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Parallel Programming Model for Distributed Architecture MPSoC

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Distributed Architecture MPSoC

- Heterogeneous distributed scalable architectures with coarse-grained cores are the trend in embedded application specific MPSoC
- Programming of coarse-grained heterogeneous MPSoC remains a challenging task
- It requires new parallel programming paradigms and computational models for application specific MPSoC -- Parallel Programming Model (PPM)

What is a **Distributed Architecture**?

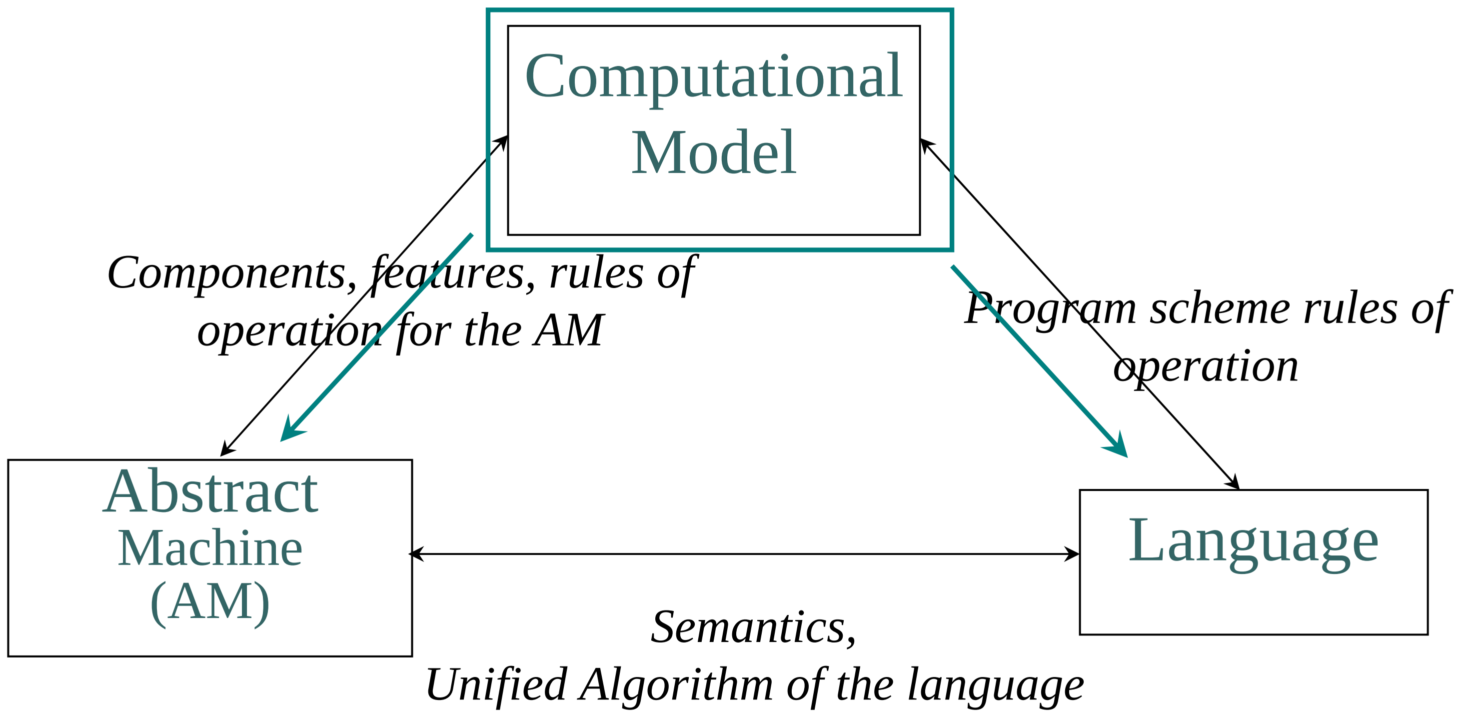
- *Distributed control* – a Computing Module (Node) has its own independent local control (“program counter”)
- *Distributed memory* – a local memory in Computing Module (Node) with a separate address space.
  No global address space
- *Message-passing* interaction between Computing Modules (Nodes)

It could be called *Network Architecture* also,
if it would not pull us too far into similarities with Internet …

Parallel Programming Model incorporates

- **Programmer's vision of the Computing Platform** :
 – a generalized representation of the computer (Abstract Machine) he is programming
- **Programmer's vision of a Parallel Computation** (principles of operation and control)
– parallel computation paradigm and model
- **Programmer's vision of Parallel Programming itself**
 – Parallel programming methodology and Parallel programming language

Development of Abstract Machine (AM) Parallel Computational Model (CM) and Parallel Programming Language (PPL) are interrelated tasks that require integral approach.



MPSoC as a platform for application-specific parallel computations

MPSoC as a specific parallel computer is *an entity for implementation of co-operating processes*.

Nature and features of systems of processes should define concepts and approach for a computer design and programming.

Core question:

What types of parallel computations
are generated by the application-specific MPSoC workload ?

