AADL performance analysis with Cheddar : a summary

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Talk overview

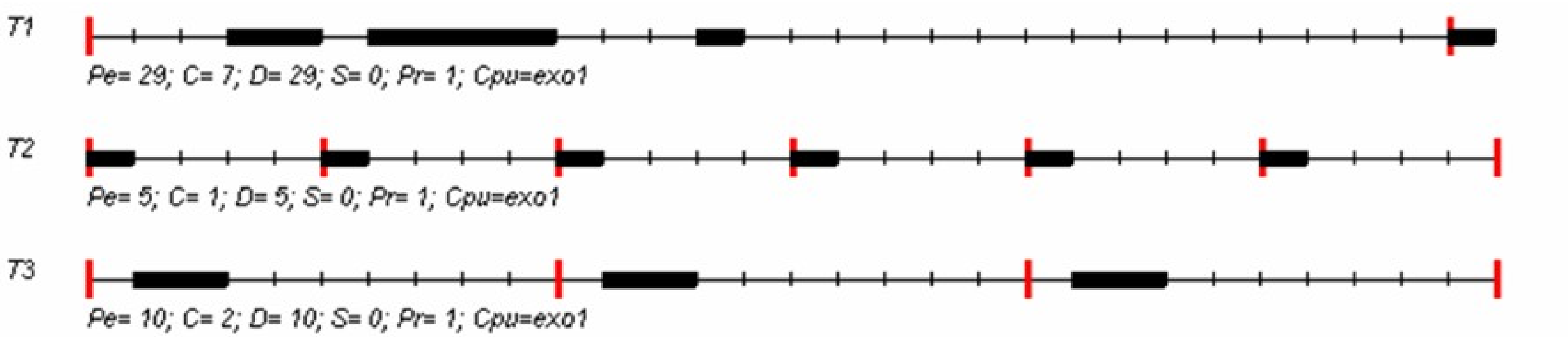
1. The Cheddar project : context and motivations
2. Simple real time scheduling analysis with Cheddar/AADL
3. Multi-resources analysis with Cheddar/AADL
4. Using user-defined schedulers and thread dispatching rules with Cheddar/AADL
5. Conclusion and roadmap

The Cheddar project : context and motivations (1/2)

- **Real time scheduling theory :**

1. **Analytical analysis (feasibility tests) :** $\sum_{i=1}^{n} \frac{Ci}{Pi} \leq 69\%$

2. **Scheduling Simulation analysis** :
   - Compute time-lines and perform analysis (eg. check thread deadline).
   - Sometimes leads to a proof (model-checking = simulation on base period).



The Cheddar project : context and motivations (2/2)

- **Few industrial projects apply real time scheduling theory.**

- **Cheddar project expects to increase its usability by :**
  - Providing tools which allow to automatically perform analysis.
  - Investigating relationships with design languages (AADL).
  - Extending the theory with practitioner requirements (eg. memory footprint analysis).

- **Cheddar project :**
  1. Started in May 2000 by the Univ. of Brest.
  2. November 2004, partnership with ENST (Cheddar relies on Ocarina).
  3. January 2008, partnership with Ellidiss Technologies (Cheddar/Stood interoperability, provides support on Cheddar).

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Simple real time scheduling analysis with Cheddar/AADL (1/3)

- **Simplest way to use Cheddar : give AADL V1 properties + some other Cheddar specific properties.**
- **AADL V1 provides most of required properties. Extra required properties :**
  - Properties related to usual schedulers (eg. POSIX 1003.1b properties, quantum, preemptivity, …).
  - Thread properties (eg. jitter, offset, priority …)
  - When shared resources are accessed by thread ? Thread behavior ?
  - Ambiguities to express thread precedence relationships from AADL connections.

