Demo

High-Performance Parallelisation of Real-Time Applications with the Upscale SDK

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CISTER-TR-170204

2017/03/27

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Abstract

Nowadays, the prevalence of computing systems in our lives is so ubiquitous that it would not be far-fetched to state that we live in a cyber-physical world dominated by computer systems. These systems demand for more and more computational performance to process large amounts of data from multiple data sources, some of them with guaranteed processing response times. In other words, systems are required to deliver their results within pre-defined (and sometimes extremely short) time bounds. Examples can be found for instance in intelligent transportation systems for fuel consumption reduction in cities or railway, or autonomous driving of vehicles.To cope with such performance requirements, chip designers produced chips with dozens or hundreds of cores, interconnected with complex networks on chip. Unfortunately, the parallelization of the computing activities brings many challenges, among which how to provide timing guarantees, as the timing behaviour of the system running within a many-core processor depends on interactions on shared resources that are most of the time not know by the system designer.P-SOCRATES (Parallel Software Framework for Time-Critical Many-core Systems) is an FP7 European project, which developed a novel methodology to facilitate the deployment of standardized parallel architectures for real-time applications. This methodology was implemented (based on existent models and components) to provide an integrated software development kit, the UpScale SDK, to fully exploit the huge performance opportunities brought by the most advanced many-core processors, whilst ensuring a predictable performance and maintaining (or even reducing) development costs of applications. The presentation will provide an overview of the UpScale SDK, its underlying methodology, and the results of its application on relevant industrial use-cases.

P-SOCRATES

Parallel Software Framework for Time-Critical many-core Systems

High-performance parallelization of real-time applications with the UpScale SDK

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Barcelona Supercomputing Center
Centro Nacional de Supercomputación

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Atos

This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement nº 611016

Outline

- P-SOCRATES at a glance
- Motivation and Vision
- Technical Approach
- The **UpScale** SDK
- Conclusions

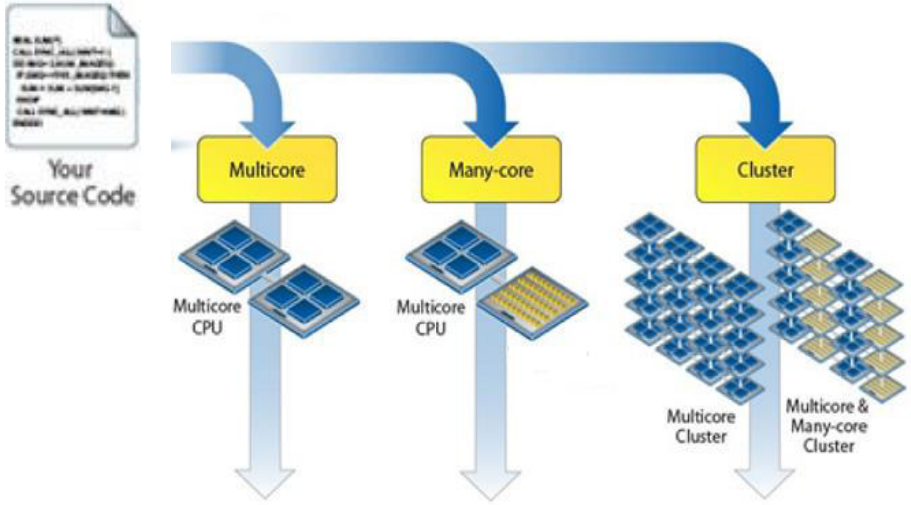
Quick fact sheet

- **P-SOCRATES: P**arallel **SO**ftware framework for time-**CR**itical m**A**ny-core sys**TE**m**S**
- Three-year FP7 STREP project (Oct-2013, Dec-2016)
- **Website:** www.p-socrates.eu
- Budget: 3.6 M€
- Partners
- Industrial Advisory Board

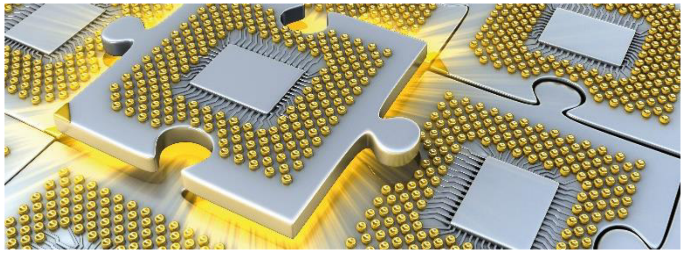
City of Bratislava

Motivation

- New applications challenge the performance capabilities of hardware platforms by crossing the boundaries of computing domains
  - Demand of increased **performance** with **guaranteed processing times**
    - Demands can only be met by **advanced parallel computing platforms**
  - **Programmability** of parallel platforms **is a major challenge**
    - Need to integrate **parallel programming models** in embedded systems



