A Graph Rewriting Model for Object-Oriented Software Refactoring

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What is refactoring?

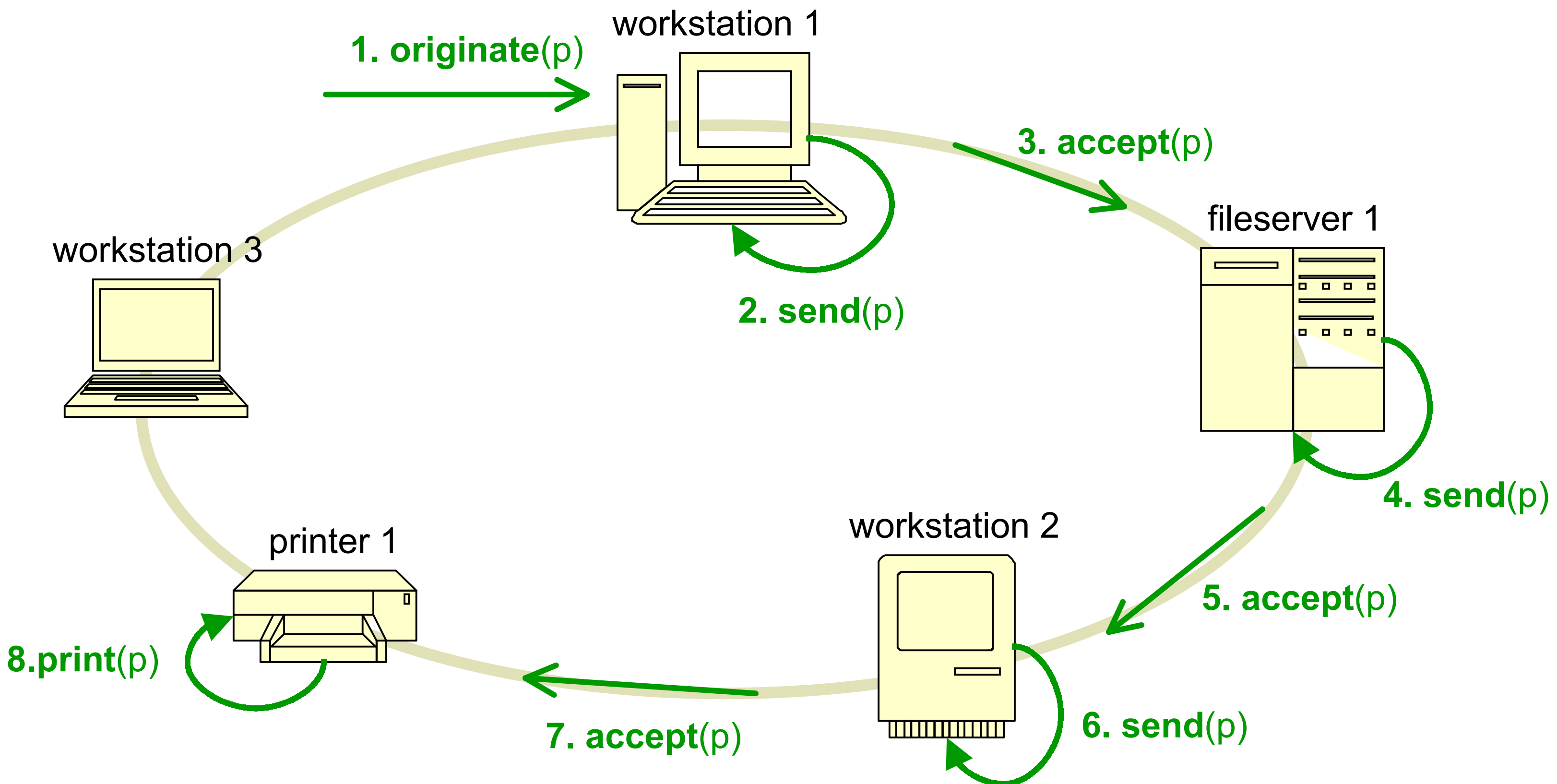
- Refactorings are software transformations that restructure an object-oriented application while preserving its behaviour.
- According to Fowler (1999), refactoring
  - improves the design of software
  - makes software easier to understand
  - helps you find bugs
  - helps you program faster