Simple real time scheduling analysis with Cheddar/AADL (2/3)

- **Example 1 :** periodic thread + POSIX 1003.1b scheduler

```
thread implementation T3.i
    properties
        Source_Text => "mes_threads.c";
        Dispatch_Protocol => Periodic;
        Compute_Execution_time => 1 ms .. 2 ms;
        Deadline => 10 ms;
        Period => 10 ms;
end T3.i;
thread implementation fifo2.i
    properties
        Dispatch_Protocol => Background;
        Compute_Execution_time => 1 ms .. 3 ms;
        Cheddar_Properties::POSIX_Scheduling_Policy =>
                SCHED_FIFO;
        Cheddar_Properties::Fixed_Priority => 5;
        Cheddar_Properties::Dispatch_Absolute_Time => 4 ms;
end fifo2.i;
```

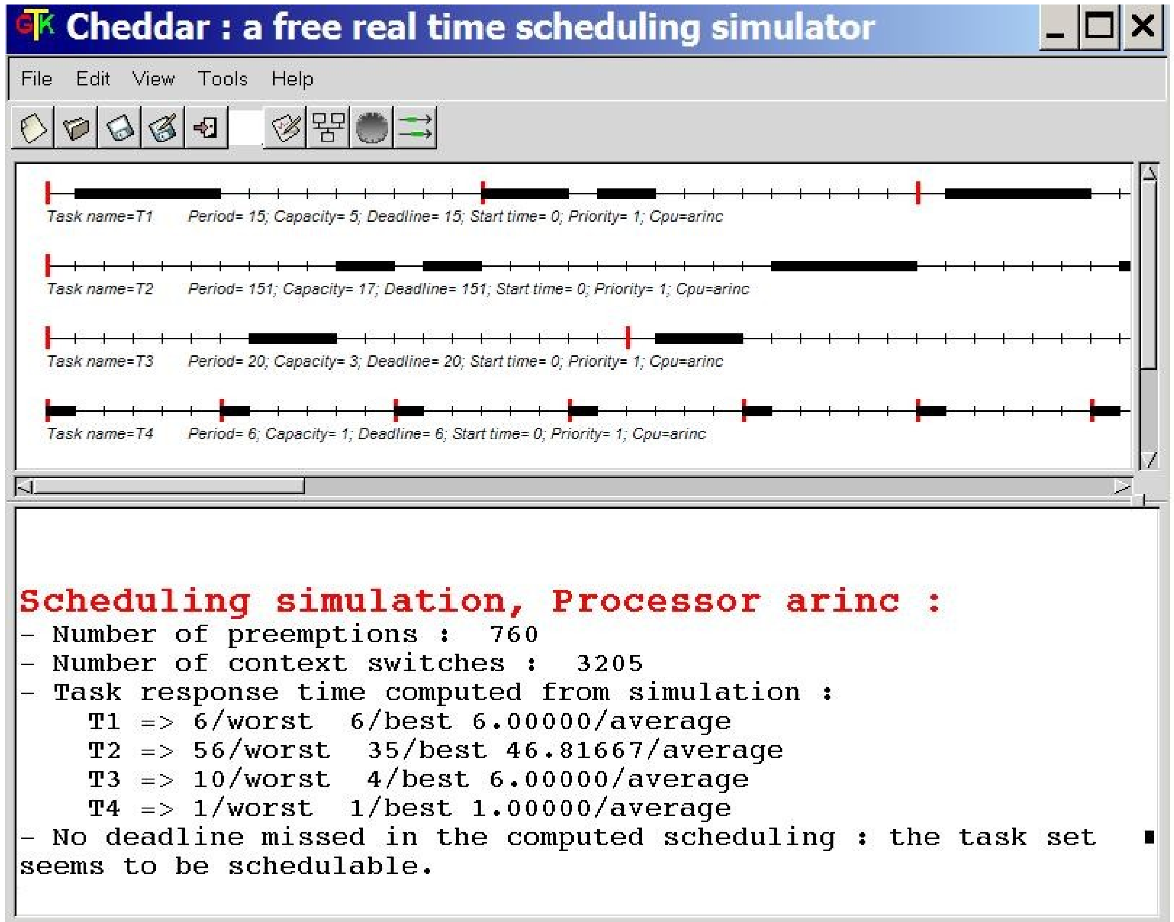
```
process implementation proc0.i
    subcomponents
        a_T3 : thread T3.i;
        ....
processor implementation rma_cpu.i
    properties
        Scheduling_Protocol => RATE_MONOTONIC;
        Cheddar_Properties::Preemptive_Scheduler => true;
        Cheddar_Properties::Scheduler_Quantum => 3 ms;

end rma_cpu.i;
system implementation a_system.Impl
  subcomponents
     a_cpu : processor rma_cpu.i:
     an_application : process proc0.i;
  properties
…
```

