Architectural View Driven Model Transformations for Supporting the Lifecycle of Parallel Applications

Ethem Arkin[1] and Bedir Tekinerdogan[2]
[1]Aselsan A.Ş., Ankara, Turkey
[2]Information Technology Group, Wageningen University, Wageningen, Netherlands

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Abstract: Two important trends can be identified in parallel computing. First of all, the scale of parallel computing platforms is rapidly increasing. Secondly, the complexity and variety of current software systems requires to consider the parallelization of application modules beyond algorithms. These two trends have led to a complexity that is not scalable and tractable anymore for manual processing, and therefore automated support is required to design and implement parallel applications. In this context, we present a model-driven transformation chain for supporting the automation of the lifecycle of parallel computing applications. The model-driven transformation chain adopts metamodels that are derived from architectural viewpoints. The transformation chain is defined as a logical sequence consisting of model-to-model transformations. We present the tool support that implements the metamodels and transformations.

1 INTRODUCTION

To increase the performance that is required from large scale applications, the current trend is towards applying parallel computing on multiple nodes. Here, unlike *serial computing* in which instructions are executed serially, multiple processing nodes are used to execute the program instructions simultaneously. To benefit from the parallel computing power, usually parallel algorithms are defined that can be executed simultaneously on multiple nodes. As such, increasing the processing nodes will increase the performance of the parallel programs. Different studies have been carried out on the design and analysis of parallel algorithms to support parallel computing (Amdahl, 2007) (Frank, 2002) (Pllana and Fahringer, 2002). These studies have provided useful results and further increased the performance of parallel computing. Several important challenges have been identified and tackled in parallel computing related to activities such as the analysis of the parallel algorithm, the definition of the logical configuration of the platform, and the mapping of the algorithm to the logical configuration platform. The research on parallel algorithms and its mapping to parallel computing platforms is still ongoing.

We can identify two important trends in parallel computing. First of all, the scale of parallel computing platforms is rapidly increasing. Over the last decade the number of processing nodes has increased dramatically to tens and hundreds of thousands of nodes providing processing performance from petascale to exascale levels (Kogge et. al., 2008). The second trend includes the increasing complexity and variety of current software systems. Here the design problem goes beyond the notion of algorithms and data structures of the computation, and the design of the overall system or application of the parallel computing systems emerges as an important problem. Hence, the challenge then becomes not only analyzing, deploying and mapping parallel *algorithms* but requires considering the overall analysis and mapping of parallel *applications* to parallel computing platform.

These two trends have led to a complexity that is not scalable and tractable anymore for manual processing, and therefore automated support is required to design and implement parallel applications. In this context, we present a model-driven transformation chain for supporting the automation of the lifecycle of parallel computing applications. The model-driven transformation chain adopts metamodels that are derived from architectural viewpoints. The architecture viewpoints have been defined in our earlier work for modeling the mapping of parallel applications to parallel computing platforms (Tekinerdogan and Arkin, 2013). In essence, the viewpoints can be used to derive

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architectural views that serve as blueprints for realizing the system. The viewpoints are in essence visual and do not support the automated processing. In this paper we map the viewpoints to domain specific languages to represent architecture views as textual executable descriptions that can be used in model transformations to automate the steps of the life cycle of parallel computing. The transformation chain is defined as a logical sequence consisting of model-to-model transformations. We present the tool support that implements the metamodels and transformations

The remainder of the paper is organized as follows. In section 2, we shortly describe the viewpoints which form the basis for the domain specific languages and the model transformations. Section 3 presents the model transformation approach and the model transformations. Section 4 describes the implementation and the toolset. Section 5 presents the related work and finally we conclude the paper in section 6.

2 PRELIMINARIES

In principle we can identify the following important concerns in the life cycle for modeling parallel applications:

- *Identifying Parallel and Serial Modules in the Application*

Depending on the application semantics, while some modules can run in parallel others can only run in serial. Typically serial modules will be mapped to a single node, while parallel modules need to be mapped to multiple nodes. For the architect it is important to depict these explicitly and as such help to identify the proper selection of parallel module.

- *Modeling of the Physical Computing Platform*

The application will run on a selected or to be selected physical configuration platform that consists of multiple nodes. The architect needs to be able to model the physical computing platform for smaller but also for very large computing platforms (e.g. exascale computing).

- *Mapping of Modules and Algorithms to Physical Nodes*

The mapping of the modules to the computing platforms can be done in different ways. The mapping can be usually done in many different alternative ways and each alternative will typically behave differently with respect to quality metrics such as speedup and efficiency. The architecture needs to be able to communicate the decision on which mapping is made. Based on this the optimal design decision can be made.