Goal

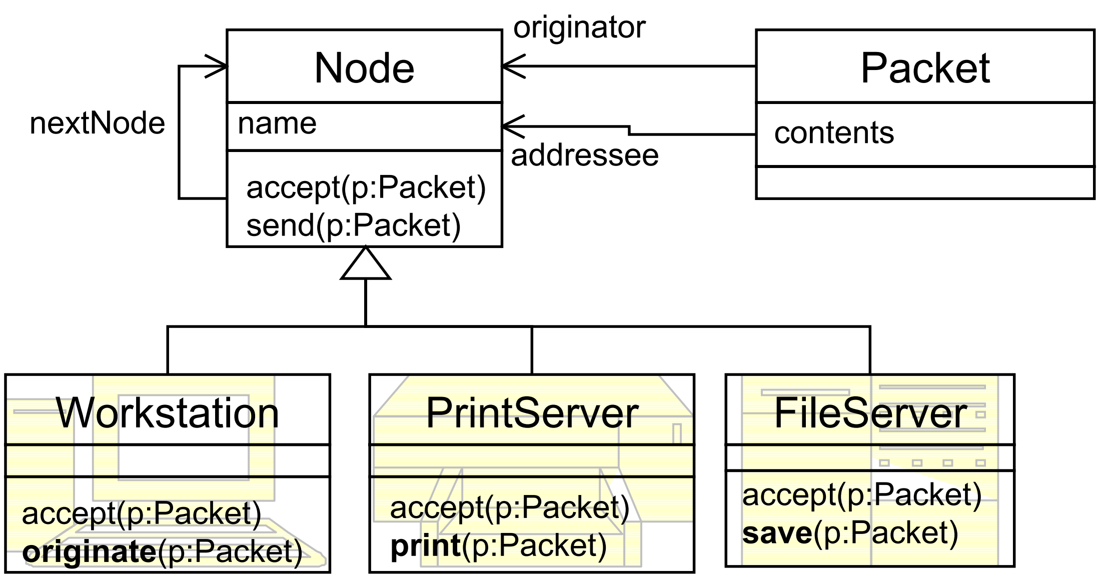
- Improve tool support for refactoring object-oriented software …
    - less *ad hoc*
    - more scalable (e.g., composite refactorings)
    - more language independent
    - more correct (e.g., guarantee behaviour preservation)
- … by providing a formal model in terms of
  - graphs
    - compact and expressive representation of program structure and behaviour
    - 2-D nature removes redundancy in source code (e.g., localised naming)
  - graph rewriting
    - intuitive description of transformation of complex graph-like structures
    - theoretical results help in the analysis of such structures
      - (confluence property, parallel/sequential independence, critical pair analysis)

Case study: LAN simulation

- Goal: show feasibility of graph rewriting formalism to express and detect various kinds of behaviour preservation



UML class diagram



Java source code

```
public class Node {
  public String name;
  public Node nextNode;
  public void accept(Packet p) {
    this.send(p); }
  protected void send(Packet p) {
    System.out.println(
      name +
      "sends to" +
      nextNode.name);
    nextNode.accept(p); }
  }
```

