst local response time, measured as the worst difference between the activation and completion times of the activity that generated the event with this result.
  - *Best_Local_Response_Time*: Best local response time, measured as the best difference between the activation and completion times of the activity that generated the event with this result.
  - *Worst_Blocking_Time*: Worst-case delay caused by the used of shared resources. It represents the blocking time for the segment of activities preceding the referenced event. A segment of activities is a set of consecutive activities that are run by the same scheduling server.
  - *Num_Of_Suspensions*: Maximum number of suspensions caused by shared resources, for the segment of activities preceding the referenced event.
  - *Worst_Global_Response_Times*: List of global response times each representing the worst-case response time relative to a particular input event.
  - *Best_Global_Response_Times*: List of global response times each representing the best-case response time relative to a particular input event.
  - *Jitters*: List of maximum output jitter values, each representing the maximum jitter relative to a particular input event.

```
Result = (
     Type                          => Timing_Result,
     Event_Name                    => Identifier,
     Worst_Local_Response_Time     => Time,
     Best_Local_Response_Time      => Time,
     Worst_Blocking_Time           => Time,
     Num_Of_Suspensions            => Natural,
     Worst_Global_Response_Times   => (
                                   Global_Response_Time 1,
                                   Global_Response_Time 2,
                                   ...),
     Best_Global_Response_Times    => (
                                   Global_Response_Time 1,
                                   Global_Response_Time 2,
                                   ...),
     Jitters                       => (
                                   Global_Response_Time 1,
                                   Global_Response_Time 2,
                                   ...));
```

- *Simulation_Timing_Result*: Represents the timing results of a relevant event of the transaction and obtained by a simulation tool. Its attributes are those of a *Timing_Result* plus the following:

- *Avg_Local_Response_Time*: Average local response time, measured as the average difference between the activation and completion times of the activity that generated the event with this result.
- *Avg_Blocking_Time*: Average-case delay caused by the used of shared resources. It represents the average blocking time for the segment of activities preceding the referenced event. A segment of activities is a set of consecutive activities that are run by the same scheduling server.
- *Max_Preemption_Time*: Maximum time spent by the activity preceding the event in the scheduler ready queue, while having been activated by a specific event instance. This is equivalent to the time the activity is being preempted by higher priority activities.
- *Suspension_Time*: Maximum time spent in the activity input queue by the event that triggered the activity preceding the event to which this result is attached. This time is larger than zero only if the triggering event arrives while the activity is still busy processing a previous event.
- *Num_Of_Queued_Activations*: Maximum number of pending activations in the input queue of the activity preceding the referenced event.
- *Avg_Global_Response_Times*: List of global response times each representing the average-case response time relative to a particular input event.
- *Local_Miss_Ratios*: List of local miss ratios, each representing the ratio of events that have missed a specific soft local deadline.
- *Global_Miss_Ratios*: List of global miss ratios, each representing the ratio of events generated at a specific input event channel, that have missed a specific soft global deadline.

```
Result = (
     Type                              => Simulation_Timing_Result,
     Event_Name                        => Identifier,
     Worst_Local_Response_Time         => Time,
     Avg_Local_Response_Time           => Time,
     Best_Local_Response_Time          => Time,
     Worst_Blocking_Time               => Time,
     Avg_Blocking_Time                 => Time,
     Max_Preemption_Time               => Time,
     Suspension_Time                   => Time,
     Num_Of_Suspensions                => Natural,
     Num_Of_Queued_Activations         => Natural,
     Worst_Global_Response_Times       => (
                                       Global_Response_Time 1,
                                       Global_Response_Time 2,
                                       ...),
     Avg_Global_Response_Times         => (
                                       Global_Response_Time 1,
                                       Global_Response_Time 2,
                                       ...),
     Best_Global_Response_Times        => (
                                       Global_Response_Time 1,
```

```
                                    Global_Response_Time 2,
                                    ...),
     Jitters                        => (
                                    Global_Response_Time 1,
                                    Global_Response_Time 2,
                                    ...),
     Local_Miss_Ratios              => (
                                    Miss_Ratio 1,
                                    Miss_Ratio 2,
                                    ...),
     Global_Miss_Ratios             => (
                                    Global_Miss_Ratio 1,
                                    Global_Miss_Ratio 2,
                                    ...));
```

A *Global_Response_Time* contains the following attributes:

- *Referenced_Event*: Name of referenced input event, used for calculating the response time.
- *Time_Value*: Global response time, calculated as the difference between the arrival of the input referenced event and the generation of the event to which the result is attached, and adding the input jitter.

```
Global_Response_Time = (
     Referenced_Event               => Identifier,
     Time_Value                     => Time),
```

A *Miss_Ratio* contains the following attributes:

- *Deadline*: Soft deadline against which the response time is compared to determine the ration of missed deadlines.
- *Ratio*: Percentage of events that have missed the soft deadline, relative to the total number of events.

```
Miss_Ratio = (
     Deadline                       => Time,
     Ratio                          => Percentage),
```