Vision

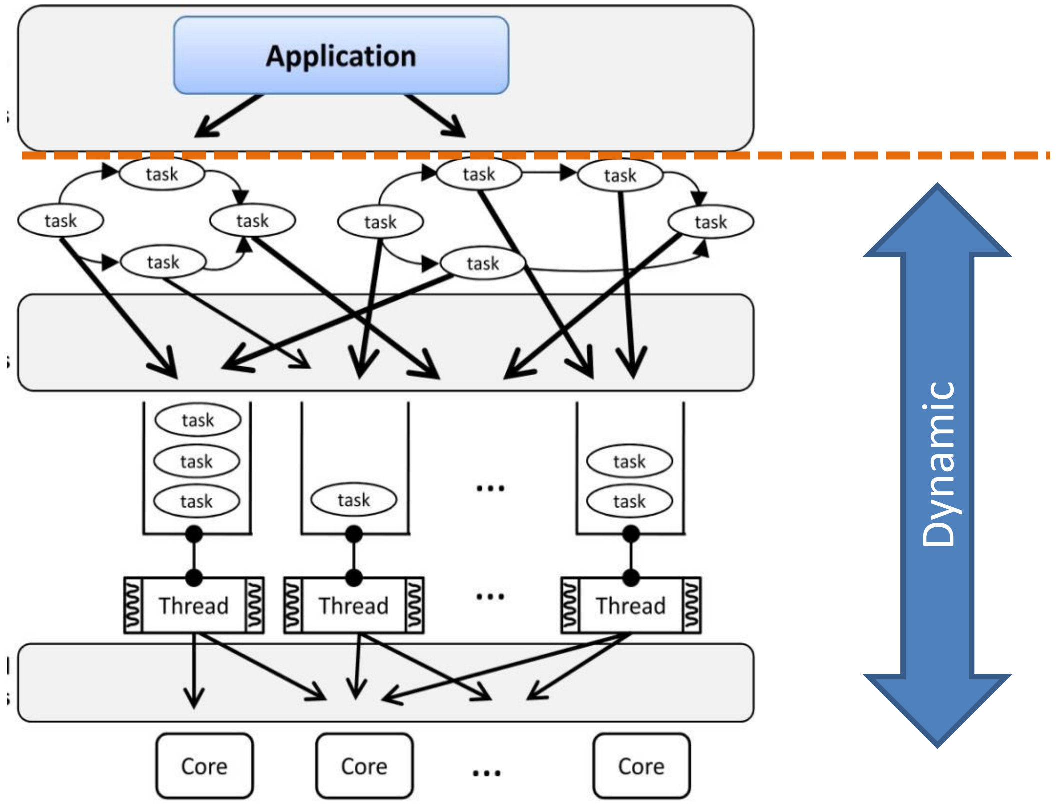


next-generation embedded **many-core accelerators**

real-time methodologies to provide **time predictability**

programmability of many-core from high-performance computing

Vision


Application
task
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...
Thread
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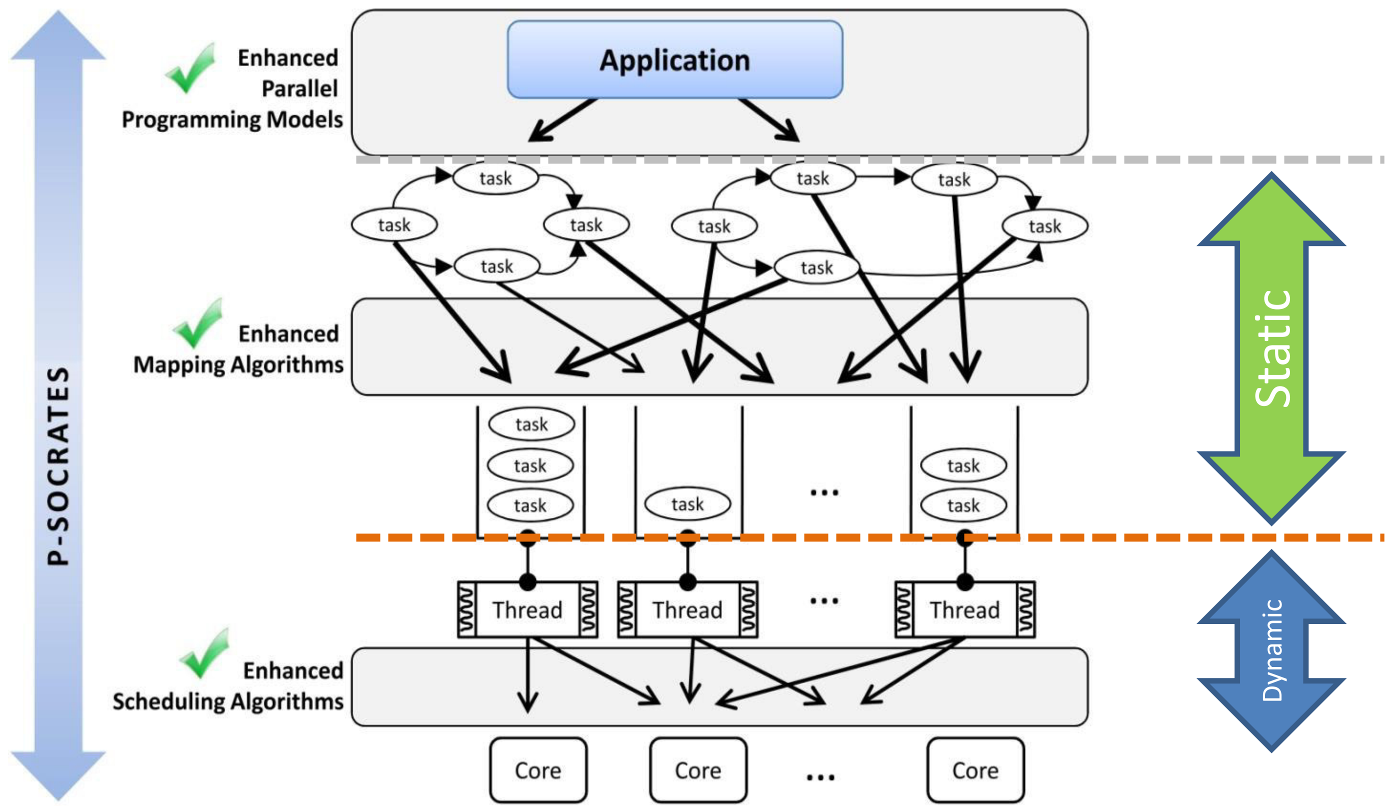
...
Thread
Core
Core
...
Core
Dynamic