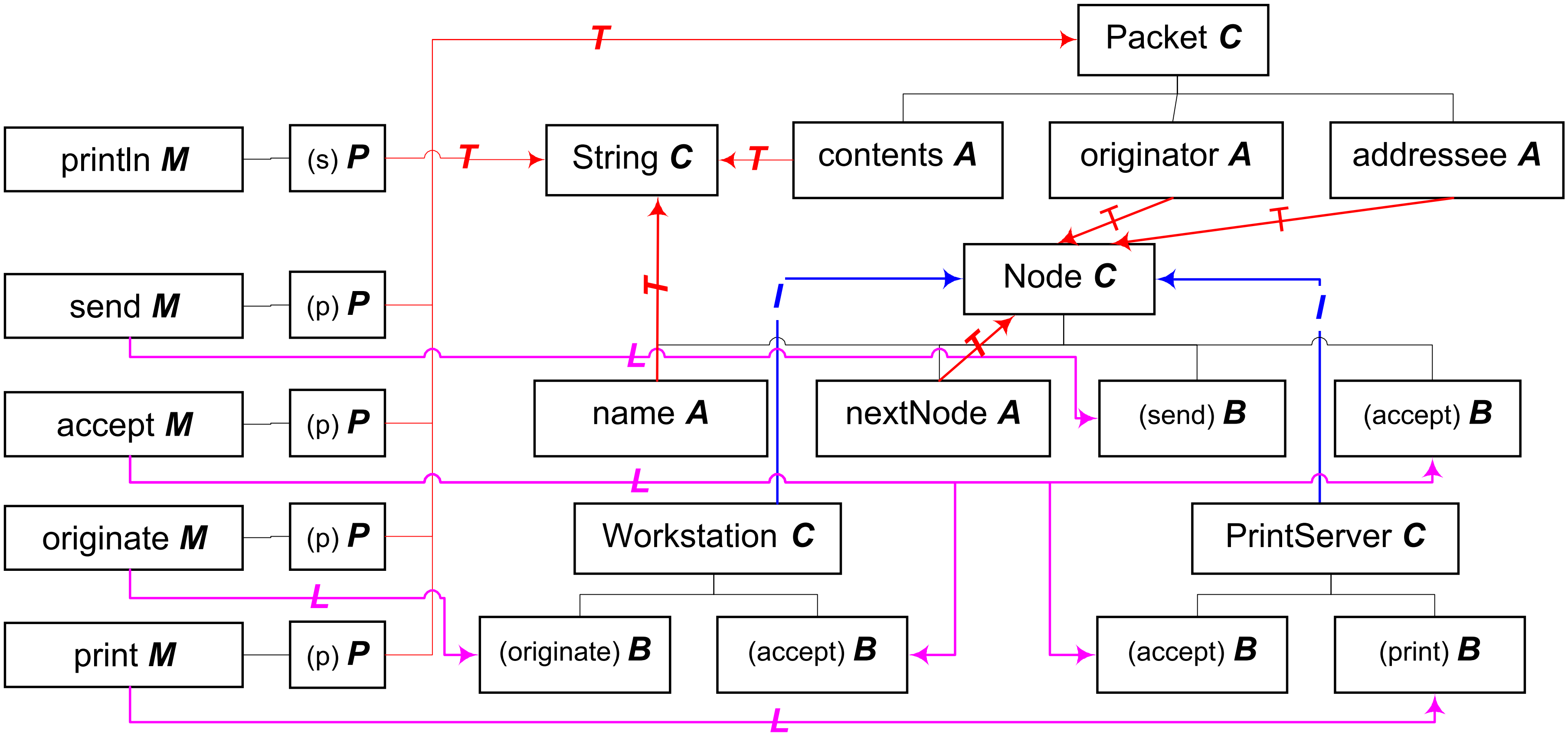
```
public class Packet {
  public String contents;
  public Node originator;
  public Node addressee;
  }
```

```
public class Printserver extends Node {
  public void print(Packet p) {
    System.out.println(p.contents);
    }
  public void accept(Packet p) {
    if(p.addressee == this)
      this.print(p);
    else
      super.accept(p);
    }
  }
```

```
public class Workstation extends Node {
  public void originate(Packet p) {
    p.originator = this;
    this.send(p);
    }
  public void accept(Packet p) {
    if(p.originator == this)
      System.err.println("no
destination");
    else super.accept(p);
    }
  }
```