Simple real time scheduling analysis with Cheddar/AADL (3/3)

Compute simulation

Analysis from scheduling simulation or with feasibility tests (eg. deadlines, response times)



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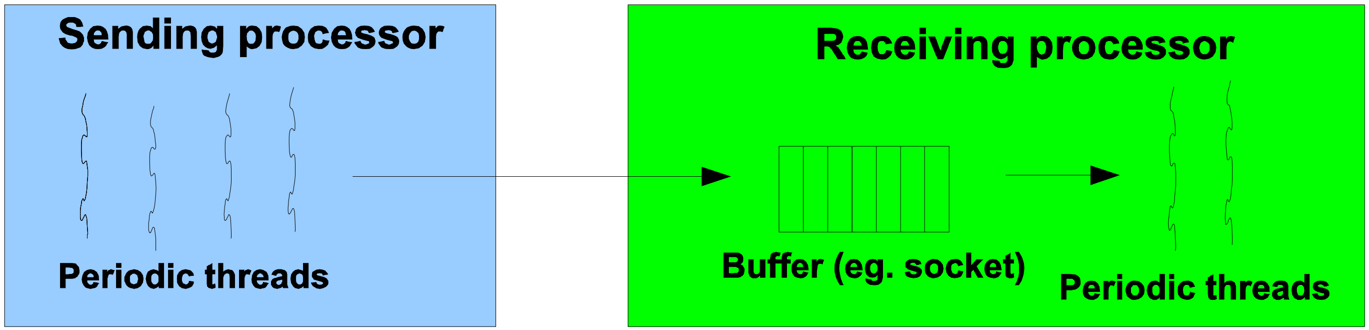
Multi-resources analysis (1/4)



- An AADL model may contain information on different resources (processor, memory, networks, …).
- AADL allows to jointly manage several resources.
- Thread communications by event data ports.
- Memory footprint analysis with queueing system analytical tools.

Multi-resources analysis (2/4)

- **Queueing system models :** define producer rate and consumer rate, in order to compute criteria such as message waiting time or number of waiting messages.

- **Define new queueing system models M/P/1 and P/P/1 :**
  - Take into account AADL threads dispatching (periodic, sporadic).
  - Take into account thread scheduling (eg. Rate Monotonic).

- **Define feasibility tests from these queueing systems models** => worst case memory footprint analysis based on P/P/1.

Multi-resources analysis (3/4)

- **Example 2 :** event data port connections

```
processor implementation cpu_rm.i
        properties
                Scheduling_Protocol => Rate_Monotonic;
                ...
end cpu_rm.i;
process implementation p0.i
 subcomponents
   Producer1 : thread Producer.i;
   Producer2 : thread Producer.i;
   Consumer1 : thread Consumer.i;
connections
   event data  port Producer1.Data_Source ->
      Consumer1.Data_Sink;
   event data  port Producer2.Data_Source ->
      Consumer1.Data_Sink;
end p0.i;
```