Vision

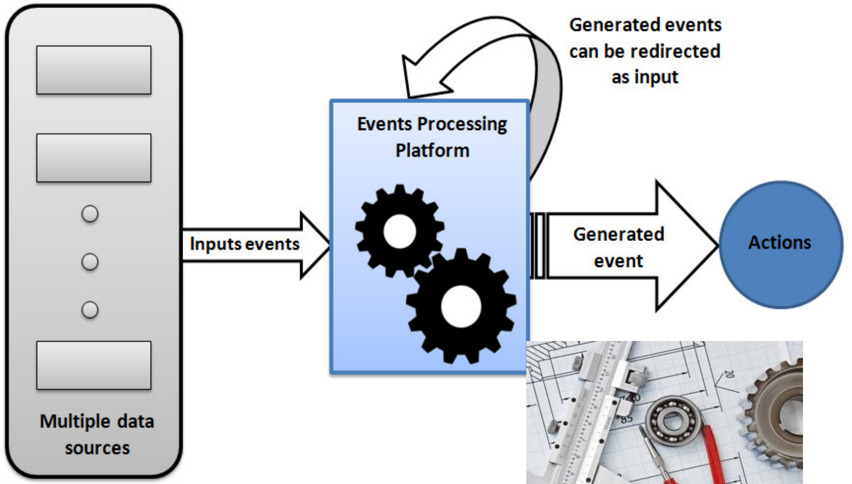


P-SOCRATES
Enhanced Parallel Programming Models
Application
task
Enhanced Mapping Algorithms
...
Thread
Enhanced Scheduling Algorithms
Core
Static
Dynamic

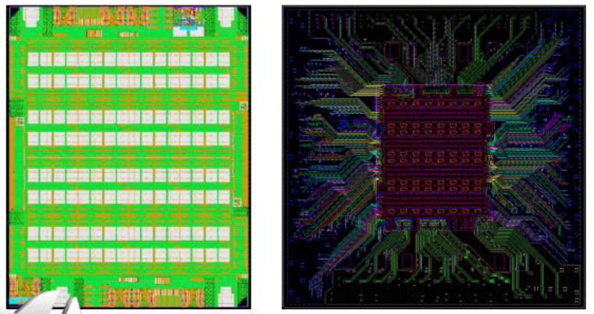
Innovation

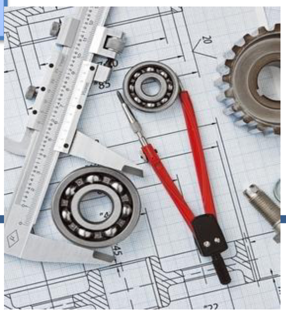
- A **generic framework**, integrating models, tools and system software, to parallel with **high performance** and **real-time** requir

