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A POSIX-Ada Interface for Application-Defined Scheduling

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1. Overview

Interface for Application-Defined Scheduling

Integrated into the POSIX-Ada bindings

- **POSIX: Portable Operating System Interface standard**

Not only an interface

- **Requires support in the operating system kernel**
- **Implemented in our operating system MaRTE OS**

Main points

- **Application-defined scheduling policies implemented by a special kind of tasks (*scheduler tasks*)**
- **Scheduler tasks can activate or suspend other tasks**

2. Motivation

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The scheduling policies defined in Ada and POSIX are not sufficient for all application environments

- **Dynamic priorities allow better use of resources**
- **Dynamic systems require flexible scheduling schemes (multimedia)**

There are many policies based on dynamic priorities

- **It is not possible to standardize them all**

Our proposal:

- **Allow applications to define their own scheduling policies and synchronization protocols**

3. Some Requirements

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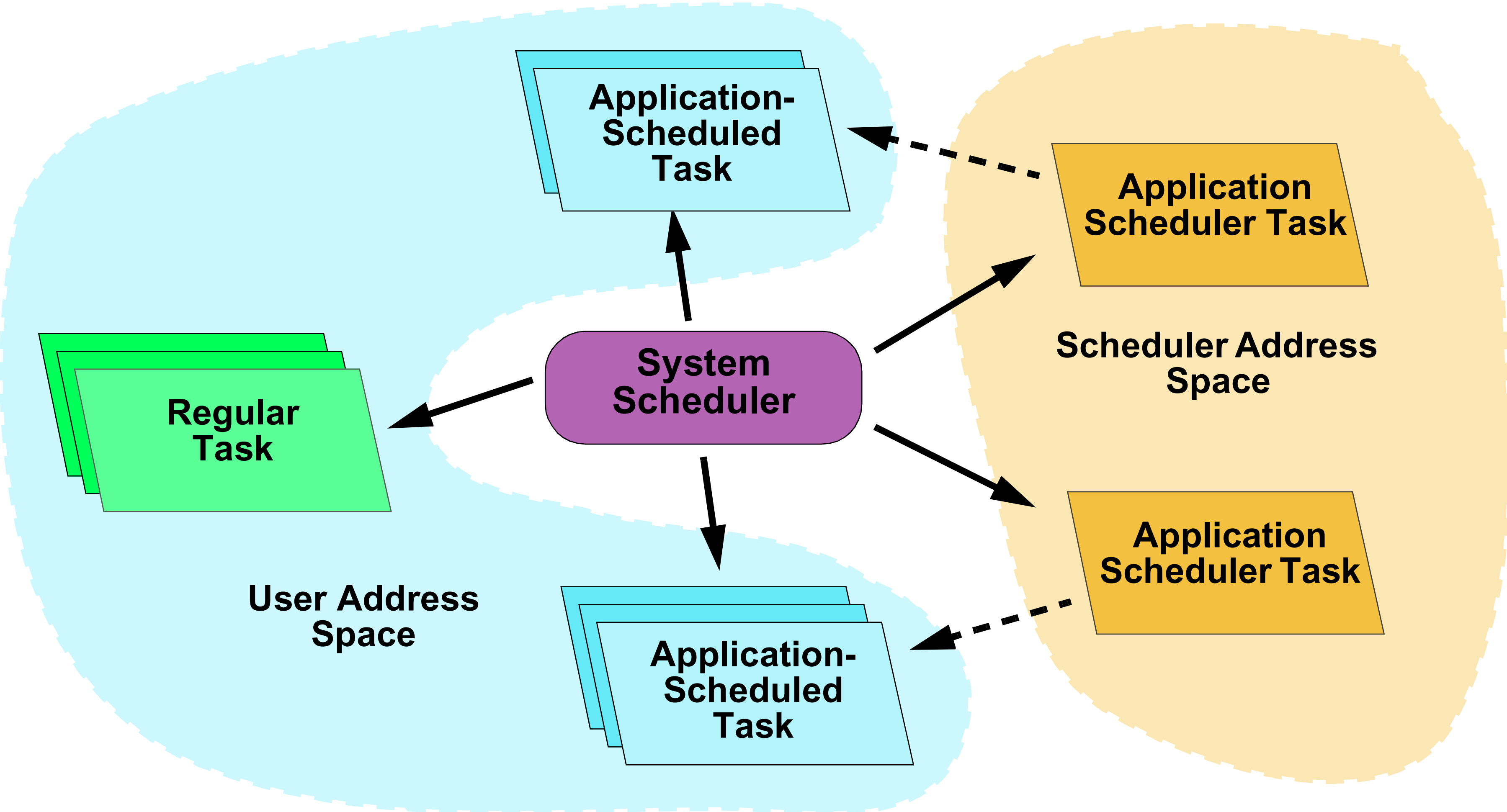
- Allow a large variety of scheduling policies
- Compatibility with current scheduling policies in POSIX and Ada
- Coexistence of several scheduling algorithms
- Isolation of critical tasks from behavior of application schedulers
- Integration of synchronization protocols to avoid priority inversion or similar effects

