Local Optimizations in Eclipse QVTc and QVTr using the Micro-Mapping Model of Computation

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OMG (Model Driven Solutions)

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QVT 1.2, 1.3, 1.4 RTF Chair

EXE 2016 @ MODELS 2016

3rd October 2016

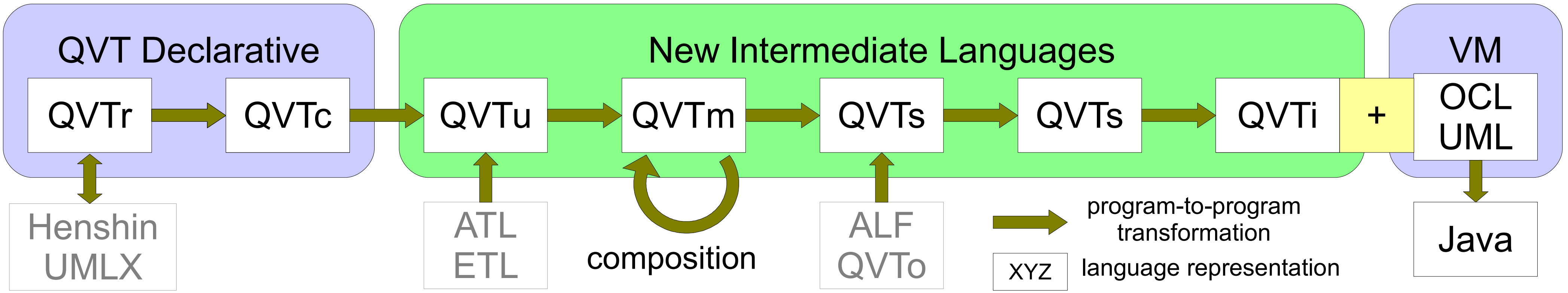
Overview

- QVT Background
- Eclipse QVTd architecture
- Do things in the right order
  - imperative/declarative
- Intra-mapping scheduling
- Example results
- Eclipse QVTc/QVTr status
- Conclusion

QVT Background Query/View/Transformation

- 2002: standard transformation language RFP
  - OMG specification - slow to mature
  - ATL took a pragmatic short cut
- 2005: Three language compromise
  - QVTo (Operational Mappings) - Imperative
    - ~~2~~ 1 good implementations : ~~SmartQVT~~, Eclipse QVTo
  - QVTr (Relational) - Declarative, rich
    - ~~2~~ 0 poor implementations : ~~ModelMorf~~, ~~Medini QVT~~
  - QVTc (Core) - Declarative, simple
    - notional common core, no implementations
- Eclipse QVTd: QVTc/QVTr editors

Eclipse QVTd Tx Chain Architecture



- QVTr2QVTc - nominally as in QVT specification
- QVTc2QVTu ⇒ Unidirectional (remove reverse bloat)
- QVTu2QVTm ⇒ Minimal (remove refinement etc)
- QVTm2QVTs ⇒ Create graphical form
- QVTs2QVTs ⇒ Optimize/schedule graphical form
- QVTs2QVTi ⇒ Imperative executable form

Correct Execution 1

- No global state => Object Orientation
- No naughty writes => Static Single Assignment
  - impractical in the large
- No naughty writes => Functional Programming
  - new system, inefficient in the large
- But
  - multiple threads
  - complex object state
  - evolving object state

Correct Execution 2

- No naughty reads
  - every property read occurs after its property write
- Functions - f(a,b,c) { return a.x + g(b.y.z, c); }
  - parameters easy to analyze - a, b, c
  - references hard to analyze - g(b.y.z, c)
  - => secret undeclared inputs, manual discipline
- Declarative Mappings/Relations/Rules
  - same problem; global analysis necessary/possible

Imperative Transformations

- Explicit control statements
- Manual programming
  - hopefully good
  - may be bad
- Tooling
  - hopefully good
  - may be bad

Declarative Transformations

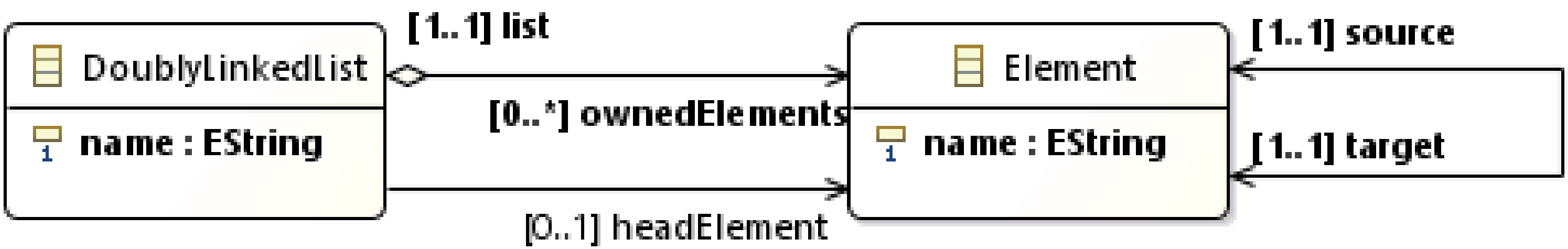
- No control statements
- Manual programming
  - different approach, may be good/bad
- Tooling
  - must discover a control strategy
  - hopefully good
  - may be VERY BAD