- *Defining the Interaction Patterns among Parallel Modules*

Parallel modules and algorithms will typically exchange information to perform the requested tasks. In general it is important to define the proper interaction patterns not only for functional reasons but also to optimize the parallelization overhead and as such increase efficiency.

- *Modeling Multiple Computer Architectures*

When considering application instead of algorithm only it appears that we cannot reduce the problem to one of the computing platforms as defined in the Flynn's taxonomy. Typically, multiple of these categories are integrated in the overall application. That is, for example, both the SIMD and MISD could be needed for realizing the application. For complex applications all the four kinds of computing architectures might be required. The Order Management case is such an example.

Based upon the number of concurrent instruction (or control) and data streams available in the architecture the so-called Flynn's Taxonomy distinguishes among the following types of computing architectures (Flynn, 1972):

- *Single Instruction, Single Data (SISD):* This architecture exploits no parallelism in either the datastream or instructions. A traditional uniprocessor computer like the PC is an example to this type of architecture.
- *Single Instruction, Multiple Data (SIMD):* This architecture exploits multiple data streams using a single instruction stream to perform operations that may be parallelized. For example, processor arrays or GPUs process multiple pixel data on an image using the same instruction set.
- *Multiple Instruction, Single Data (MISD)*: In this architecture multiple instructions operate on a single data stream. Pipeline architectures are often considered as an example of this type.
- *Multiple Instruction, Multiple Data (MIMD)*: This architecture exploits multiple processors executing different instructions on different data simultaneously. Distributed systems, clusters, grid systems are examples of MIMD architectures.

Based on the above concerns we have proposed an architecture framework consisting of a coherent set of viewpoints which addresses the different concerns for supporting the design of parallel applications (Tekinerdogan and Arkin, 2015). These six viewpoints are as follows:

- *Application Decomposition Viewpoint*

This viewpoint aims to support the analysis and decomposition of the application into parallel and serial modules. A module can be either a package that is a grouping module element to group a set of modules or a module that can be serial, parallel, serial algorithm or parallel algorithm. A serial module and a serial algorithm module is the implementation of a set of instructions or algorithm which is executed on a single processing unit. A parallel module is a module with the instruction set that run on multiple processing units simultaneously.

- *Algorithm Decomposition Viewpoint*

Each module in the application decomposition viewpoint has a separate behavior for the deployment of the application. A serial module or a serial algorithm module can be deployed and executed on a single processing unit. A parallel module consists of a set of instructions that will be executed among different processing units simultaneously. A parallel algorithm module includes serial or parallel sections that determines the behavior of the algorithm and must be decomposed into sections that will be executed serial or parallel.

- *Component Viewpoint*

According to the decomposition of the parallel application, a component view includes serial components, serial algorithm components, parallel components and parallel algorithm components. The types of the components are determined by the module that is compiled to the component.

- *Physical Configuration Viewpoint*

Physical configuration viewpoint includes the hardware configuration for the parallel computing platform including nodes, network, processing units, memory and bus.

- *Deployment Viewpoint*

Deployment viewpoint is used to represent the deployment of components to the physical configuration view.

- *Logical Configuration Viewpoint*

This viewpoint is used to represent the logical communication patterns and the dynamic behavior of the algorithm. Logical configuration is generated according to the tile and communication pattern definitions which is described in our earlier study (Tekinerdogan and Arkin, 2013).

To illustrate the problem we will use the Order Management Application architecture as an example. The Order Management application is typically a critical part of commercial systems including, for example, packages like Order Entry, Financial and Inventory. To increase the performance of such a system several modules need to be run in parallel.

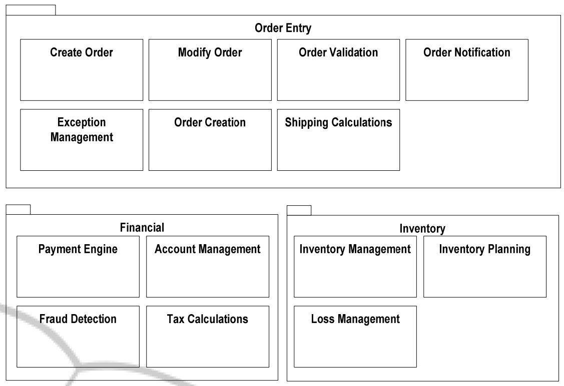


Figure 1: Order Management Application Architecture (Decomposition View).