A *Global_Miss_Ratio* contains the following attributes:

- *Referenced_Event*: Name of referenced input event, used for calculating the response time.
- *Miss_Ratios*: List of miss ratios.

```
Global_Miss_Ratio = (
     Referenced_Event               => Identifier,
     Miss_Ratios                    => (
                                    Miss_Ratio 1,
                                    Miss_Ratio 2,
                                    ...)),
```

4.3 Processing_Resource

The processing resource results are relative to a processing resource in the system that has been analyzed, and contain the name of the resource and a set of results (described below) , using the following format:

```
Processing_Resource(
     Name                                => Identifier,
     Results                             => (
                                         Result 1,
                                         Result 2,
                                         ...));
```

The specific results that may refer to a processing resource are:

- *Slack*: If positive, it is the percentage by which all the execution times of all the operations executed in the processing resource may be increased while still keeping the system schedulable. If negative, it is the percentage by which all the execution times of all the operations executed in the processing resource have to be decreased to make the system schedulable. If zero, it means that the processing resource is just schedulable.

```
Result = (
     Type                                => Slack,
     Value                               => Processing resource slack)
```

- *Utilization*: This result measures the relation, in percentage, between the time that the processing resource is being used to execute activities, and the total elapsed time. It may contain the following attributes:
  - *Total*: overall utilization in the processing result.

```
Result = (
     Type                                => Utilization,
     Total                               => percentage)
```

- *Detailed Utilization*: This result measures the relation, in percentage, between the time that the processing resource is being used to execute activities, and the total elapsed time. It may contain the following attributes:
  - *Total*: overall utilization in the processing result.
  - *Application*: utilization of the processing resource by the application code, i.e., without the overhead elements included in the MAST model: context and interrupt switches, network drivers, and system timers.
  - *Context_Switch*: utilization of the processing resource by context and interrupt switch activities.
  - *Timer*: utilization of the processing resource by the system timer overhead.
  - *Driver*: utilization of the processing resource by the network drivers overhead.

```
Result = (
     Type                                => Detailed_Utilization,
```


```
     Total                          => percentage,
     Application                    => percentage,
     Context_Switch                 => percentage,
     Timer                          => percentage,
     Driver                         => percentage)
```

- *Ready_Queue_Size*: It contains the following attributes:
  - *Max_Num*: Maximum number of scheduling servers that are simultaneously ready in the processing resource.

```
Result = (
     Type                           => Ready_Queue_Size,
     Max_Num                        => Positive)
```

4.4 Operation

The operation results are relative to an operation in the system that has been analyzed, and contain the name of the operation and a set of results (described below) , using the following format:

```
Operation (
     Name                           => Name of the operation,
     Results                        => (
                                    Result 1,
                                    Result 2,
                                    ...));
```

The specific results that may refer to an operation are:

- *Slack*: If positive, it is the percentage by which the execution times of the operation may be increased while still keeping the system schedulable. If negative, it is the percentage by which the execution times of the operation have to be decreased to make the system schedulable. If zero, it means that the system is just schedulable with regard to this operation.

```
Result = (
     Type                           => Slack,
     Value                          => Percentage)
```

4.5 Scheduling Server

The scheduling server results are relative to a scheduling server in the system that has been analyzed, and contain the name of the scheduling server and a set of results (described below) , using the following format:

```
Scheduling_Server (
     Name                           => Name of the scheduling server,
     Results                        => (
                                    Result 1,
                                    Result 2,
                                    ...));
```

The specific results that may refer to a scheduling server are:

- *Scheduling_Parameters*: The scheduling parameters that were used in the analyzed system. Usually they are only written to the file if they were automatically calculated by the priority assignment tools. See section on "Scheduling Parameters" for a description of their format.

```
Result = (
     Type                              => Scheduling_Parameters,
     Server_Sched_Parameters           => Fixed_Priority_Sched_Parameters)
```

4.6 Shared Resource

The shared resource results are relative to a shared resource in the system that has been analyzed, and contain the name of the shared resource and a set of results (described below) , using the following format:

```
Shared_Resource (
     Name                              => Name of the shared resource,
     Results                           => (
                                       Result 1,
                                       Result 2,
                                       ...));
```

The specific results that may refer to a shared resource are:

- *Ceiling*: The priority ceiling automatically calculated by the MAST tool. Only shared resources of the type *Immediate_Ceiling_Resource* may have this type of result.

```
Result = (
     Type                              => Priority_Ceiling,
     Ceiling                           => Any_Priority)
```

- *Queue_Size*: Size of the waiting queue of the shared resource. It contains the following attributes:
  - *Max_Num*: Maximum number of threads that were queued in the shared resource, waiting to lock it.

```
Result = (
     Type                              => Queue_Size,
     Max_Num                           => Maximum number)
```

- *Utilization*: It measures the total time that the shared resource has been locked during a simulation, relative to the total elapsed time

```
Result = (
     Type                              => Utilization,
     Total                             => percentage)
```