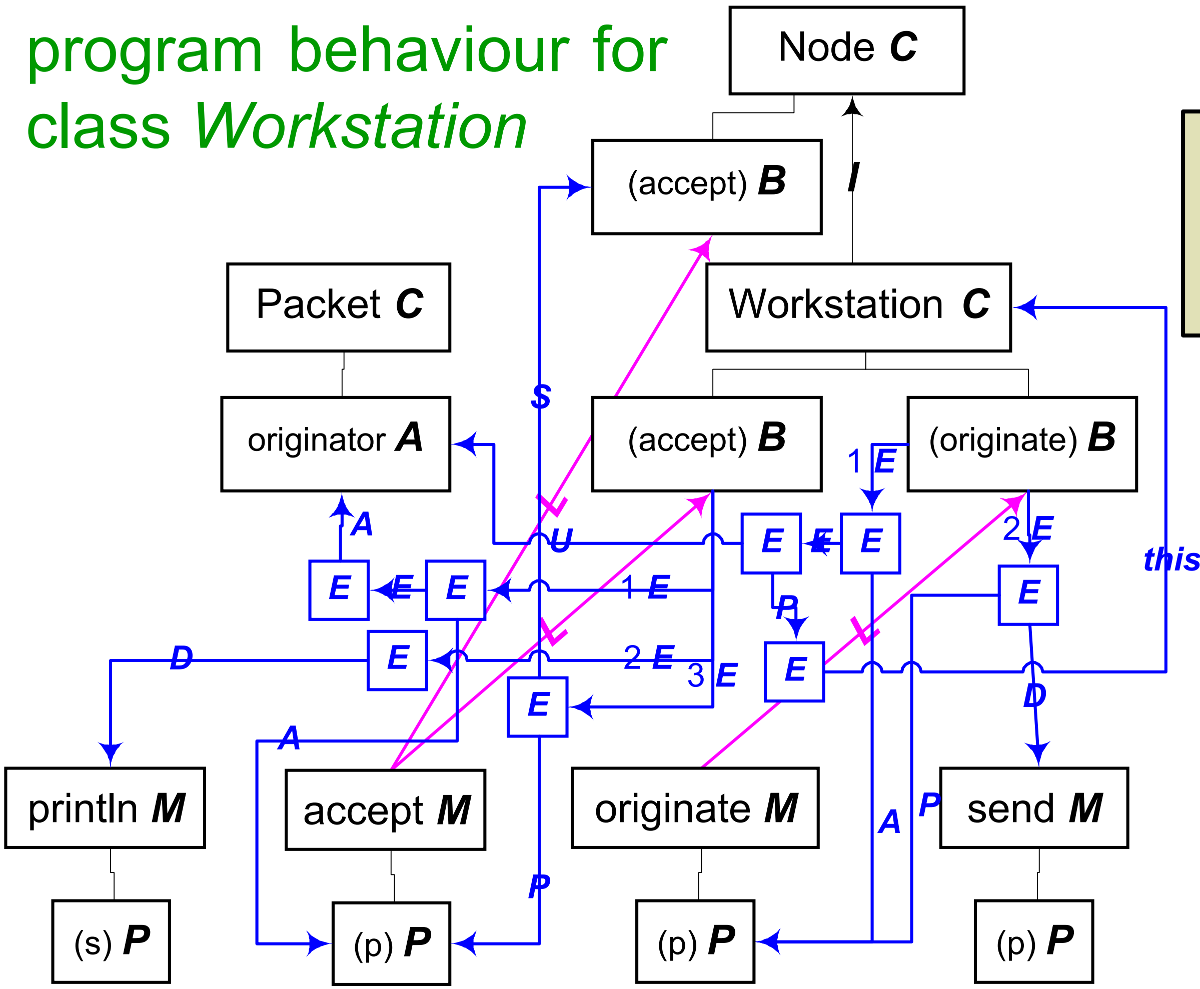
Graph representation – part 1

- program structure



Graph representation – part 2

- program behaviour for class *Workstation*




```
void originate(Packet p)
1:{ p.originator = this;
2:  this.send(p); }
```