3 ARCHITECTURE VIEW DRIVEN TRANSFORMATIONS

The architecture viewpoints of the previous section can be used to realize the mapping of parallel applications to parallel computing platforms. However, the viewpoints are mainly visual and not appropriate for automated support. In this section we present the approach for automating the overall process using the architecture viewpoints. Figure 2 represents the transformation chain including views

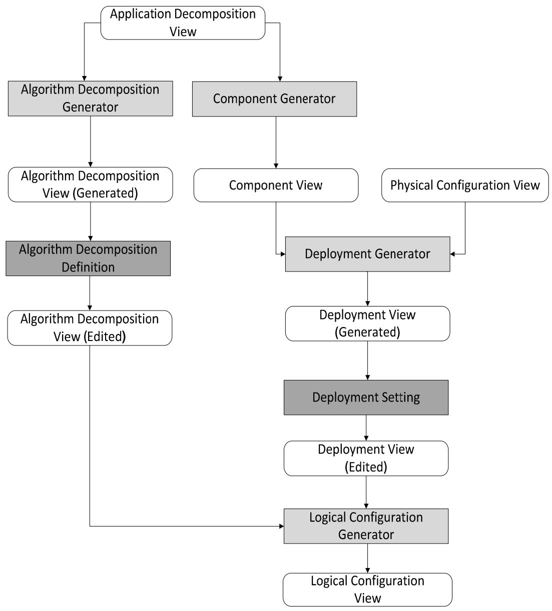
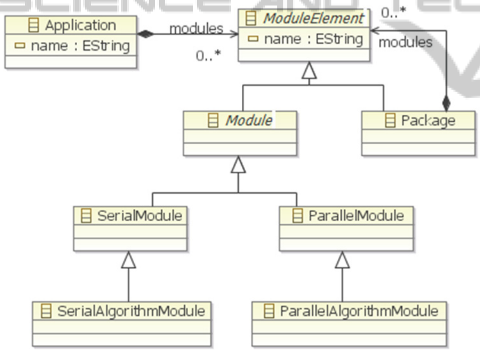


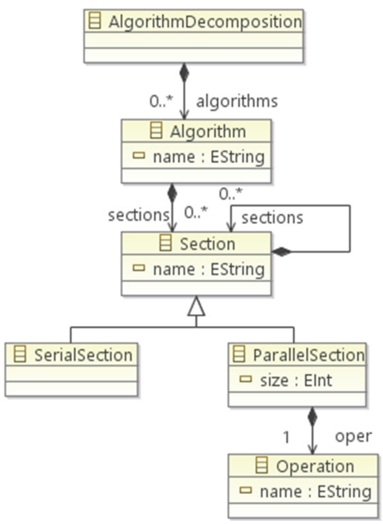
Figure 2: Transformation Chain for Supporting the Lifecycle of Parallel Applications.

and transformations between the views for parallel computing architectures. Four transformation processes are defined including *Algorithm Decomposition Generator*, *Component Generator*, *Deployment Generator*, and *Logical Configuration Generator*. In the following subsections we discuss each generator in detail. In addition to the generators the transformation chain include the two manual activities *Algorithm Decomposition Definition* and *Deployment Setting*. Both activities are used to enhance additional details to the generated views. In the activity *Algorithm Decomposition Definition* the preliminary generated *Algorithm Decomposition View* is manually edited for identifying the parallel and serial sections of the algorithm (Arkin et. al., 2013). In the activity *Deployment Setting* the parallel components are manually assigned to physical configuration processing units.

3.1 Algorithm Decomposition Generator



a) Application Decomposition Metamodel



b) Algorithm Decomposition Metamodel

Figure 3: Metamodels for Algorithm Decomposition Generator.