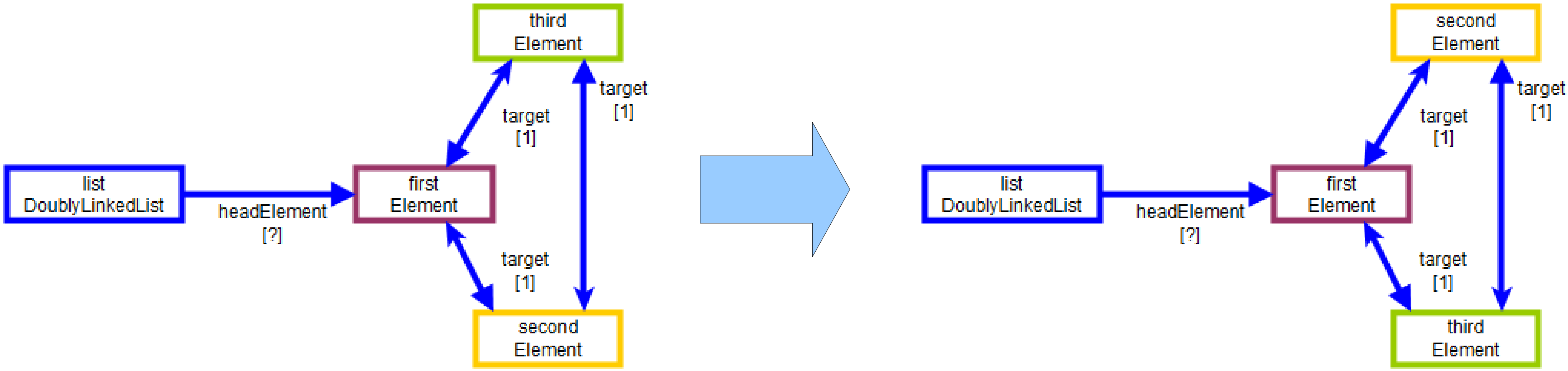
Naive Polling Schedule

Retry loop - loop until all work done
  Mapping loop - loop over all possible mappings
    Object loops - multi-dimensional loop for all object/argument pairings
      Compatibility guard - if object/argument pairings are type compatible
      Repetition guard - if this is not a repeated execution
      Validity guard - if all input objects are ready
      Execute mapping for given object/argument pairings
      Create a memento of the successful execution

- Works for any declarative transformation
- Hideously inefficient - VERY VERY BAD
- Optimization goal - a statically ordered schedule

Doubly Linked List Reversal Example





ATL solution

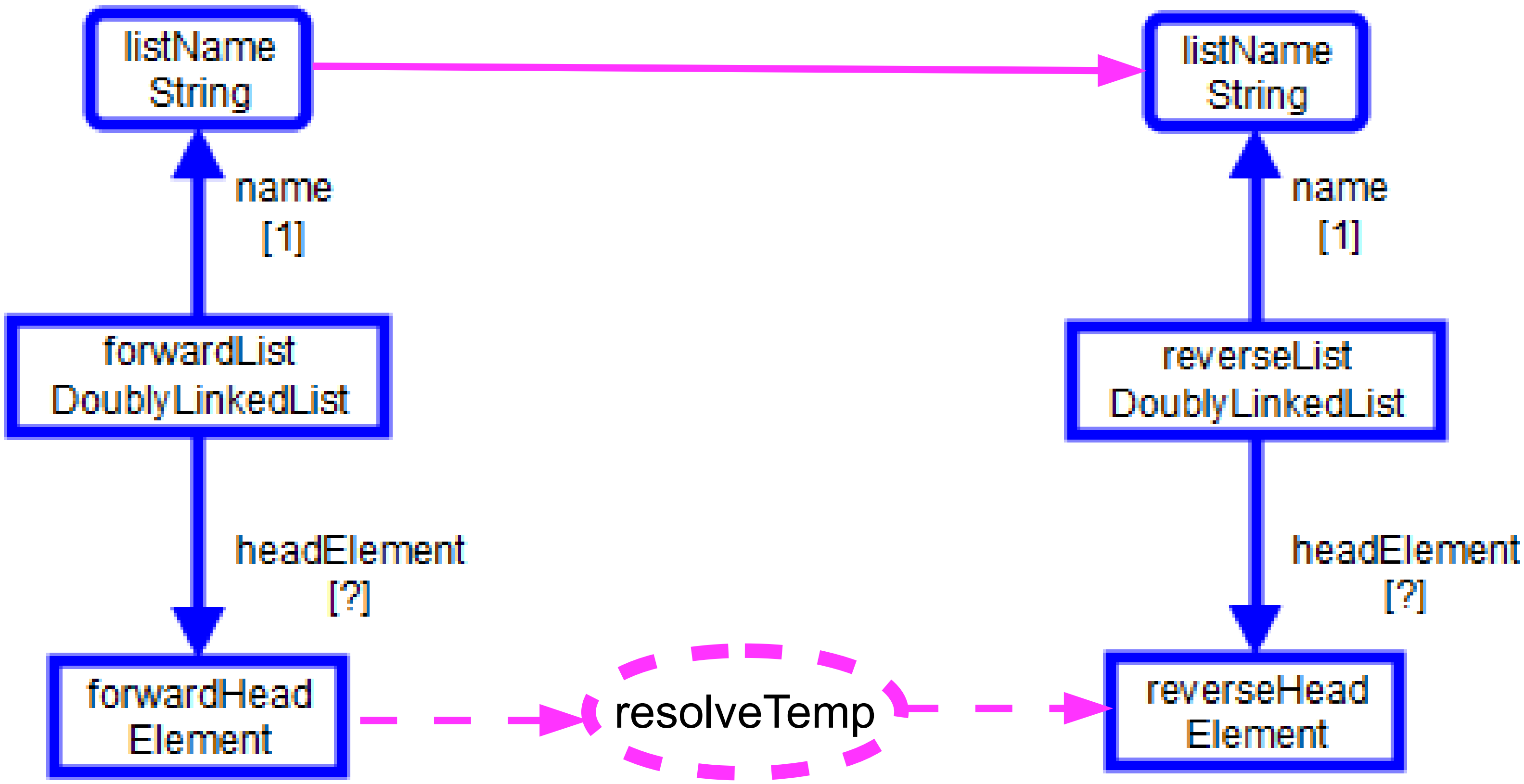
```
module Forward2Reverse;
create OUT : ReverseList from IN : ForwardList;

rule list2list {
  from
    forwardList : ForwardList!DoublyLinkedList
  to
    reverseList : ReverseList!DoublyLinkedList (
      name <- forwardList.name,
      headElement <- forwardList.headElement -- resolveTemp
    )
}

rule element2element {
  from
    forwardElement : ForwardList!Element
  to
    reverseElement : ReverseList!Element (
      name <- forwardElement.name,
      list <- forwardElement.list,             -- resolveTemp
      source <- forwardElement.target          -- resolveTemp
    )
}
```

QVTr solution

```
top relation list2list {
    enforce domain forward
        forwardList : DoublyLinkedList {
            name = listName : String{},
            headElement = forwardHead : Element{}
        };
    enforce domain reverse
        reverseList : DoublyLinkedList {
            name = listName,
            headElement = reverseHead : Element{}
        };
    when {
        element2element(forwardHead, reverseHead);
    }
}
top relation element2element {
    domain forward forwardElement : Element {
        list = forwardList : DoublyLinkedList{},
        name = elementName : String{},
        target = forwardTarget : Element{}
    };
    enforce domain reverse reverseElement : Element {
        list = reverseList : DoublyLinkedList{},
        name = elementName,
        source = reverseSource : Element{}
    };
    when {
        list2list(forwardList, reverseList);
        element2element(forwardTarget, reverseSource);
    }
}
```