- Parallelism level and granularity
- Fixed / Static / Dynamic

MPSoC Parallelism Levels

3 levels of MPSoC Parallelism:

- *Task-level parallelism (**tlp**)*
  To be used in:
  - Parallel Algorithms development;
  - Parallel source code programming;
- *Procedure-level parallelism (**plp**)*
  To be used in:
  - Parallel source code programming;
  - Source code translation and linking;
  - Parallel program optimization;
  - Parallel object code mapping to MPSoC PEs
- *MCA engines' units parallelism (**mup**)*
  To be used in:
  - Procedure program optimization and local parallelization;
  - Multiple Procedure programs mapping to MPSoC PEs

Static vs Dynamic parallel computations

Static computation

+ Low control overheads
+ Low response time

- Excess MPSoC resources (PEs, memory, I/O) expenditure
- Excess power consumption
- Scheduling for maximum function processing time → overrated processing time, underrated performance
- Problems of computation adaptation to varying tasks, MPSoC components faults

Dynamic computation

- Higher control overheads
- Higher response time

+ Judicious MPSoC resources expenditure (memory, PEs)
+ Economical power consumption
+ Scheduling for actual function processing time → increased performance
+ Natural computation adaptation to varying tasks, to MPSoC components faults

Rational parallel computations in application-specific MPSoCs - a combination of static and dynamic computations

***Dynamic computations* are parallel computations, which set of components and links between them depend on data values and change in the cause of computation**

A formal Parallel Computation Model that covers both static and dynamic parallel computations is required

Asynchronous Growing Processes (AGP-model) - dynamic parallel computation model, that covers static parallel computations as its particular cases

Formal models are required for:

- Parallel Programming Language semantics specification
- Parallel algorithms and programs optimization, verification and debugging
- Mapping parallel programs to distributed heterogeneous MPSoC structure
- Tolerant control of distributed parallel computations in MPSoC
- Methodology for balancing parallel software with MPSoC features and characteristics

Asynchronous **G**rowing **P**rocesses (**AGP-models**)

Schema – Partially-interpreted Schema - Program

General AGP-model of parallel computations

***Non-interpreted* program scheme**

Interpretation of control components in a program schema, restrictions on program scheme structure

Special AGP-model of parallel computations

***Partially-interpreted* program scheme**

Interpretation of all the components of a program scheme

Language of parallel Abstract Machine

Fully-interpreted* program scheme = *Program

AGP-model features and ideas (informally)

- Parallel program scheme is represented by a directed graph. Vertexes represent *operators* and *data-objects*.
- ***All*** interactions of processes are ***explicitly*** represented in the parallel program scheme. Processes interact through data-objects. Thus it can be controlled and verified at the level of parallel program scheme.
- Data, which are accessed by several operators, are explicitly represented in parallel program scheme as *data-objects*. Thus, data shared by several processes are in the frame of the model, as well as buffered data between a pair of operators (like in data-flow graphs)
- Control of computation in the AGP-model is defined in correspondence with MPSoC distributed architecture features. Control is ***distributed***, ***parallel*** and ***asynchronous***. It helps to fill MPSoC resources with computations and to pull high-parallel computations through limited MPSoC resources.

AGP-model features and ideas (informally), *continued*

- Parallel program scheme is transformed, in general, at every computation step – Dynamic parallel computation.
  The *graph itself* is changing, not only its marking (as in data-flow computations or Petri nets).

- Alternative computation (*if, case,* etc.) can be implemented as generation of alternative parallel program scheme fragments,
  instead of routing data to one of data-flow branches, which simultaneously occupy resources. Thus we can save MPSoC resources and power consumption.

- Static parallel computations can be represented as particular cases of dynamic computation.
  It gives a way to seamless integration of dynamic and static parallel computations in a single formal model.

MPSoC Parallel programming concepts

We believe:

- Programs and algorithms should be developed as parallel ones from the beginning.
  Inherent parallelism of an application should be defined and extracted at user/application level
- Parallel programming (with a right language and right tools) is not more complicated then sequential programming
- Parallel program should be rather made correct automatically (correct by construction, verification), than debugged
- Sequential programs of processes should be absolutely encapsulated. No inter-process interaction directives inside a sequential program!

MPSoC Parallel programming concepts

- Splitting programming into
  - programming of a parallel program scheme and
  - programming of interpretation of its nodes – operators and data-objects

  Explicit programming of a parallel program scheme

- Two levels of programming languages:
  - new PPL for parallel computation scheme programming
  - conventional programming languages (C, Embedded C) for sequential process programs.

  It corresponds well to the coarse-grain functions in application-specific MPSoCs.