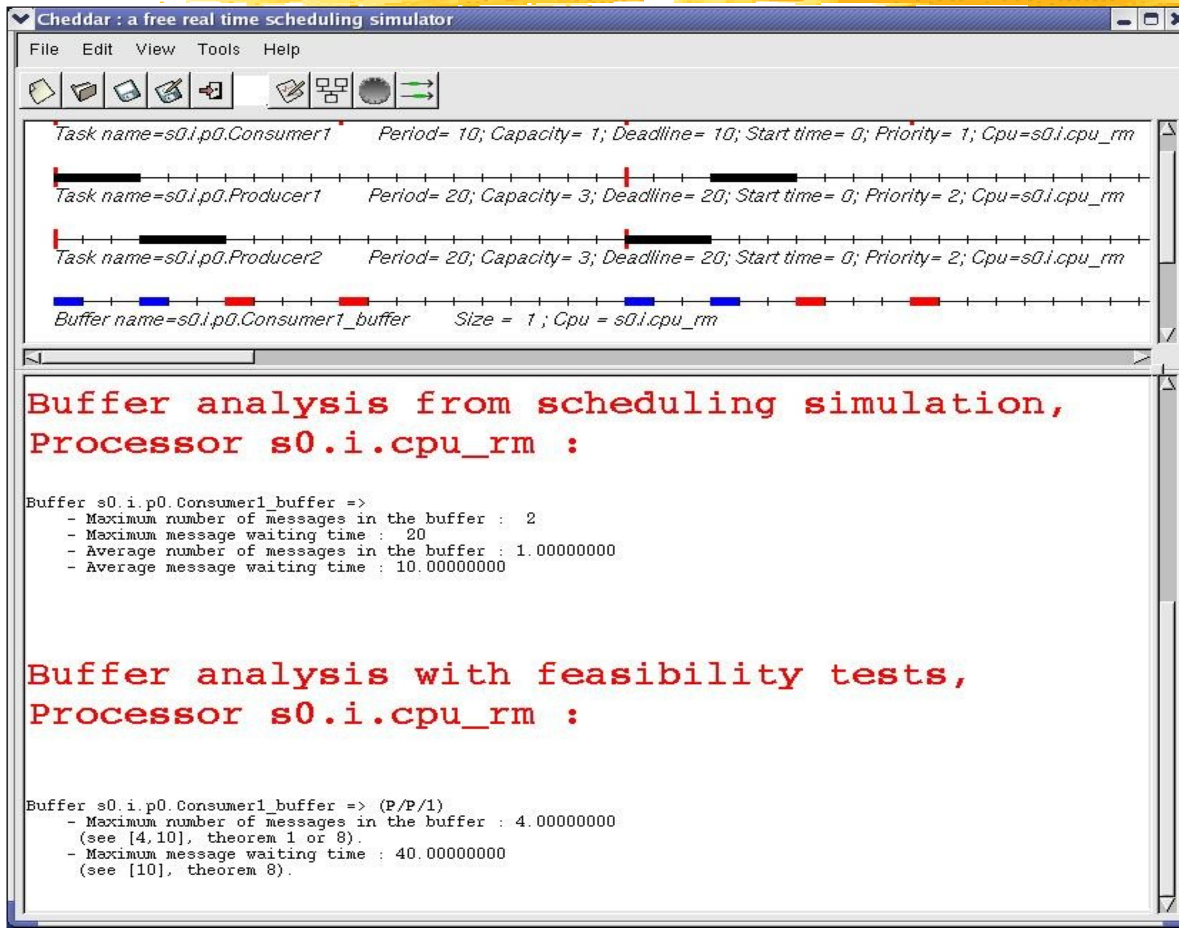
```
thread Producer
 Features
   Data_Source : out event data port;
end Producer;
thread Consumer
 features
   Data_Sink : in event data port;
end Consumer;

thread implementation Producer.i
        properties
                Dispatch_Protocol=>periodic;
                ...
end Producer.i;
thread implementation Consumer.i
        properties
                Dispatch_Protocol=>periodic;
                ...
end Consumer.i;
```

Multi-resources analysis (4/4)

Buffer simulation

Analysis from simulation

Worst case queueing system analysis (based on P/P/1)



AADL tools interoperability

- **For most AADL designers, using Cheddar alone is difficult**

=> investigate Stood and Cheddar interoperability.

- **Define properties that we look for :**

  A. The worst case thread response times;
  B. The bounds on the thread waiting time due to data access;
  C. The deadlocks and priority inversions due to data access,
  D. …

- **Define design patterns to be analyzed :**

	performance criteria			
1. Synchronous Data flows..........	A			
2. Mutex protected shared Data..	A	B	C	
3. Blackboard...............................	A	B	C	
4. Queued Buffer..........................	A	B	C	D

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The Cheddar domain specific language (1/6)

- **The Cheddar language aims at modelling of real time schedulers and thread dispatching rules.**

- **Modelling a real time scheduler requires:**

  1. Modelling arithmetic and logical statements
     (eg. how to compute priorities, how to select a thread).
  2. Modelling timing and synchronization relationships between threads and schedulers
     (eg. when threads must be released by schedulers, how schedulers must work all together, …).