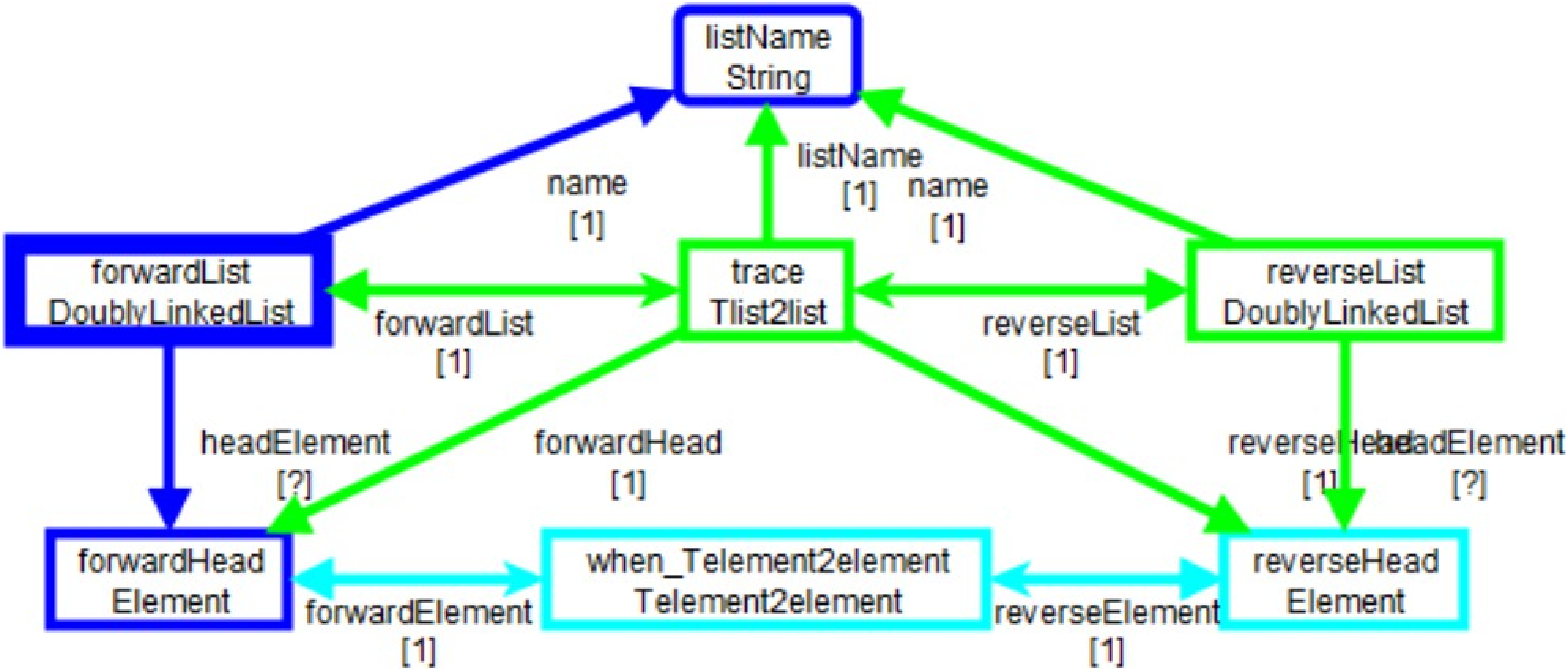
Underlying (ATL) functionality

```
rule list2list {
  from
    forwardList : ForwardList!DoublyLinkedList
  to
    reverseList : ReverseList!DoublyLinkedList (
      name <- forwardList.name,
      headElement <- forwardList.headElement -- resolveTemp
    )
}
```