4. Model Description



Model Description (Cont'd)

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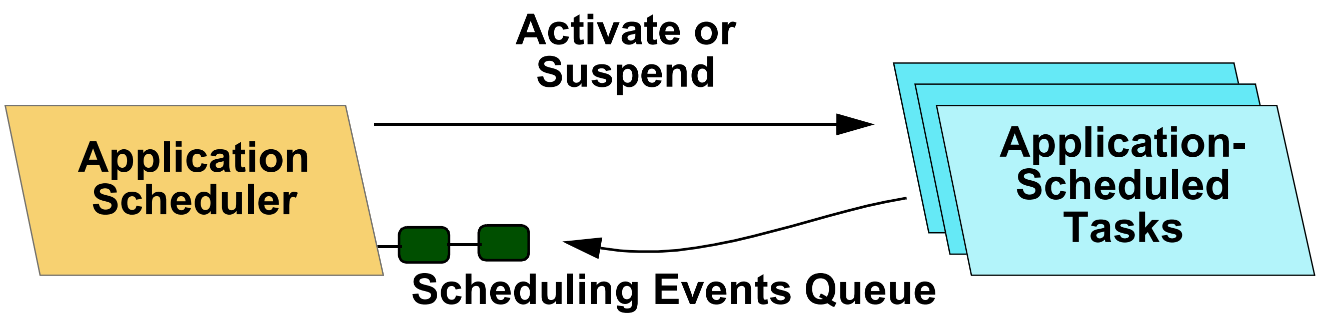
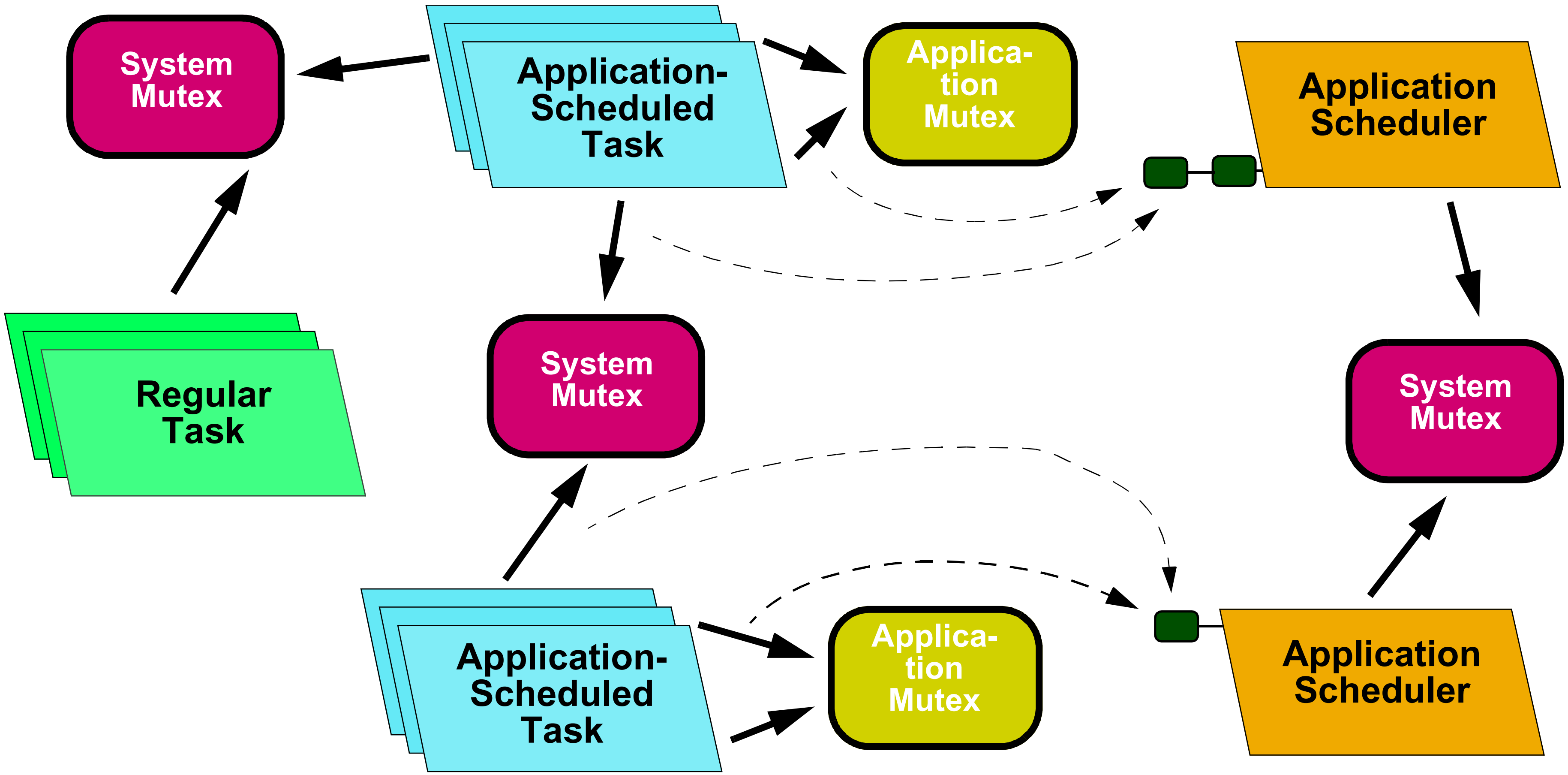
- Scheduler tasks are always invoked before their scheduled tasks
  - They inherit all the priorities inherited by them
  - Schedulers have precedence if same priority
- Schedulers can activate or suspend any of their tasks, and must accept (or reject) them at creation
- They are notified about events related to their scheduled tasks