P~~-SOCRATES~~

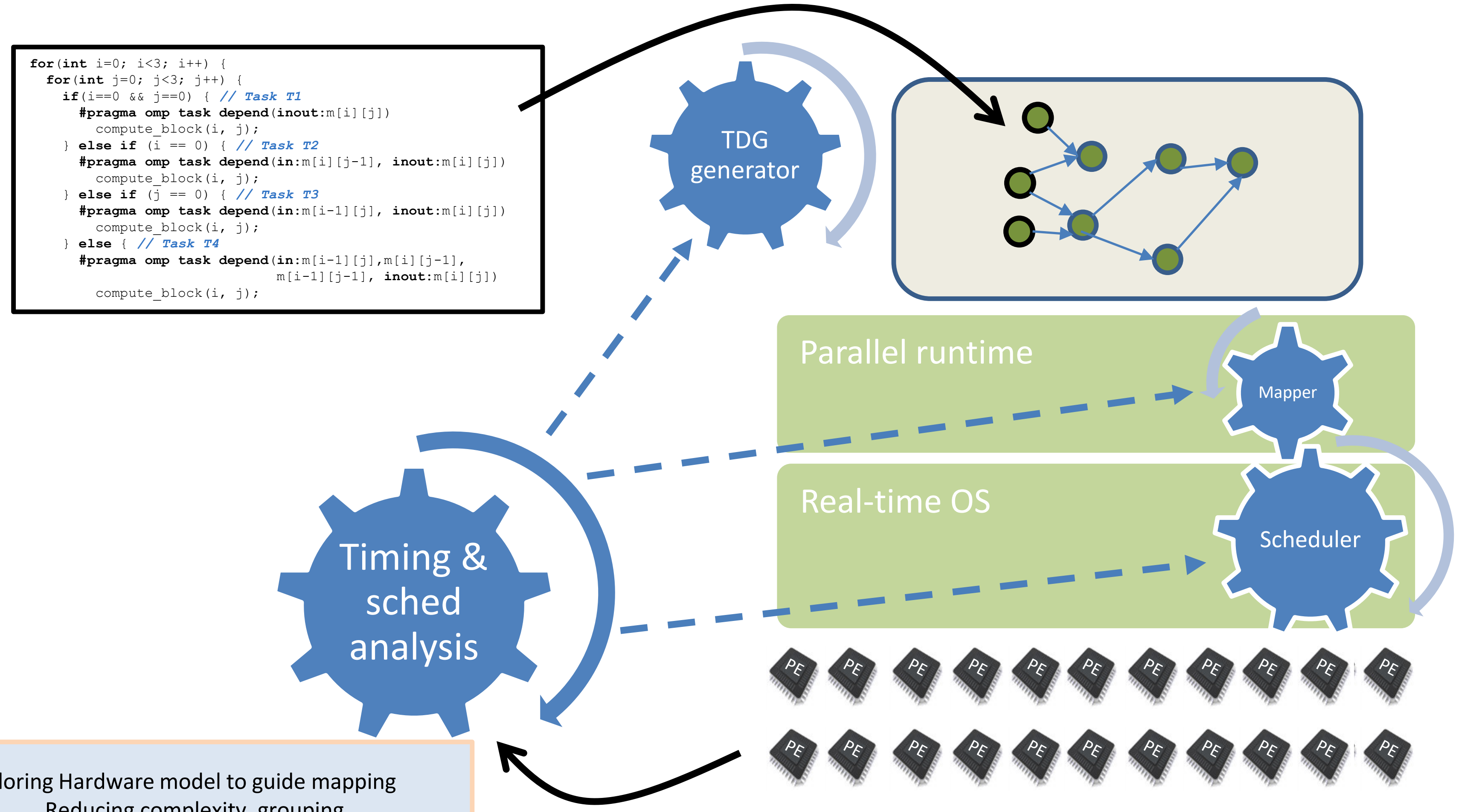


Multiple data sources
Inputs events
Events Processing Platform
Generated events can be redirected as input
Generated event
Actions





Technical Approach



```
for(int i=0; i<3; i++) {
  for(int j=0; j<3; j++) {
    if(i==0 && j==0) { // Task T1
      #pragma omp task depend(inout:m[i][j])
        compute_block(i, j);
    } else if (i == 0) { // Task T2
      #pragma omp task depend(in:m[i][j-1], inout:m[i][j])
        compute_block(i, j);
    } else if (j == 0) { // Task T3
      #pragma omp task depend(in:m[i-1][j], inout:m[i][j])
        compute_block(i, j);
    } else { // Task T4
      #pragma omp task depend(in:m[i-1][j],m[i][j-1],
                                  m[i-1][j-1], inout:m[i][j])
        compute_block(i, j);
```