The Cheddar domain specific language (2/6)

- **The Cheddar language is composed of 2 parts :**

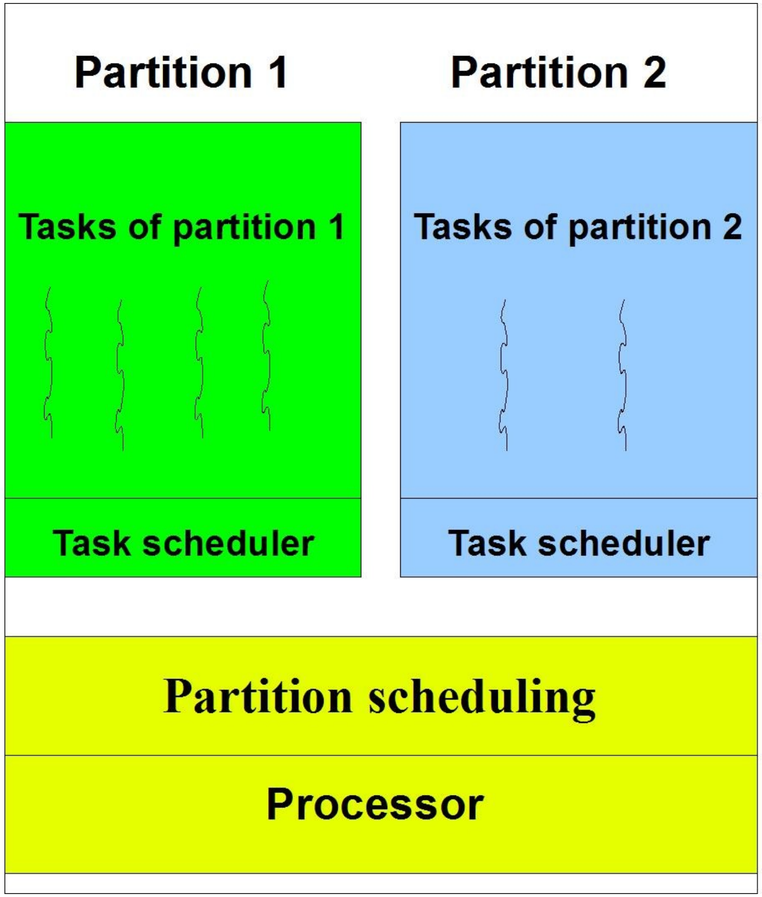
1. **An Ada subset modelling the arithmetic/logical statements :**
   - A Cheddar program is a set of sections (sub-programs).
   - Types of section :
     - Start sections : variable declaration and initialization.
     - Priority sections : compute priorities during simulation.
     - Election sections : choose the thread to run.

2. **A timed automaton language modelling timed synchronization :**
   - A set of UPPAAL like timed automata modelling thread and scheduler behavior.
   - States. Transitions. Transitions may express synchronization, guards and clock statements.

The Cheddar domain specific language (3/6)

- **Partition =** application with timing and memory isolation.

- **ARINC 653 scheduling (hierarchical scheduling) :**
  1. Choose when each partition must be activated. This scheduling is fixed at design time.
  2. Run tasks of a given partition according to a fixed priority scheduler (eg. Rate Monotonic).



The Cheddar domain specific language (4/6)

- **Modelling such a kind of hierarchical system with AADL version 1 require to :**
  - Model the architecture point of view (**AADL V1**).
  - Model the scheduler behavior (**Cheddar programs**).

The Cheddar domain specific language (5/6)