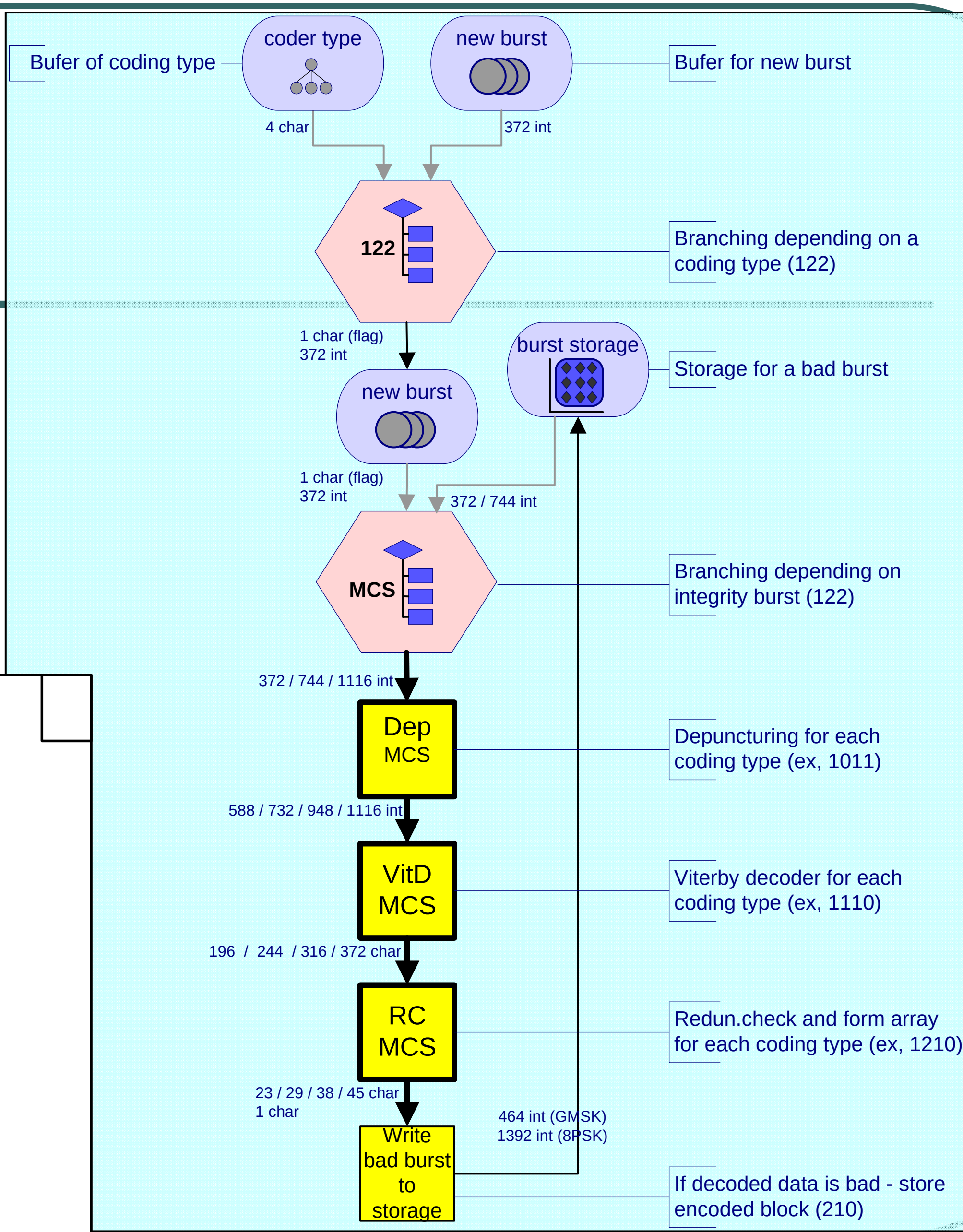
- Algorithmic completeness
  – means for computations control in dependence of data values
  at the level of a parallel program scheme

Visa
-- Parallel Programming Language for parallel program schemes programming

- The ***Visa*** language semantics is formally specified in terms of the AGP-model
- Control operators are generators of program scheme fragments
- Program control of a computation - through generation of different scheme fragments depending on data values. Dynamic and Static parallel computations unrolling.
- Visual (graphical) PPL for programming of a parallel program scheme. Parallel program scheme visual representation as a hierarchical diagram
- ***Visa*** - *Interactive* language and visual programming tools
- Scalable language.
  Standard operators (library functions) and user definable operator types and data types (user-written C code for functions)

A ***Visa*** program fragment Example

Commented view



Conclusion

The Parallel Programming Model and the Visa PPLanguage give a way

- To work with *static and dynamic* parallel computations in MPSoC, with their manageable integration in particular application software for MPSoC
- To work with distributed memory paradigm (e.g. data-flow computations, message-passing) and with shared data
- To represent different programming styles and paradigms (MIMD, data parallel, data flow) in the single Programming Model, thus – integrate them in one software system
- To mate parallel scheme programming in new PPL with programming of its nodes in conventional programming languages
- To have manageable and adjustable granularity for application-specific MPSoC parallel computations.
- To build correct-by-construction parallel programs or to verify parallel program properties
- To reduce parallel program debugging to debugging of its sequential implementation

Conclusion

- Research is going on to get all these fine features and properties for wider classes of parallel software for MPSoC

Thank you !