Exploring Hardware model to guide mapping

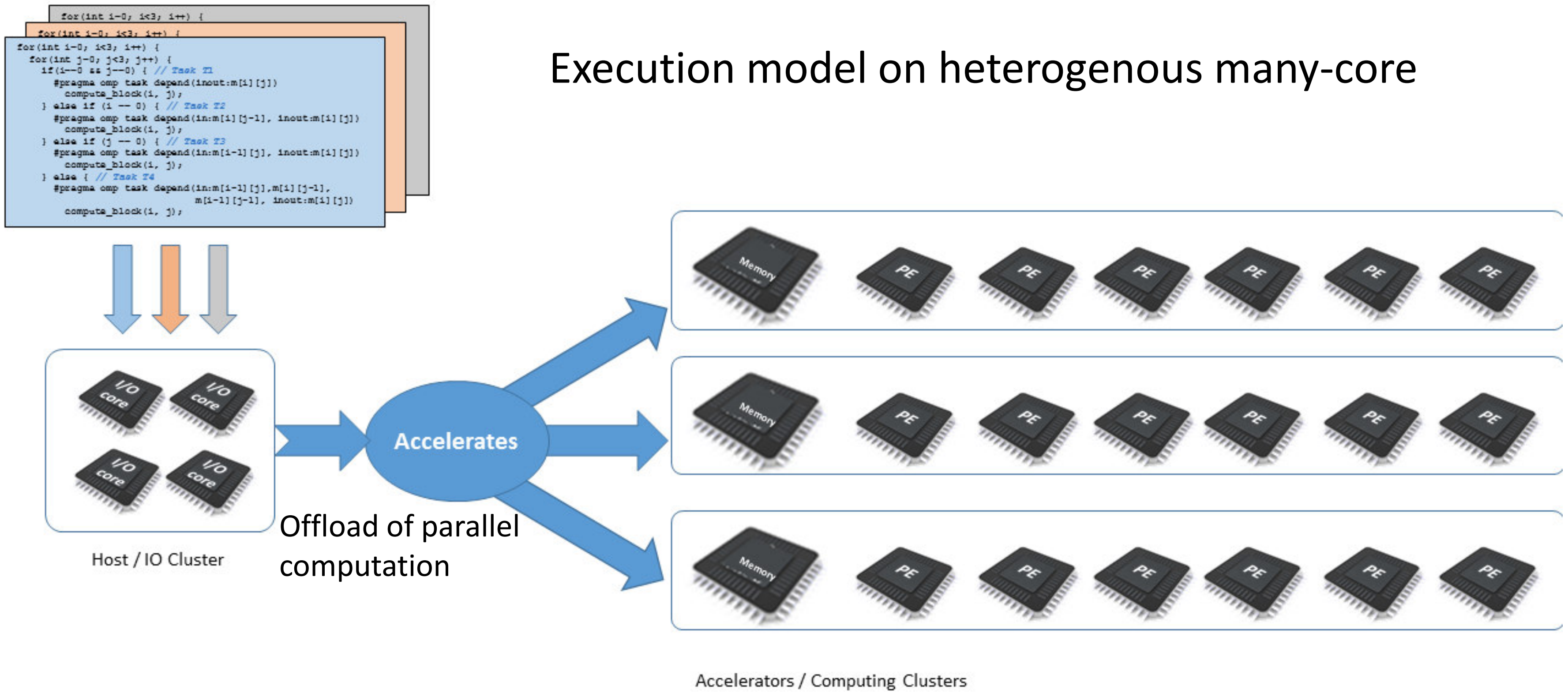
- Reducing complexity, grouping
- Scheduling communication/computation
- Explore measurement-based approaches