Algorithm Decomposition Generator transforms the *ParallelAlgorithmModule* elements of application decomposition view to *Algorithm* elements of algorithm decomposition view. Figure 3 shows the metamodels of the application decomposition viewpoint and algorithms decomposition viewpoint. Application Decomposition metamodel (Figure 3a) has a main *Application* element. *Application* includes the *Module Elements* which can be either a *Package* or a *Module*. *Package* contains other module elements that can be either *ParallelModule*, *SerialModule*, *ParallelAlgorithmModule* or *SerialAlgorithmModule*. Algorithm Decomposition metamodel (Figure 3b) contains parallel algorithms used for the parallel application. Algorithm includes Sections, Parallel Sections and Serial Sections. Each section can contain other sections. A parallel application is related to a parallel Operation that is defined in the parallel library. This library is used for defining reusable parallel operations using tiles and communication patterns which are described in detail in (Arkin et. al., 2013).


```
rule AlgorithmDecompositionGenerator
   transform app :
     applicationdecomposition!Application
   to algs :
algorithmdecomposition!AlgorithmDecomposition
{
  algs.algorithms = Sequence{};
  for (module in app.modules)
  {
    generateAlgorithm(algs, module);
  }
}
operation generateAlgorithm
    (algs:
algorithmdecomposition!AlgorithmDecomposition,
    module:
applicationdecomposition!ModuleElement)
{
  if(module.isTypeOf(
    applicationdecomposition!
                  ParallelAlgorithmModule))
  {
    var alg = new
algorithmdecomposition!Algorithm;
    alg.name = module.name;
    algs.algorithms.add(alg);
  }
  if(module.isTypeOf(
    applicationdecomposition!Package))
  {
    for (m in module.modules)
    {
      generateAlgorithm(algs, m);
    }
  }
}
```

Figure 4: Algorithm Decomposition Generator Transformation Rules.

The *Algorithm Decomposition Generator* searches for the *Parallel Algorithm Modules* in the application decomposition view and generates the algorithm decomposition view. Figure 4 shows the transformation rules of *Algorithm Decompostion Generator*.

The main transformation rule iterates over the modules of the application and calls the operation *generateAlgorithm* for the module (lines 7-10). The *generateAlgorithm* operation (lines 12-33) first checks the module whether it is a *ParallelAlgorithmModule* or a *Package*. If the module is a *Parallel Algorithm Module*, then a new algorithm instance is created and added to algorithm list (lines 17-25). If the module is a *Package*, then generateAlgorithm operation is recursively called for each submodule (lines 26-32).

3.2 Component Generator

Component Generator transforms modules of application decomposition view to components for component view. The transformation uses *Application Decomposition Metamodel* (Figure 3a) and *Component Metamodel* (Figure 5). Component metamodel includes *Application* element as main element. *Application* consists of *Packages* and *Components*. Similarly, components can be either *Parallel Component*, *Serial Component*, *Parallel Algorithm Component* or *Serial Algorithm Component*. Each component has an Interface relation with another component. A component has required and provided interfaces.

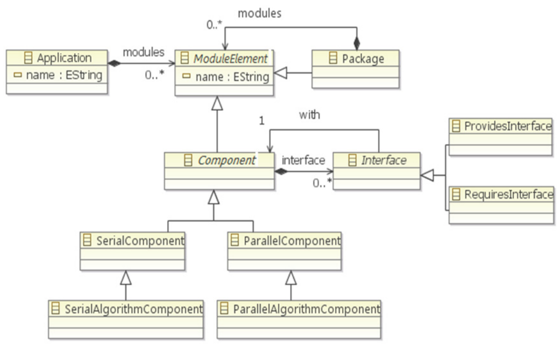


Figure 5: Component Metamodel.

The transformation rules for Component Generator is shown in Figure 6. The main transformation rule is shown from lines 2 to 10. The application decomposition view modules are transformed into component view modules. The *transformModule* operation is defined to implement this transformation. The transformed module is added to component view in lines 7-8. In the *transformModule* operation, the type of the application decomposition module is checked. Each module type is transformed to the counter component. If the module is *ParallelModule*, then a new *ParallelComponent* instance is created with the same name (lines 16-21). If the module is *SerialModule*, then a new *SerialComponent* instance is created (lines 22-27). In lines 28-35, *ParallelAlgorithmComponent* is created from *ParallelAlgorithmModule* and in lines