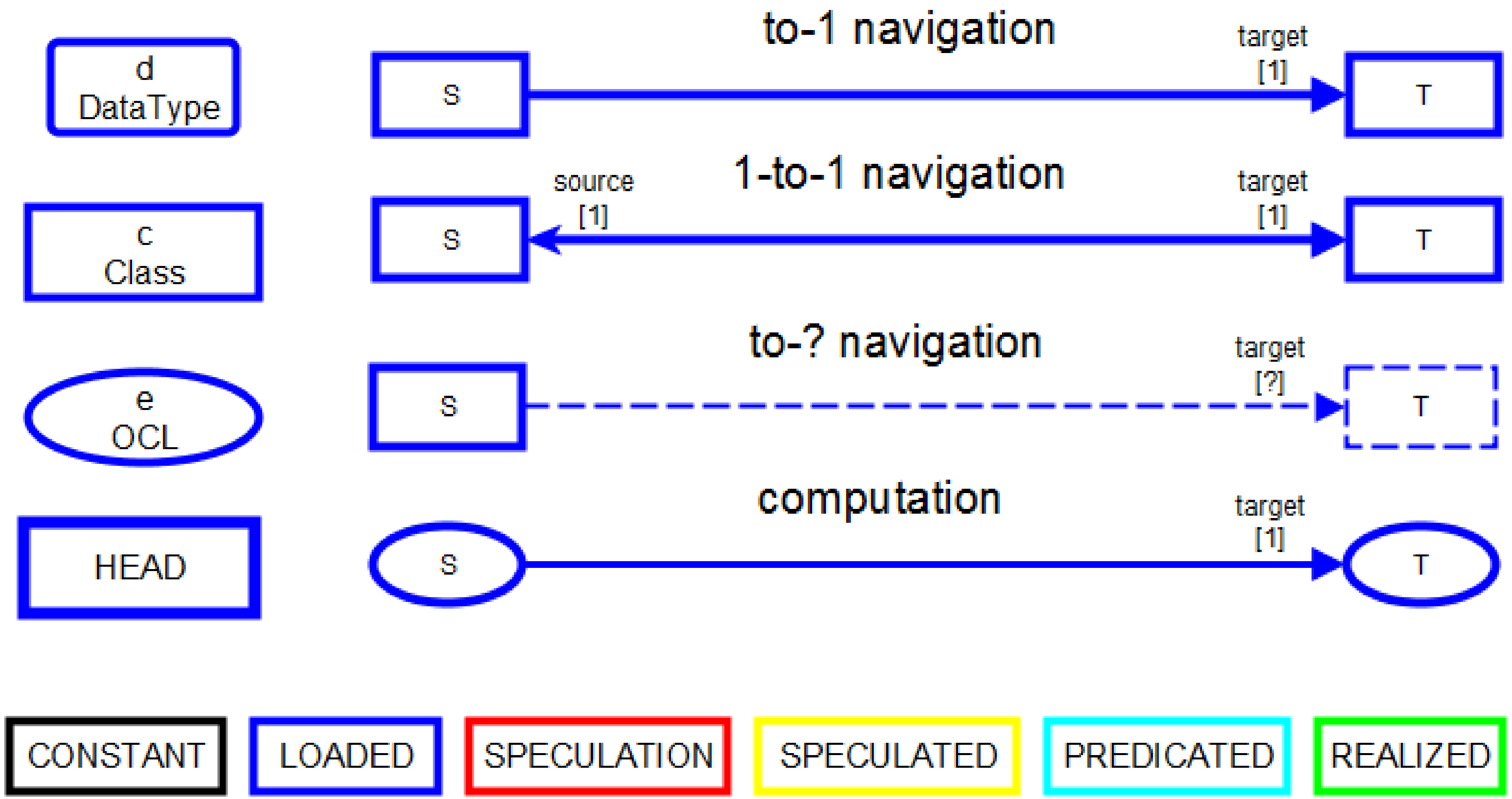


Underlying QVTr in QVTc functionality

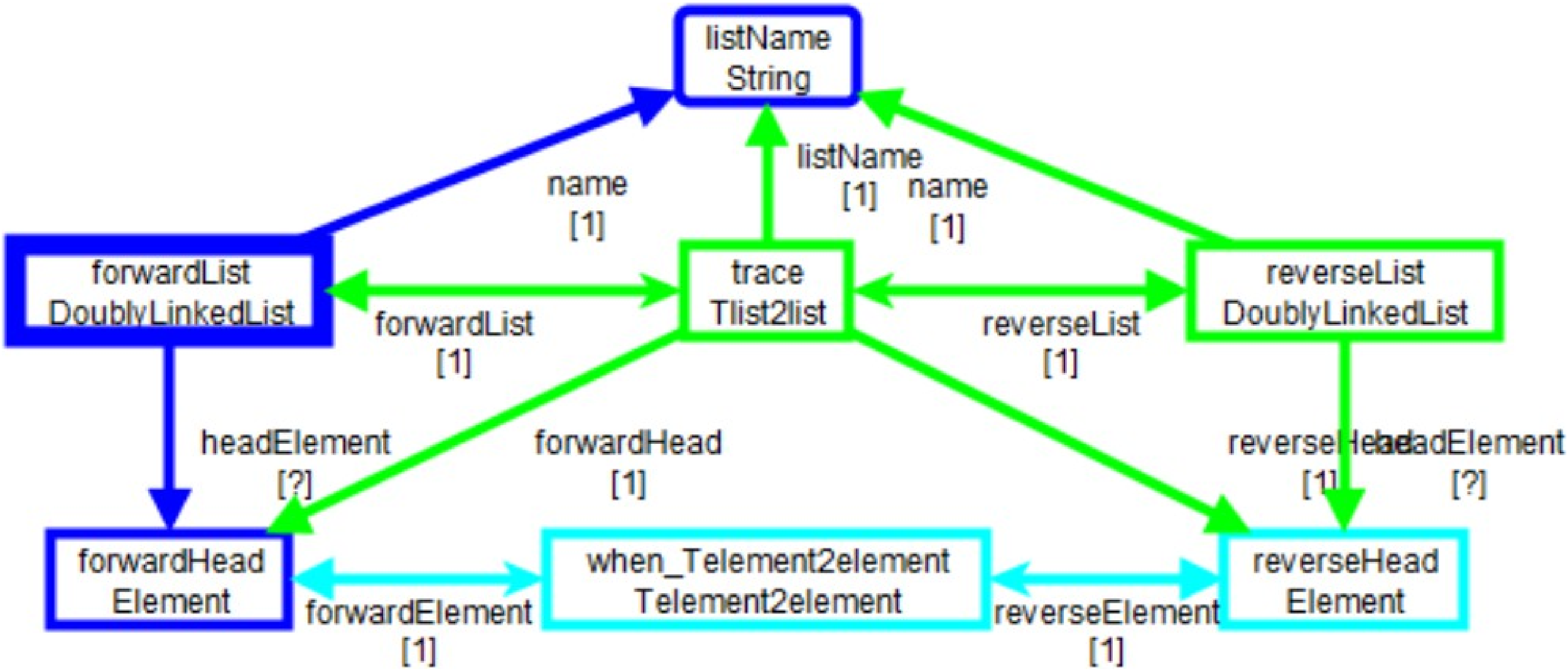
```
map list2list_reverse in org::eclipse::qvtd::xtext::qvtrelation2::tests::forward2reverse::Forward2Reverse {
    check forward(forwardList : listMM::DoublyLinkedList[1], forwardHead : listMM::Element[1] |) {
        listName : String[1] |}
    enforce reverse(reverseHead : listMM::Element[1] |) {
        realize reverseList : listMM::DoublyLinkedList[1] |}
    where(when_Telement2element : PForward2Reverse::Telement2element[1] |
        when_Telement2element.forwardElement = forwardHead;
        when_Telement2element.reverseElement = reverseHead;) {
        realize trace : PForward2Reverse::Tlist2list[1] |
        trace.forwardHead := forwardHead;
        trace.forwardList := forwardList;
        forwardList.headElement := forwardHead;
        reverseList.headElement := reverseHead;
        trace.listName := listName;
        forwardList.name := listName;
        reverseList.name := listName;
        trace.reverseHead := reverseHead;
        trace.reverseList := reverseList;
    }
}
```



Mapping Diagram Artefacts



Mapping MoC



- Truth - after execution
  - to-1 relationships
    - => 1:1 group of objects
    - => HEAD from which all 1:1 objects can be reached