Clustered architecture to provide composability

Run-time tracing

Technical Approach

Execution model on heterogenous many-core



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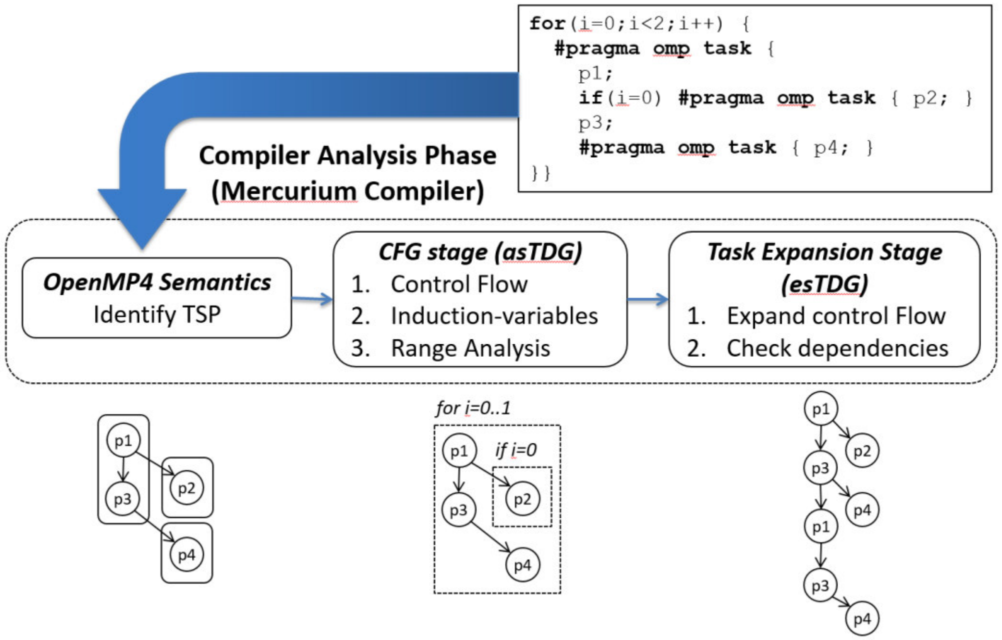
    } else { // Task T4
      #pragma omp task depend(in:m[i-1][j],m[i][j-1],
                                 m[i-1][j-1], inout:m[i][j])
        compute_block(i, j);
```

Offload of parallel computation

Technical Approach

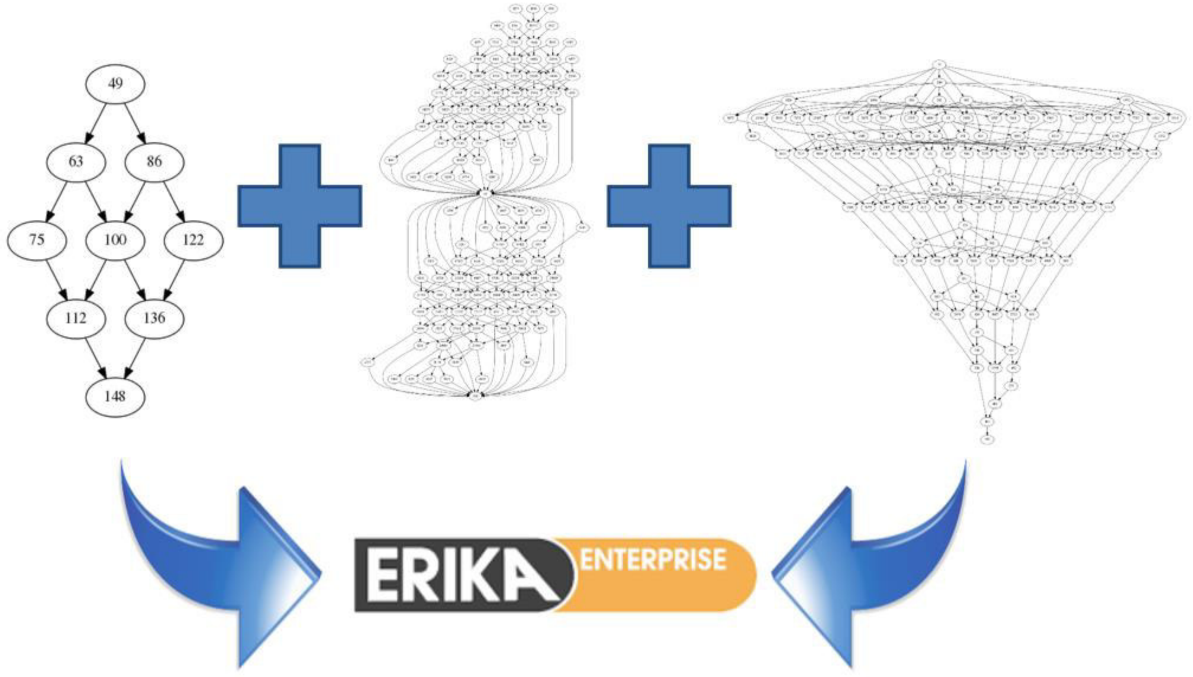
- Extraction of parallelism with data-flow annotations
  - OpenMP tasking semantics generates a graph of control and data flow task execution



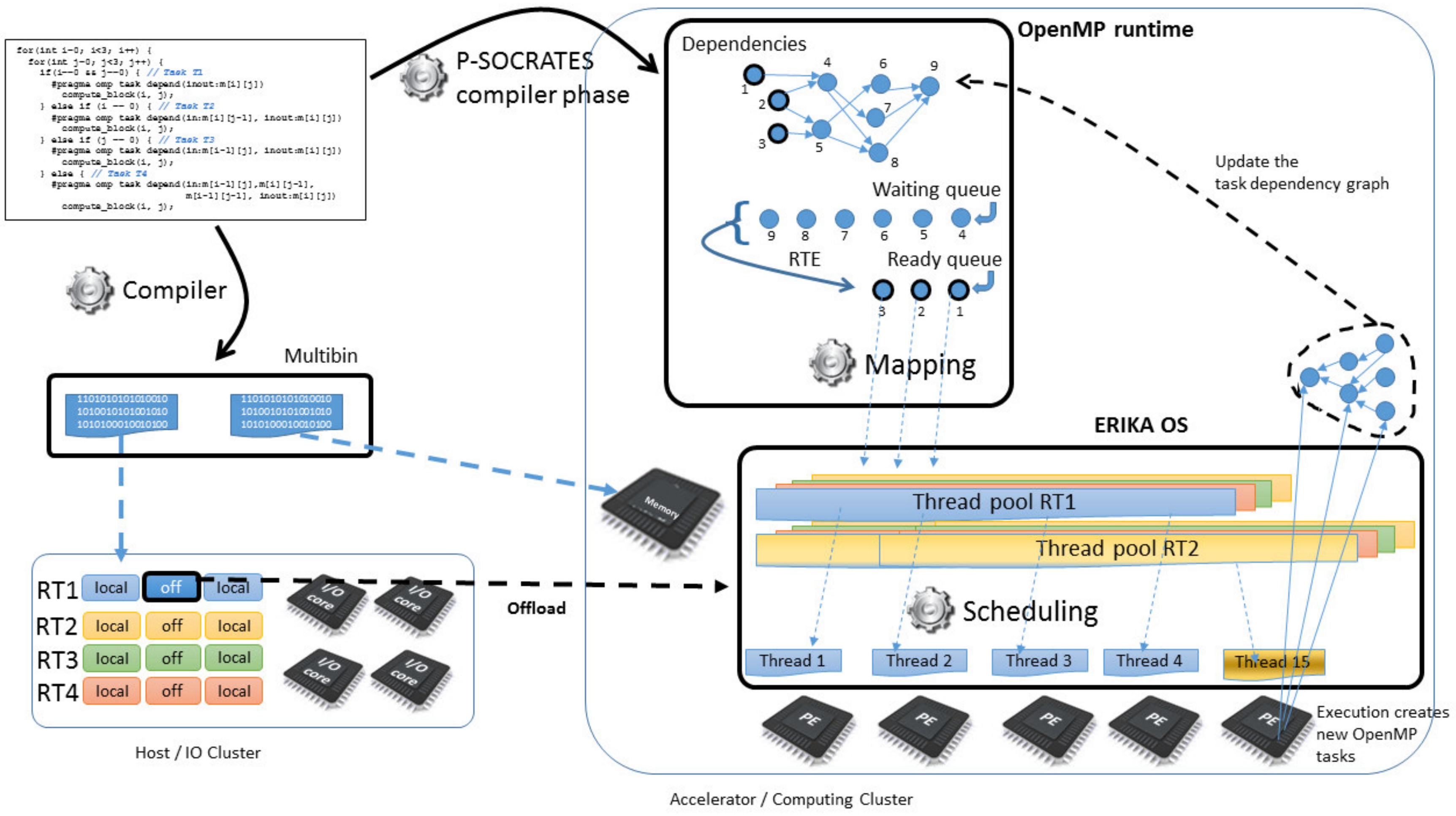
```
for(i=0;i<2;i++) {
  #pragma omp task {
    p1;
    if(i=0) #pragma omp task { p2; }
    p3;
    #pragma omp task { p4; }
}}
```

Technical Approach

- Scheduler
  - Both static mapping partitioned and dynamic mapping global scheduling approaches



Technical Approach



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      #pragma omp task depend(in:m[i-1][j],m[i][j-1],
                                  m[i-1][j-1], inout:m[i][j])
        compute_block(i, j);
```
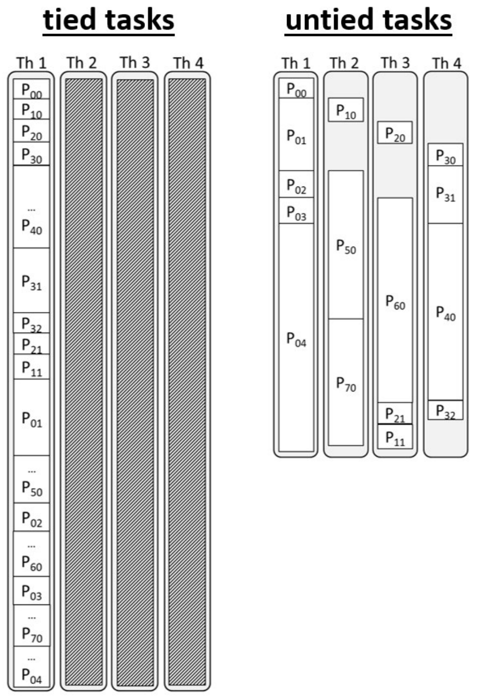