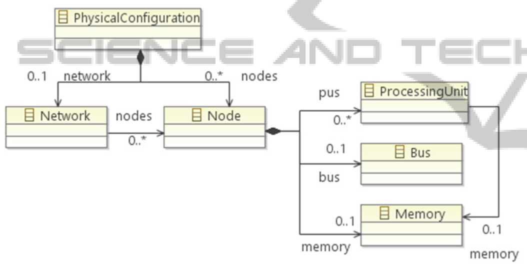
```
1.  rule ComponentGenerator
2.    transform app :
    applicationdecomposition!Application
3.     to capp : component!Application {
4.     capp.name = app.name;
5.     capp.modules = Sequence{};
6.     for (module in app.modules) {
7.       capp.modules.add(
8.              transformModule(module));
9.      }
10. }
11. operation transformModule
12.     (module:
13.
    applicationdecomposition!ModuleElement
14.     ) : component!ModuleElement {
15.   var comp;
16.   if(module.isTypeOf(
17.
    applicationdecomposition!ParallelModule))
18.   {
19.     comp = new component!ParallelComponent;
20.     comp.name = module.name;
21.   }
22.   if(module.isTypeOf(
23.     applicationdecomposition!SerialModule))
24.   {
25.     comp = new component!SerialComponent;
26.     comp.name = module.name;
27.   }
28.   if(module.isTypeOf(
29.     applicationdecomposition!
30.                ParallelAlgorithmModule))
31.   {
32.     comp = new
33.
    component!ParallelAlgorithmComponent;
34.     comp.name=module.name;
35.   }
36.   if(module.isTypeOf(
37.     applicationdecomposition!
38.                SerialAlgorithmModule))
39.   {
40.     comp = new
41.         component!SerialAlgorithmComponent;
42.     comp.name = module.name;
43.   }
44.   if(module.isTypeOf(
45.     applicationdecomposition!Package))
46.   {
47.     comp = new component!Package;
48.     comp.name = module.name;
49.     comp.modules = Sequence{};
50.     for (m in module.modules) {
51.       comp.modules.add(transformModule(m));
52.     }
53.   }
54.   return comp;
55. }
```

Figure 6: Component Generator Transformation Rules.

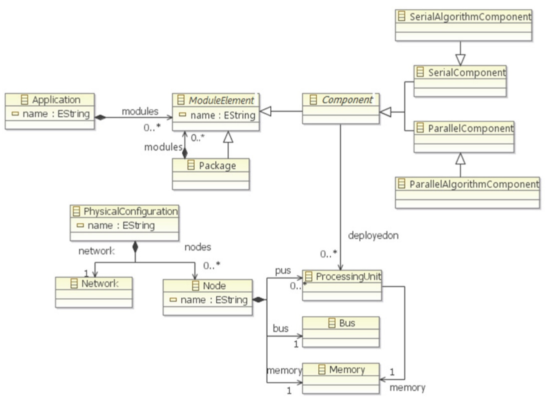
36-43, *SerialAlgorithmComponent* is created from *SerialAlgorithmModule*. If the module is a *Package*, then the *transformModule* operation is called for its submodules (lines 44-53).

3.3 Deployment Generator

Deployment Generator merges and transforms the component view and physical configuration view to deployment view. The transformation uses the *Component Metamodel* (Figure 5), *Physical Configuration Metamodel* (Figure 7a) and *Deployment Metamodel* (Figure 7b). The *Physical Configuration* metamodel is adopted from (Tekinerdogan and Arkin, 2013) which includes *Network*, *Node*, *Processing Unit*, *Bus* and *Memory* elements. Deployment metamodel is a composition of component metamodel and physical configuration metamodel which has a relation of <<deployed on>> from component to processing unit.



a) Physical Configuration Metamodel



b) Deployment Metamodel

Figure 7: Metamodels for Deployment Generator.

The transformation rules as shown in Figure 8 have two main rules. The first rule transforms the physical configuration elements to deployment view elements. The *Physical Configuration Transform* rule transforms the physical configuration to deployment configuration in which the network and nodes are transformed to deployment instances. Each node of the physical configuration is transformed to deployment node calling *transformNode* operation in line 8. The *transformNode* operation creates a new node instance and transforms the *memory*, *bus* and *processing unit* elements in the node (lines 12-19).

```
1.  rule PhysicalConfigurationTransform
2.    transform pc :
physicalconfiguration!PhysicalConfiguration
3.    to dpc : deployment!PhysicalConfiguration
{
4.    dpc.name = pc.name;
5.    dpc.network = new deployment!Network;
6.    dpc.nodes = Sequence{};
7.    for (node in pc.nodes) {
8.           dpc.nodes.add( transformNode(node)
);}
9.  }
10. operation transformNode
11.     (node: physicalconfiguration!Node) :
deployment!Node {
12.   var n = new deployment!Node;
13.   n.memory = new deployment!Memory;
14.   n.bus = new deployment!Bus;
15.   n.pus = Sequence{};
16.   for (pu in node.pus) {
17.          var p = new
deployment!ProcessingUnit;
18.          p.memory = n.memory;
19.          n.pus.add(p);}
20.   return n;
21. }
22. rule ApplicationTransform
23.   transform app : component!Application
24.   to dapp : deployment!Application {
25.   dapp.name = app.name;
26.   dapp.modules = Sequence{};
27.   for (module in app.modules) {
28.
    dapp.modules.add(transformModule(module))
;}
29. }
30. operation transformModule
31.    (module: component!ModuleElement) :
deployment!ModuleElement {
32.   var comp;
33.   if(module.isTypeOf(component!ParallelComp
onent)) {
34.          comp = new
deployment!ParallelComponent;
35.          comp.name = module.name;}
36.   if(module.isTypeOf(component!SerialCompon
ent)) {
37.          comp = new
deployment!SerialComponent;
38.          comp.name = module.name;}
39.   if(module.isTypeOf(component!ParallelAlgo
rithmComponent)) {
40.          comp = new
deployment!ParallelAlgorithmComponent;
41.          comp.name = module.name;}
42.   if(module.isTypeOf(component!SerialAlgori
thmComponent)) {
43.          comp = new
deployment!SerialAlgorithmComponent;
44.          comp.name = module.name;}
45.   if(module.isTypeOf(component!Package)) {
46.          comp = new deployment!Package;
47.          comp.name = module.name;
48.          comp.modules = Sequence{};
49.          for (m in module.modules) {
50.
    comp.modules.add(transformModule(m));}}
51.   return comp;
52. }
```