Model Description (Cont'd)



5. Scheduling Events

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They represent situations relevant to the application scheduler

They contain the following information

- Type of event
- Task that caused the event
- Event-dependent information:
  - Inherited priority
  - Involved application mutex
  - Signal received
  - Application-specific information

Events may be filtered by type

Scheduling Events (Cont'd)

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Scheduling event type	Additional information
NEW_TASK	none
TERMINATE_TASK	none
READY	none
BLOCK	none
YIELD	none
SIGNAL	POSIX signal information
CHANGE_SCHED_PARAM	none
EXPLICIT_CALL	Application message
TIMEOUT	none

Scheduling Events (Cont'd)

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Scheduling event type	Additional information
PRIORITY_INHERIT	Inherited system priority
PRIORITY_UNINHERIT	Uninherited system priority
INIT_MUTEX	Pointer to the app. mutex
DESTROY_MUTEX	Pointer to the app. mutex
LOCK_MUTEX	Pointer to the app. mutex
TRYLOCK_MUTEX	Pointer to the app. mutex
UNLOCK_MUTEX	Pointer to the app. mutex
BLOCK_AT_MUTEX	Pointer to the app. mutex
CHANGE_MUTEX_SCHED_PARAM	Pointer to the app. mutex

6. Scheduling Actions

Schedulers have an operation (Execute_Actions) to request execution of multiple actions, including:

- accept or reject a task that has requested attachment
- activate or suspend a task
- accept or reject initialization of an application mutex
- grant the lock on an application mutex

As part of Execute_Actions, the scheduler suspends until:

- the next scheduling event,
- arrival of a POSIX signal (usually indicating expiration of regular or CPU-time timers)
- or the expiration of a timeout

Execute Actions

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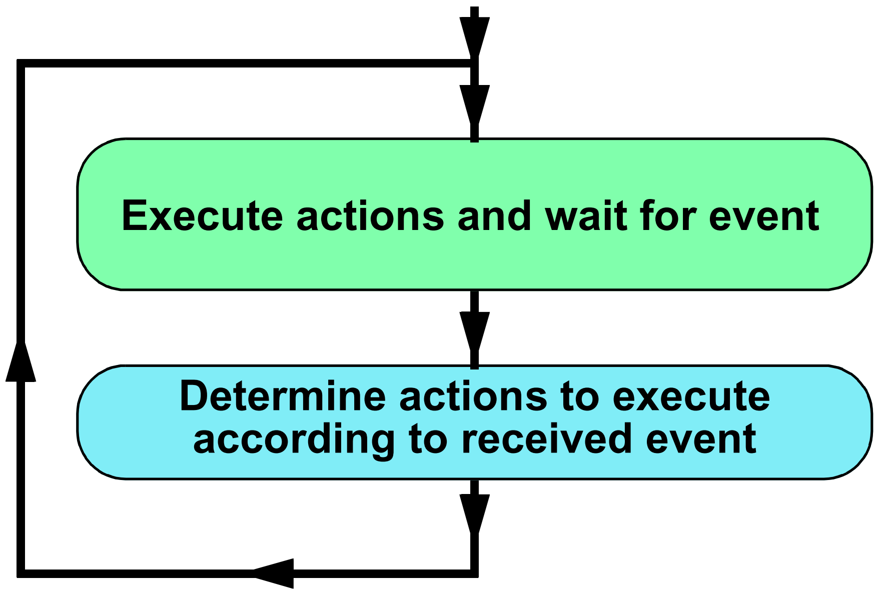
```
procedure Execute_Actions
   (Sched_Actions : in  Scheduling_Actions;
    Set           : in  POSIX_Signals.Signal_Set;
    Event         : out Scheduling_Event;
    Timeout       : in  POSIX.Timespec;
    Current_Time  : out POSIX.Timespec)
    -- other overloaded versions exist
```