Dependency Conflicts

```
module Forward2Reverse;
create OUT : ReverseList from IN : ForwardList;

rule list2list {
  from
    forwardList : ForwardList!DoublyLinkedList
  to
    reverseList : ReverseList!DoublyLinkedList (
      name <- forwardList.name,
      headElement <- forwardList.headElement -- resolv
    )
}

rule element2element {
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    forwardElement : ForwardList!Element
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    reverseElement : ReverseList!Element (
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    )
}
```
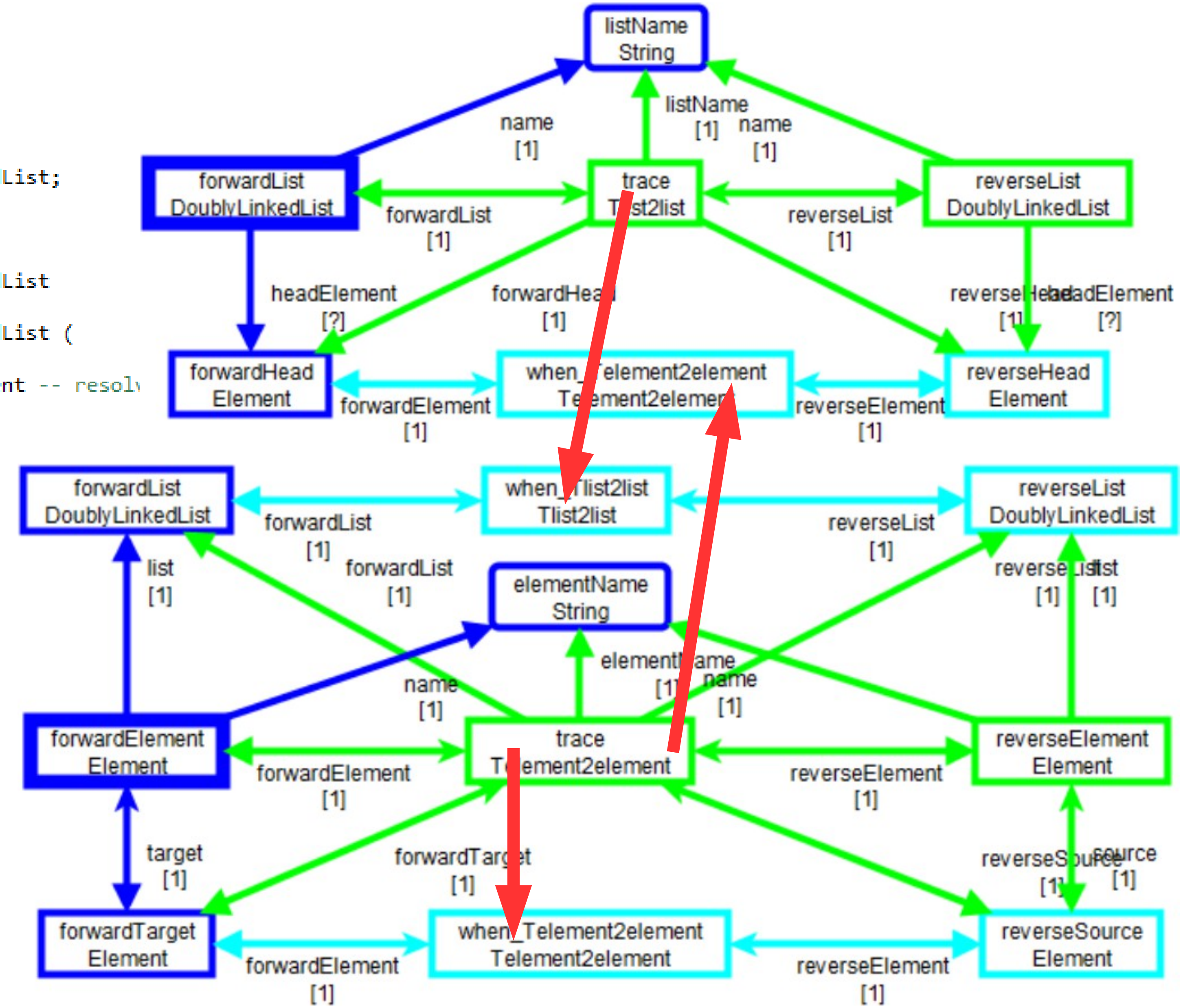



REALIZE

before

PREDICATE

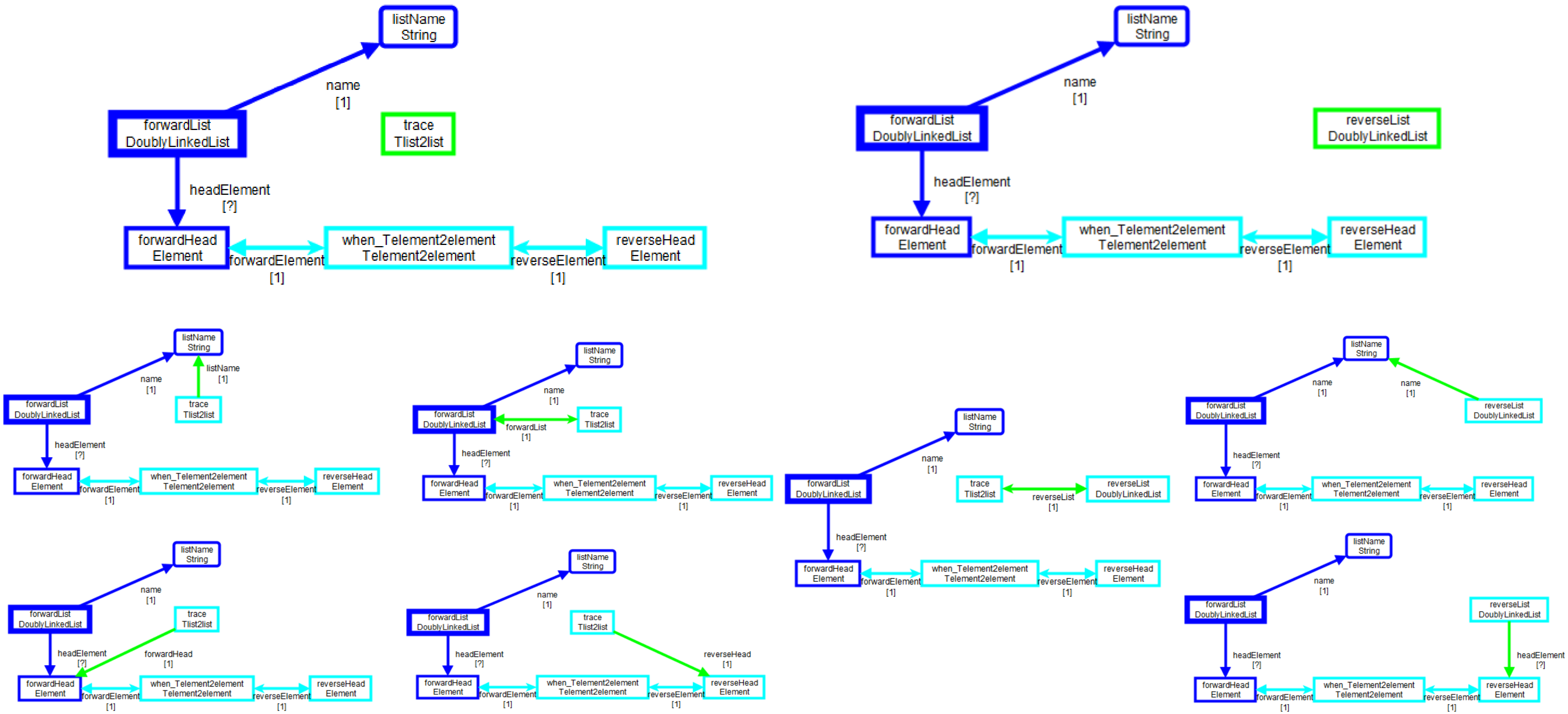
Declarative Transformation Execution

- Transformation specifies numerous 'final' truths
  - relationships between output and input model elements
- Execution must proceed step by step
  - permutations of input objects that match mappings
  - compute step sequence at compile time
- Mapping
  - good / useful unit of programming
    - relevant relationships for a few types
  - bad execution step
    - deadlocks between relationships