Figure 8: Deployment Generator Transformation Rules.

The second rule transforms the component application elements into deployment application elements. Here, the modules of the component view are transformed using *transformModule* operation (lines 30-51), which checks the type of the module and transforms to the counter element in the deployment view.

3.4 Logical Configuration Generator

Logical Configuration Generator transforms an algorithm decomposition view to a logical configuration view using the information of the deployment of parallel algorithm components to processing units. The metamodel for logical configuration is adopted and is used to generate the dynamic behaviour of the algorithm using tiles, communication patterns and operations. The transformation rules to generate the logical configuration is defined in Figure 9. The transformation rules consist of three main parts. In the first part, tiles that will be used according to deployment view and algorithm sections are found from the base library (lines 20-31). The prime factorization method is used to find the tile size of appropriate tiles. In the second part, patterns are selected to generate the communication patterns for the tiles with respect to the operations for the algorithm sections (lines 32-44). Subsequently, these selected patterns are added to the patterns list of the corresponding operation. Later on when it is needed the pattern can be reused in the last section in which the final logical configuration is generated (lines 45-54).

4 IMPLEMENTATION AND TOOLSET

To assist the architect for applying the architecture views and transforming using the transformation chain, we have developed the toolset that implements each architecture viewpoint metamodel and defined transformation rules. For this we have used the Epsilon (2014) toolset for Eclipse IDE that is used to represent the notation (concrete syntax) of the viewpoints. For each viewpoint we have defined the corresponding metamodel. The metamodels are defined in the Eclipse Modeling Framework (EMF) using Emfatic language in Epsilon.

Figure 10 shows the architecture views for the earlier defined case study, which are generated by the transformation chain in the toolset. In Figure 10a a test

```
1.   operation library!Pattern
     isDominating(tile:library!Core) : Boolean
2.   operation logicalconfiguration!Pattern
     getTile
3.       (i:Integer, j:Integer) :
     logicalconfiguration!Tile
4.   operation logicalconfiguration!Pattern
     setCommunication
5.       (from_i:Integer, from_j:Integer,
     to_i:Integer, to_j:Integer,
6.        patternList:Sequence, level:Integer)
7.   operation logicalconfiguration!Pattern
     setCommunication
8.       (ft:logicalconfiguration!Tile,
     tt:logicalconfiguration!Tile)
9.   operation createPattern
10.      (main:logicalconfiguration!Pattern,
     i:Integer, j:Integer,
11.       patternList:Sequence,
     commLevel:Integer, level:Integer,
12.       parentSize:Integer, scaling:Any)
13.
14.  rule LogicalConfigurationGenerator
15.    merge base : library!AssetBase
16.    with algorithm : algorithm!Algorithm
17.    into lc :
     logicalconfiguration!LogicalConfiguration {
18.    for(parallelSection in
19.          algorithm!ParallelSection.all) {
20.    //FIND TILES
21.    var n = coreSize;
22.    while (i<=n) {
23.      while ((n - (n/i * i)) = 0) {
24.        factors.add(i);
25.        n = n / i;}
26.      i = i + 1;}
27.    var
     operationName=parallelSection.oper.name;
28.    var sizeList = Sequence{};
29.    i = 0;
30.    while(i < factors.size()){
31.      sizeList.add(factors.get(i)); i = i +
     1;}
32.    //FIND PATTERNS
33.    var patternList = Sequence{};
34.    for(factor in sizeList){
35.      for(oper in base.operations) {
36.        if(oper.name == operationName) {
37.          for(pattern in oper.uses) {
38.            if(pattern.size == factor) {
39.              //pattern.name.println();
40.              //commLevel.println();
41.              patternList.add(pattern);}}}}}
42.    var commLevel = 0;
43.    if(scaling == base!ScalingType#UP) {
44.      commLevel = patternList.size - 1; }
45.    //GENERATE LOGICAL CONFIGURATION
46.    for(pattern in patternList) {
47.      var mainPattern = new
48.
     logicalconfiguration!Pattern;
49.      createPattern(mainPattern, 0, 0,
     patternList,
50.                commLevel, 0, 1,
     pattern.scaling);
51.      var patternOperation = new
52.
     logicalconfiguration!Operation;
53.      mainPattern.implements =
     patternOperation;}
54.    lc.tiles.add(sectionPattern);}}
```