Technical Approach

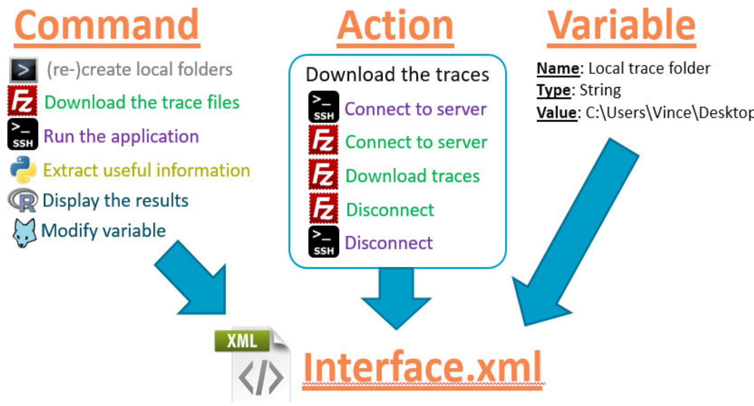
- Schedulability Analysis
  - Schedulability analysis of OpenMP tasking DAGs, considering both tied and untied tasks

```
#pragma omp parallel num_threads(N) {
#pragma omp single { // T0
  part00
  #pragma omp task { // T1
    part10
    #pragma omp task {  // T2
      part20
      #pragma omp task {  // T3
        part30
        #pragma omp task { part40 } // T4
        #pragma omp taskwait
        part31
      }
      #pragma omp taskwait
      part21
    }
    #pragma omp taskwait
    part11
  }
  part01
  #pragma omp task { part50 } // T5
  part02
  #pragma omp task { part60 } // T6
  part03
  #pragma omp task { part70 } // T7
  part04
}}
```