Micro-Mapping

- Executable step in a declarative execution
  - no deadlocks between steps
- Primitive Micro-Mapping
  - many dependencies to be satisfied
  - single action - object creation / property assignment
- Composite Micro-Mapping
  - merge primitives with identical dependencies
  - multiple actions

Primitive Micro-Mappings

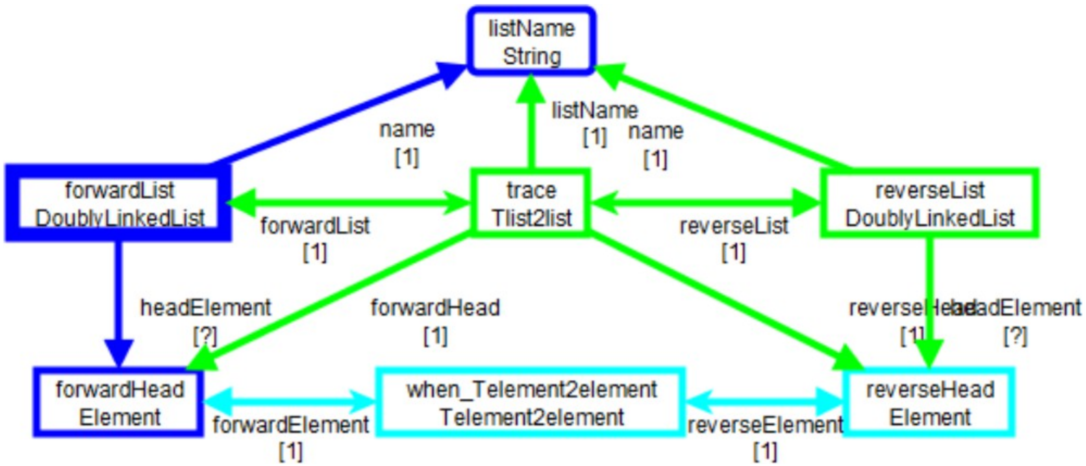


- One **GREEN** action at a time
  - once **CYAN** predicates satisfied

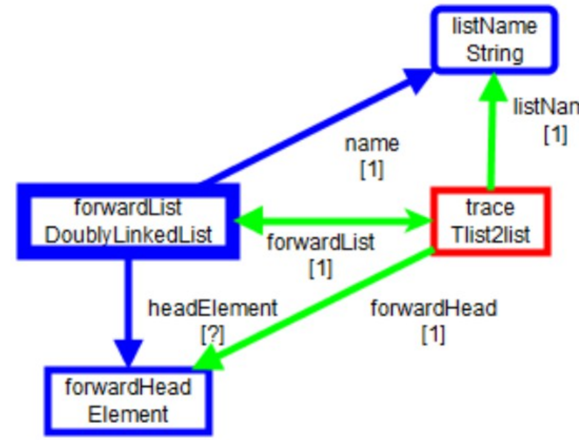
Speculation

- All Primitive Micro-Mappings share predicate
- Acyclic dependency resolveable at run-time
- Cyclic dependency insoluble
  - need to speculate
- defer predicates
  - ATL ignores inter-mapping predicates
    - works for typical transformations
  - Eclipse QVTd ignores predicates wrt trace creation
    - checks predicates wrt output objects/properties