Figure 9: Logical Configuration Generator Transformation Rules.

computer is defined with four nodes and a network among nodes. Each node has four processing units, a bus and a memory. Application decomposition for Order Management Application, which is shown in Figure 10b, is composed of three packages and each package includes modules. In Figure 10c, Algorithm Decomposition View is generated using application decomposition viewpoint, where parallel algorithm module *ShippingCalculations* is defined. Component viewpoint (Figure 10d) is generated using application decomposition. Deployment view (Figure 10e) includes test computer definition (physical configuration), order management components and <<deployedon>> relation property for each component. Logical configuration (Figure 10f) is generated from algorithm decomposition using parallel mapping library and the information that the parallel algorithm component is deployed on which processing units.

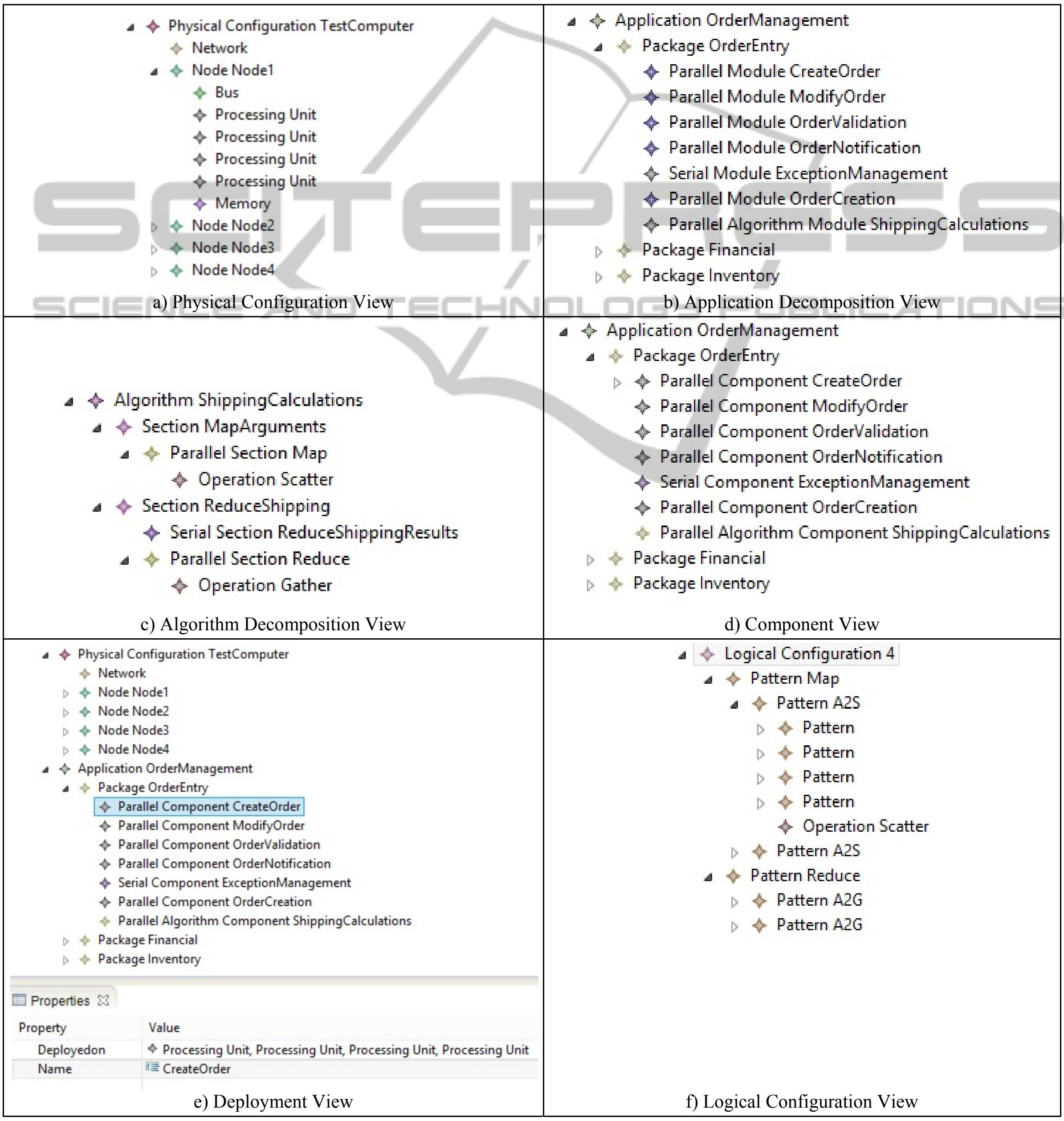


Figure 10: Architecture views generated by transformation chain.

Moreover, in the toolset we have implemented view editors for the architecture view definitions. The Eclipse Graphical Modeling Framework (GMF) models are generated from the EMF models using EuGENia tool in Epsilon.

Figure 11 shows a snapshot of the toolset with the example for *Physical Configuration Editor*. The user interface of the editor provides four panels: 1) *Project Explorer*, 2) *Outline Overview*, 3) *Editor Panel* and 4) *Palet Panel*. *Project Explorer* shows the projects to define different physical configuration models. *Outline Overview* shows the outline of the editing physical configuration. *Editor Panel*, provides the panel for editing the physical configuration using the Viewpoint structures which can be selected and easily added to the model by drag and drop. Finally, the *Palet Panel* includes the view structures. In the example a physical configuration with two nodes and a network is given. Each node has 4 processing units and a memory with a bus.

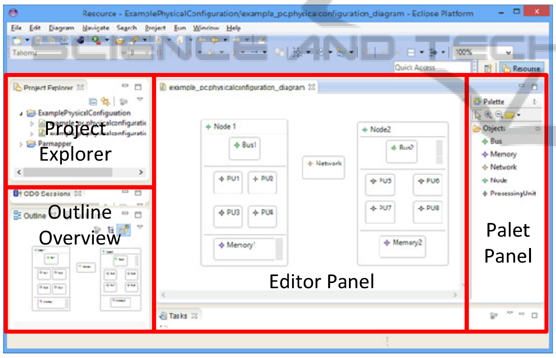


Figure 11: Physical Configuration Editor.

5 RELATED WORK

In the literature of parallel computing the particular focus seems to have been on parallel programming models such as MPI, OpenMP, CILK etc. (Talia, 2001) but the design and the modeling got less attention. Several papers have focused in particular on higher level design abstractions in parallel computing and the adoption of model-driven development.