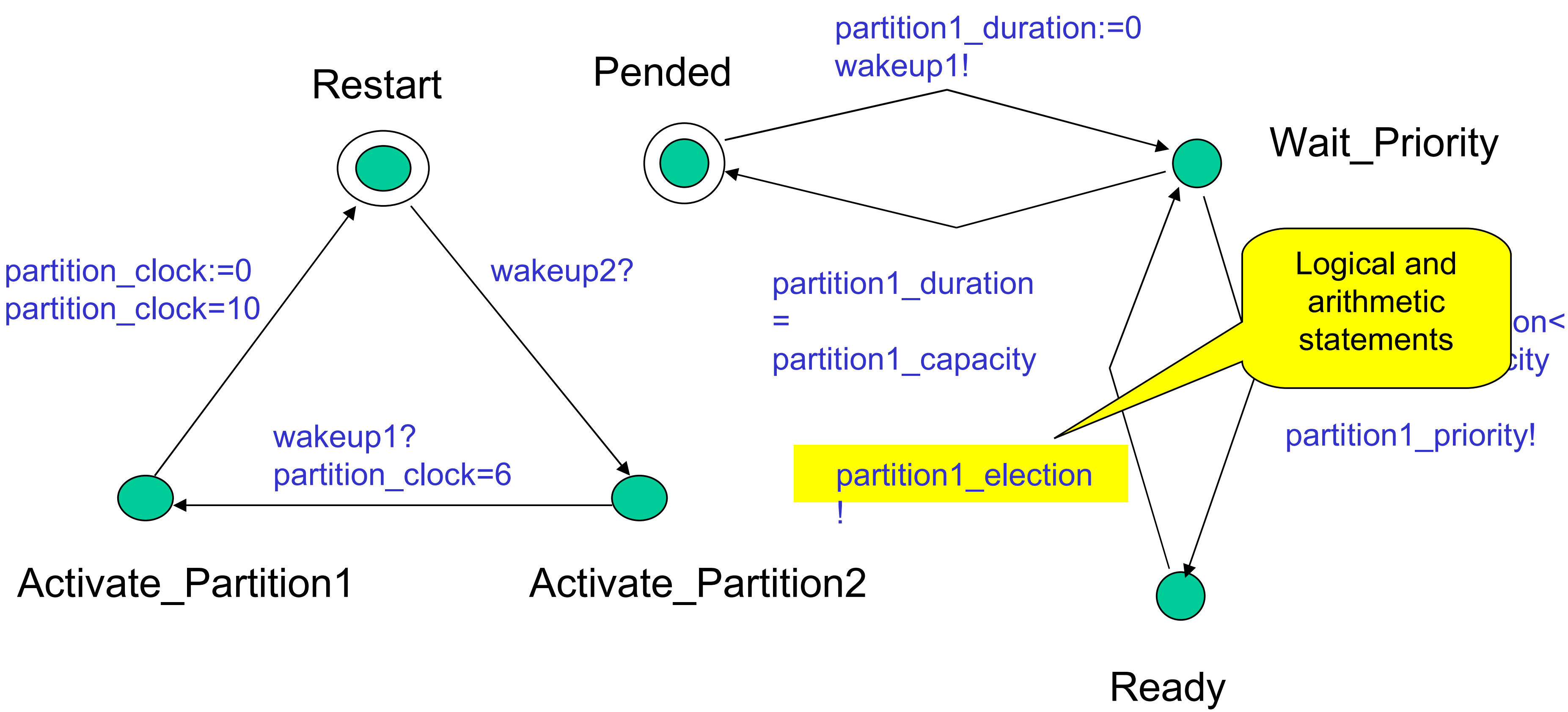
- **Example 3:** AADL Version 1 modelling the architecture

```
thread T1 …
thread T2 …
…
process implementation partition1.Impl
   subcomponents
      T3 : thread T3.Impl;
      T4 : thread T4.Impl;
   properties
      Scheduling_Protocol
         =>  Automaton_User_Defined_Protocol;
end partition1.Impl;
```

```
processor implementation arinc.Impl
   properties
      Scheduling_Protocol
         => Automaton_User_Defined_Protocol;
…
system implementation auto_arinc.Impl
   subcomponents
      arinc : processor arinc.Impl;
      partition1 : process partition1.Impl;
      partition2 : process partition2.Impl;
   properties
      Actual_Processor_Binding => reference
         arinc applies to partition1;
      Actual_Processor_Binding => reference
         arinc applies to partition2;
end auto_arinc.Impl;
```

The Cheddar domain specific language (6/6)

- Cheddar programs modelling a hierarchical scheduler:



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Conclusion and roadmap

- **Current status of Cheddar/AADL :**
  - First release in November 2005.
  - Cheddar/AADL relies on Ocarina (ENST, http://ocarina.enst.fr).
  - Cheddar web site : http://beru.univ-brest.fr/~singhoff/cheddar

- **Roadmap :**
  1. May 2008, new release of Cheddar (managed by Ellidiss).
     - Fixed bugs + Cheddar language with AADL version 1
  2. November 2008, Stood/Cheddar experiments :
     - AADL tool interoperability : design patterns in AADL/behavioral annex.
     - Behavioral annex meta-model and Ada parser (should work with Ocarina).
     - Towards AADL V2 : from Cheddar program to behavioral annex ?