Structure of a scheduler:



7. Example of an Application-Defined Policy: EDF

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Application scheduled task:

```
with POSIX_Application_Scheduling;
package AppSched renames POSIX_Application_Scheduling;
...
package EDF_Policy is new
   AppSched.Application_Defined_Policy (EDF_Parameters);
...

task body Periodic_EDF_Task is
   Param : EDF_Parameters := (Deadline, Period);
begin
   EDF_Policy.Change_Task_Policy (EDF_Scheduler_Task_Id, Param);
   loop
      -- do useful work
      ...;
      -- task will wait until the next period
      AppSched.Invoke_Scheduler;
   end loop;
end Periodic_EDF_Task;
```

Example of an Application-Defined Policy: EDF (Cont'd)

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Application Scheduler task:

```
task body EDF_Scheduler is
   ...;
   Most_Urgent_Task     : Task_Id;
   Now, Earliest_Start : POSIX.Timespec;
   Event                : AppSched.Scheduling_Event;
   Sched_Actions        : AppSched.Scheduling_Actions;

begin
   AppSched.Become_An_Application_Scheduler;

   AppSched.Set_Clock(Clock_Realtime);
   AppSched.Set_Flags(Absolute_Timeout);
   Now := POSIX_Timers.Get_Time(Clock_Realtime);

   -- Scheduling events processing loop
   loop
      Schedule_Next(Most_Urgent_Task, Earliest_Start);
```

Example of an Application-Defined policy: EDF (Cont'd)

```
if Most_Urgent_Task /= Null_Task_Id then
   AppSched.Add_Activate (Sched_Actions, Most_Urgent_Task);
end case;
AppSched.Execute_Actions_with_Timeout
           (Sched_Actions, Event, Earliest_Start);

-- process scheduling events
case AppSched.Get_Event_Code(Event) is

 when New_Task =>
   if Schedulability_Test (AppSched.Get_Task(Event)) then
     AppSched.Add_Accept (Sched_Actions,
                          AppSched.Get_Task(Event));
     Add_To_List_of_Tasks (AppSched.Get_Task(Event), Now);
   else
     AppSched.Add_Reject (Sched_Actions,
                          AppSched.Get_Task(Event));
   end if;

 when Terminate_Task =>
   Eliminate_From_List_of_Tasks (AppSched.Get_Task(Event));
```

Example of an Application-Defined policy: EDF (Cont'd)

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```
      when Ready =>
        Make_Active (AppSched.Get_Task (Event));

      when Block =>
        Make_Blocked (AppSched.Get_Task (Event));

      when Explicit_Call =>
        AppSched.Add_Suspend (Sched_Actions,
                              AppSched.Get_Task (Event));
        Make_Timed (AppSched.Get_Task (Event));

      when Timeout =>
        null;

      when Others =>  null;
     end case;

   end loop; -- Scheduling events processing loop

end EDF_Scheduler;
```

MaRTE OS

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***M**inim**a**l **R**eal-**T**ime OS for **E**mbedded Applications*

- Follows the POSIX.13 Minimum Realtime System Profile
  - Single process
  - No file system
- Adds new POSIX interfaces: CPU-time Timers
- Written in Ada, with few parts in C or assembly language
- Gnat run-time system runs on top of it
- POSIX threads interface for C threads
- Usable both for C and Ada (and mixed) applications
- Free software

http://marte.unican.es

Performance on a 1.1GHz Pentium III

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Context switches in Ada

Scheduling Algorithm	Context switch (μs)	Overhead for a 1KHz task
Regular Ada delay until statement	5	1%
Round robin within priorities	4.5	0.9%
Constant Bandwidth Server	6	1.2%

Conclusions and Further Work

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APIs for application scheduling in Ada and C

- Performance is acceptable
- Great flexibility
- Compatible with previous fixed priority scheduling
- Implemented in MaRTE OS

Future work

- POSIX standardization
- Integration into the Ada language
  - will require some language extensions (pragmas, ...), specially for protected objects