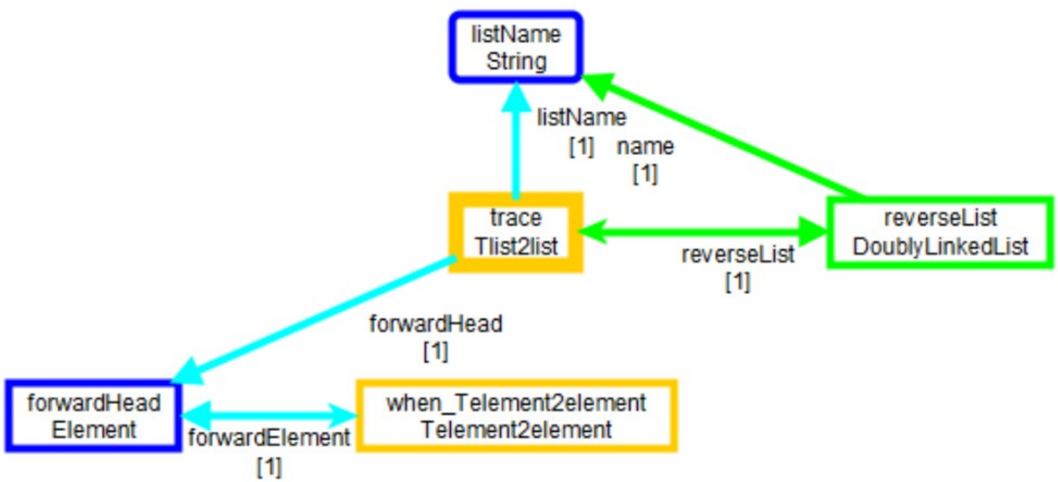
Speculation Partitioning



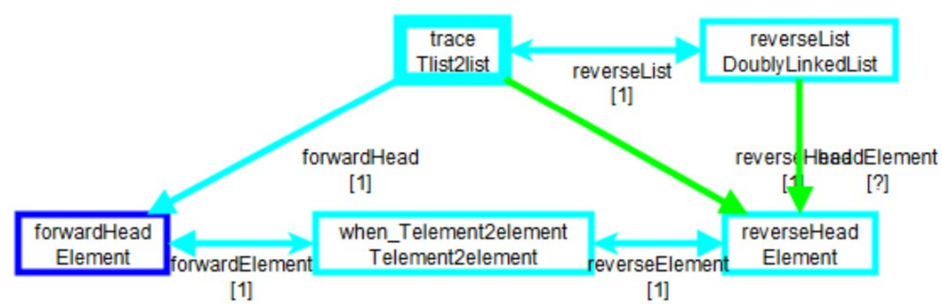
Overall



1: Speculating

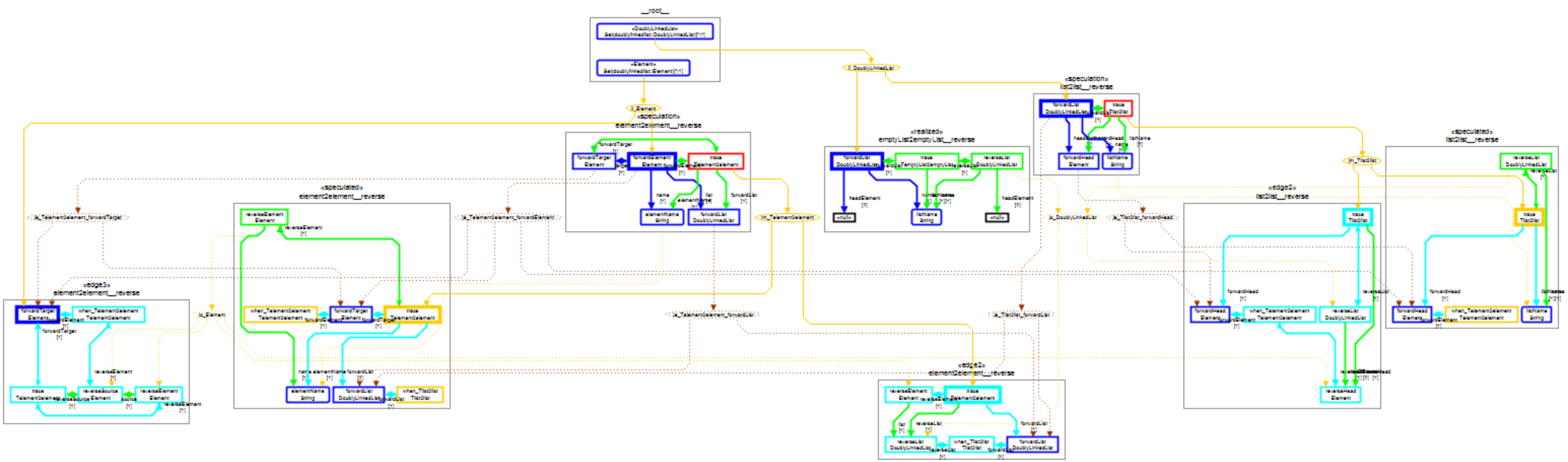


2: Speculated

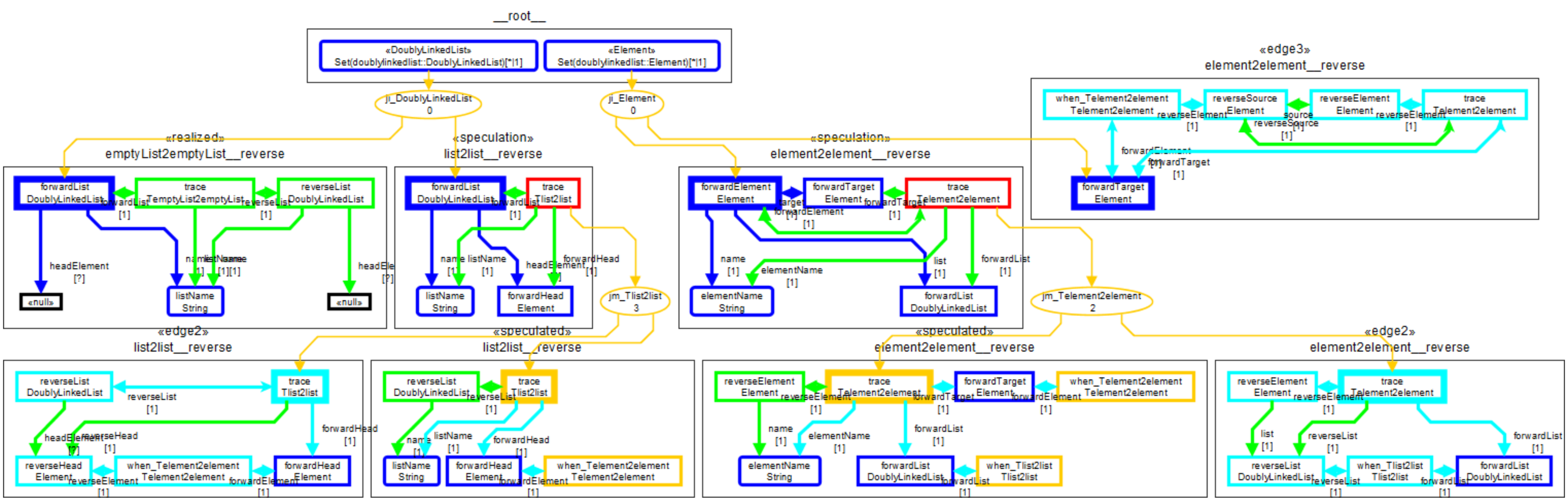


3: Residue

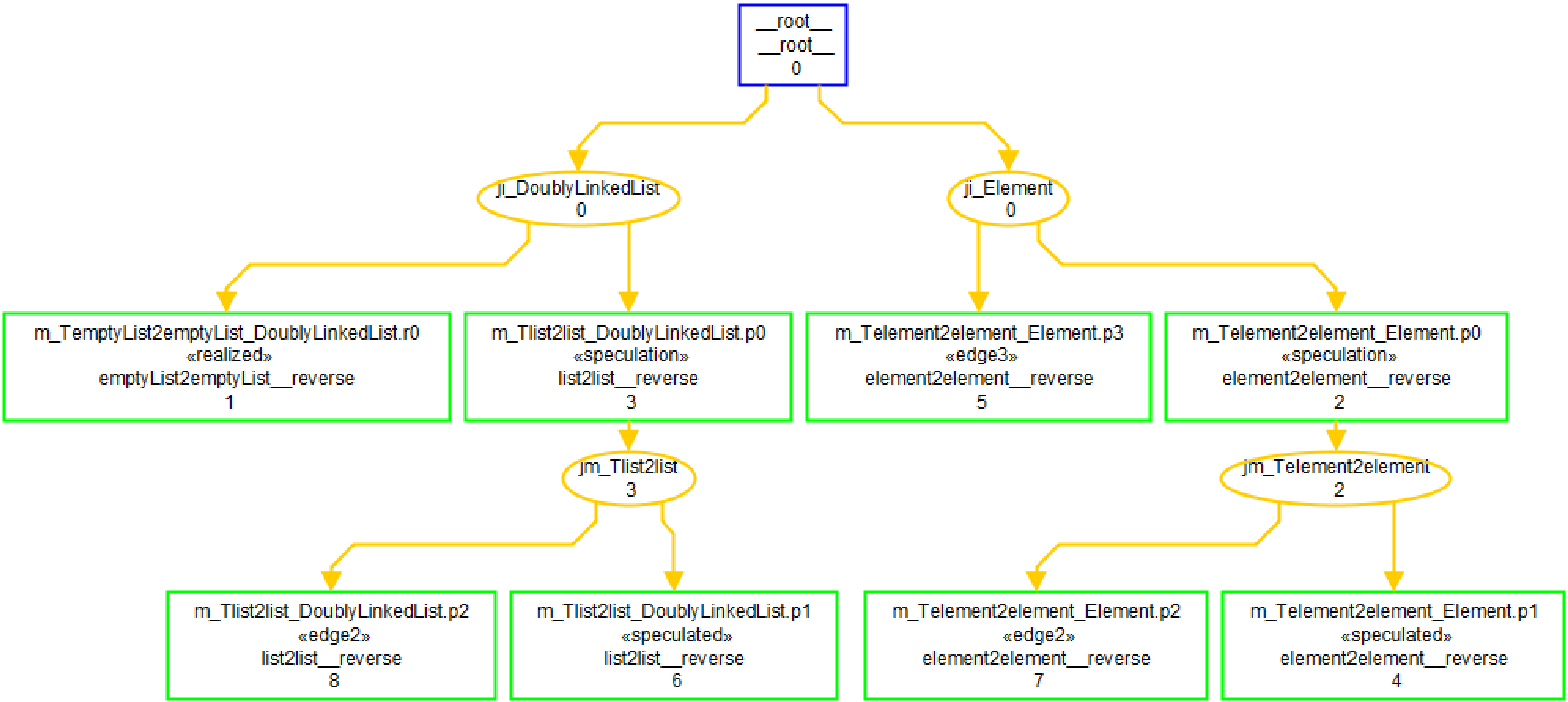
Mapping with all dependencies



Scheduled Mapping, pruned dependencies

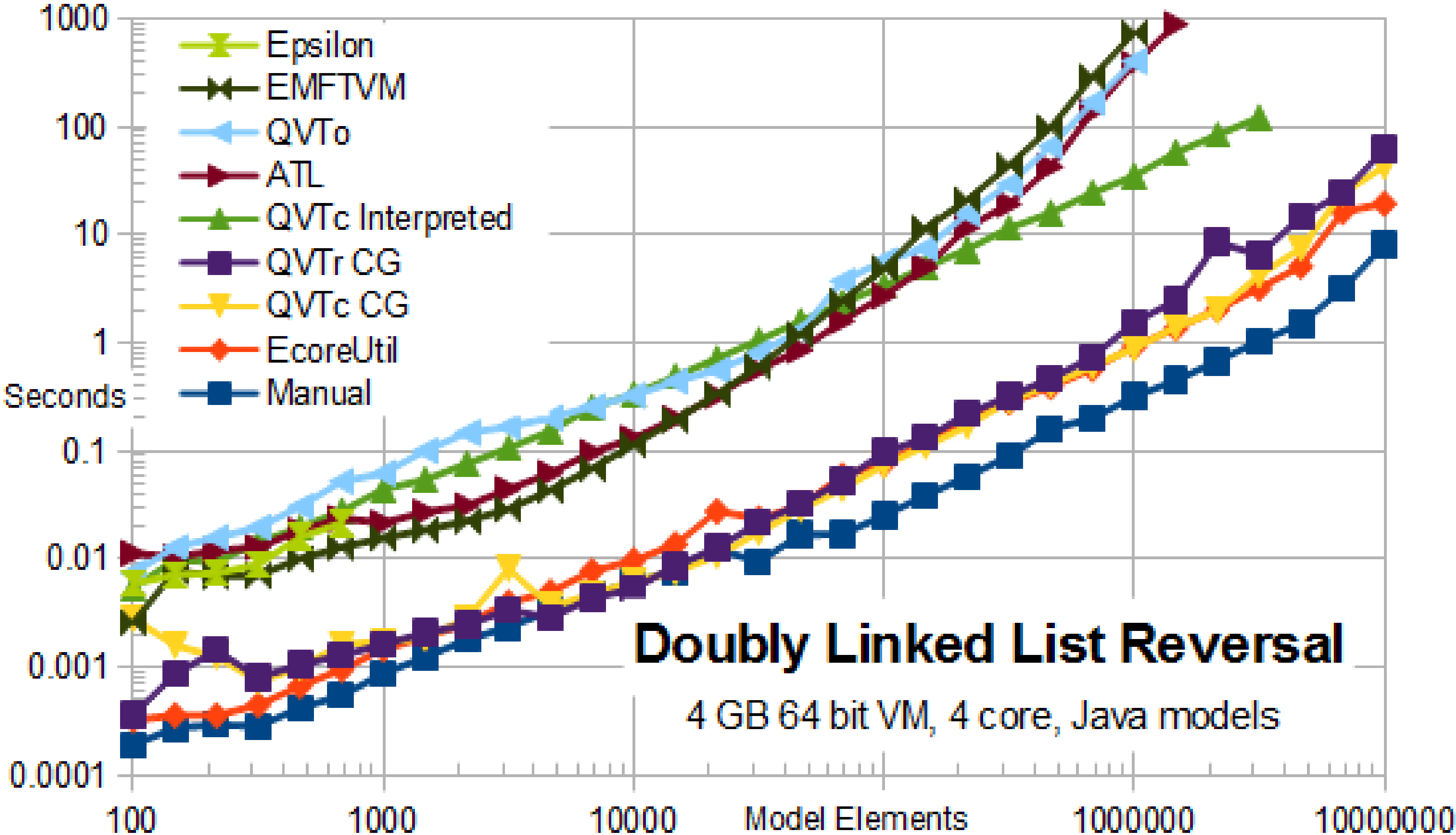


Overview static schedule



- 2 Mappings
  - => 1 Root, 4 communication buffers, 8 Micro-Mappings,
    - TODO post-scheduling merge

Doubly Linked List Reversal Results



Eclipse QVTd Status

- 0.12.0 (Mars - June 2015)
  - QVTi execution (code generated or interpreted)
- 0.13.0 (Neon - June 2016)
  - preliminary QVTc / QVTr execution
    - low quality - research only
  - no incremental / check / in-place facilities
  - no debugger
  - minimal documentation / examples
- 1.0.0 (Oxygen - June 2017)
  - first release functionality (? with UMLX ?)

Conclusion

- Do things in the right order
  - Mappings declare the order
  - Micro-Mappings can be ordered (graphically)
- First implementation of the QVTc specification.
- First optimized implementation of QVTr.
- First direct code generator for model transformations.
- Thirty fold speed-up.
- Many more optimizations to do.