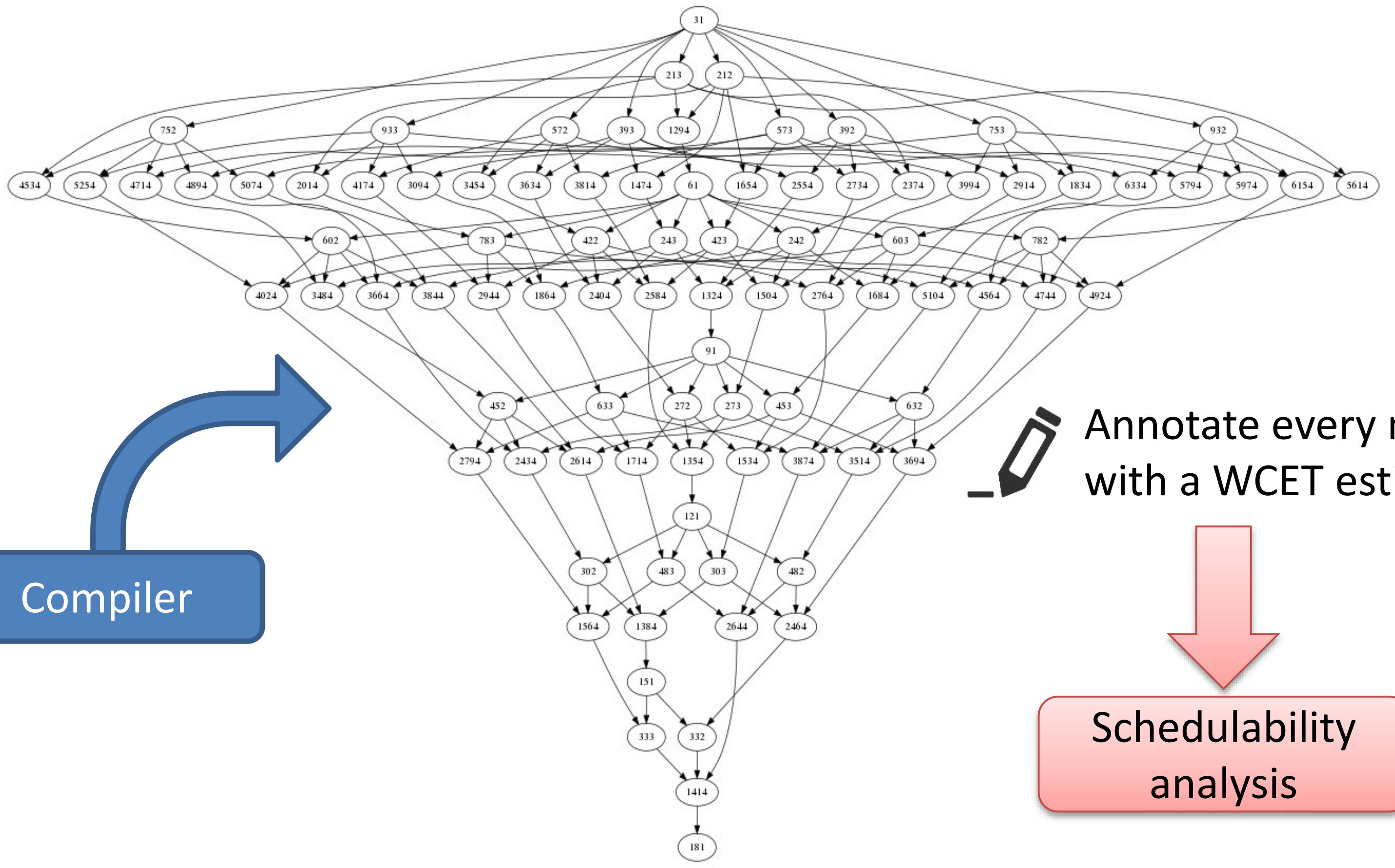


Technical Approach

- Timing Analysis
  - Exploring measurement-based approaches
    - Allowing to analyze and reason about an application timing behavior
  - Collecting execution traces is a tedious process
    - Involves many steps, in different languages
  - Developed measurement-based trace collecting and analysis tool
    - Collecting runtime execution traces is fully automatic
    - Extract and compute statistical information from the traces



P-SOCRATES TA Objectives



Compiler

Annotate every node with a WCET estimate

Schedulability analysis

Use-cases

- Intelligent Traffic Application
  - Complex event processing engine for public transport
- Space Case Study
  - Pre-processing application for infrared detectors used for the Ecluid space mission
- Online Text Semantics
  - Tool performs semantic analysis, categorizes and extracts information from text
- All case studies will execute on a COTS processor
  - Kalray MPPA Bostan

Conclusions

- Integrating time-predictability in high-performance embedded computing brings difficult challenges that need to be addressed
  - High-performance hardware and software stacks are not designed for predictability.
- The P-SOCRATES project tackled this important challenge by devising a methodology and the UpScale SDK
  - Allows to reason on the timing and schedulability analysis of real-time high-performance applications.
- The dynamic configuration approach achieves the same average performance than the default SDK
  - Static approach achieves higher **Guaranteed Performance**, with similar average performance (~10%)

Thank you

Post-project work partially supported by National Funds through FCT/MEC (Portuguese Foundation for Science and Technology) and co-financed by ERDF (European Regional Development Fund) under the PT2020 Partnership, within the CISTER Research Unit (CEC/04234).