Palyart et. al. (2012) propose an approach for using model-driven engineering in high performance computing. They focus on automated support for the design of a high performance computing application based on abstract platform independent model. The approach includes the steps for successive model transformations that enrich progressively the model with platform information. The approach is supported by a tool called Archi-MDE. Gamatie et al. (2011) represent the Graphical Array Specification for Parallel and Distributed Computing (GASPARD) framework for massively parallel embedded systems to support the optimization of the usage of hardware resources. GASPARD uses MARTE standard profile for modeling embedded systems at a high abstraction level. MARTE models are then refined and used to automatically generate code. Our approach can be considered an alternative approach to both GASPARD and Archi-MDE. The difference of our approach is the particular focus on optimization at the design level using architecture viewpoints.

In our earlier study (Arkin et. al., 2013) (Tekinerdogan and Arkin, 2013), we have proposed an architecture framework for mapping parallel algorithms to parallel computing platforms. In that study we only focused on parallel algorithms and did not consider the broader concept of application. Also we assumed a distributed memory model in which each node has its own memory unit and, as such, targeted the MISD architecture of the Flynn's taxonomy. The current approach is more general and detailed in the sense that it focuses on software application, supports both modules and algorithms, can represent different memory models, supports modeling different computing architectures, and most importantly, supports the generation of the views.

6 CONCLUSIONS

We have applied model-driven transformation techniques to support the automation of the mapping of parallel applications to parallel computing platforms. We have mainly focused on the practical aspects and showed that this is indeed possible. We could define the domain specific languages without substantial problems and use these in the generators that we implemented. The overall approach provides a substantial support for the scalability problem in parallel computing and increases the productivity and quality. In our future work we will focus on supporting design aspects beyond modeling, and focus on optimizing the deployment configurations of parallel applications.

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