Refactoring – Encapsulate Field

Fowler 1999, page 206

There is a public field

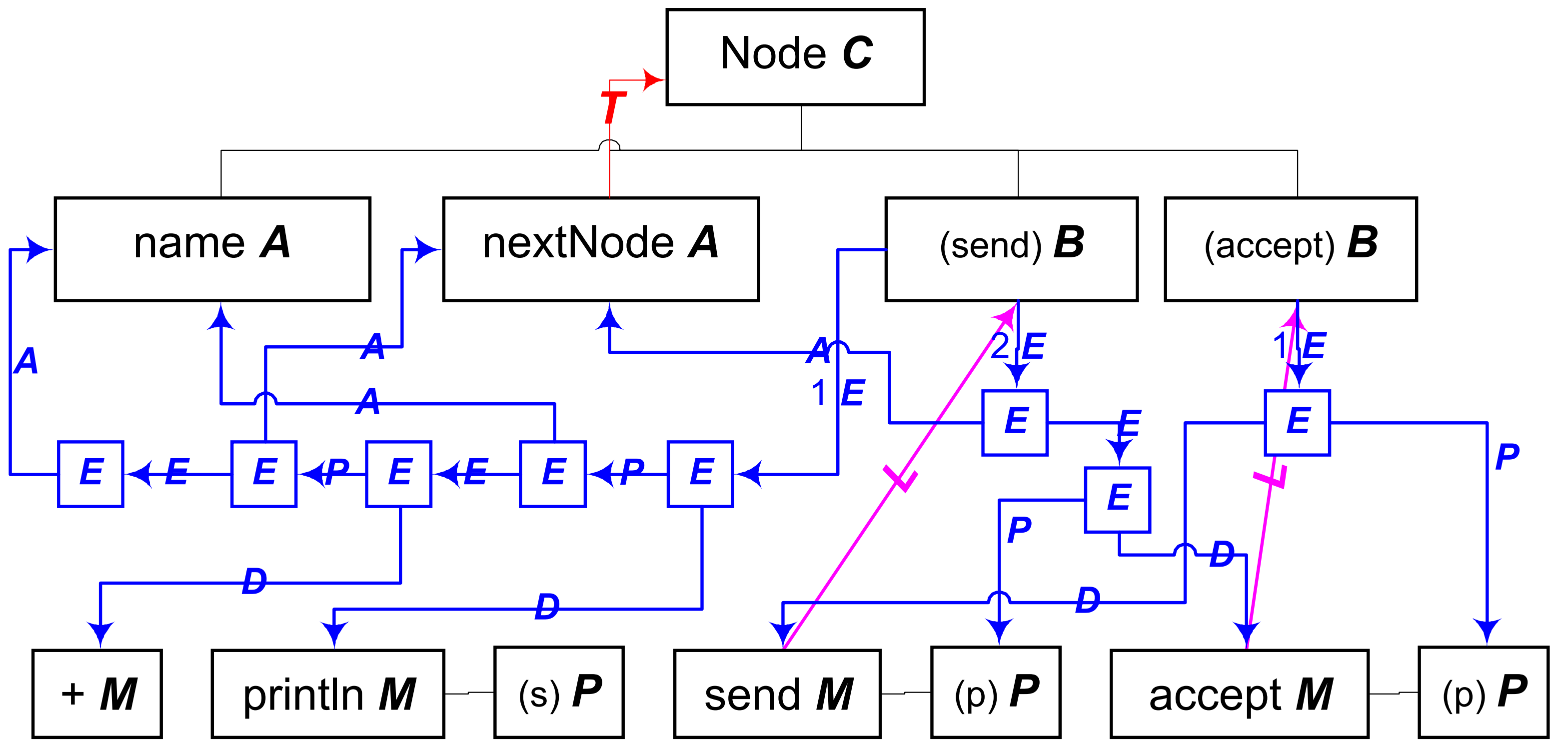
Make it private and provide accessors

```
public class Node {
  public String name;
  public Node nextNode;
  public void accept(Packet p) {
    this.send(p); }
  protected void send(Packet p) {
    System.out.println(
      name +
      "sends to" +
      nextNode.name);
    nextNode.accept(p); }
  }
```

```
public class Node {
  private String name;
  private Node nextNode;
  public String getName() {
    return this.name; }
  public void setName(String s) {
    this.name = s; }
  public Node getNextNode() {
    return this.nextNode; }
  public void setNextNode(Node n) {
    this.nextNode = n; }
  public void accept(Packet p) {
    this.send(p); }
  protected void send(Packet p) {
    System.out.println(
      this.getName() +
      "sends to" +
      this.getNextNode().getName());
    this.getNextNode().accept(p); }
}
```

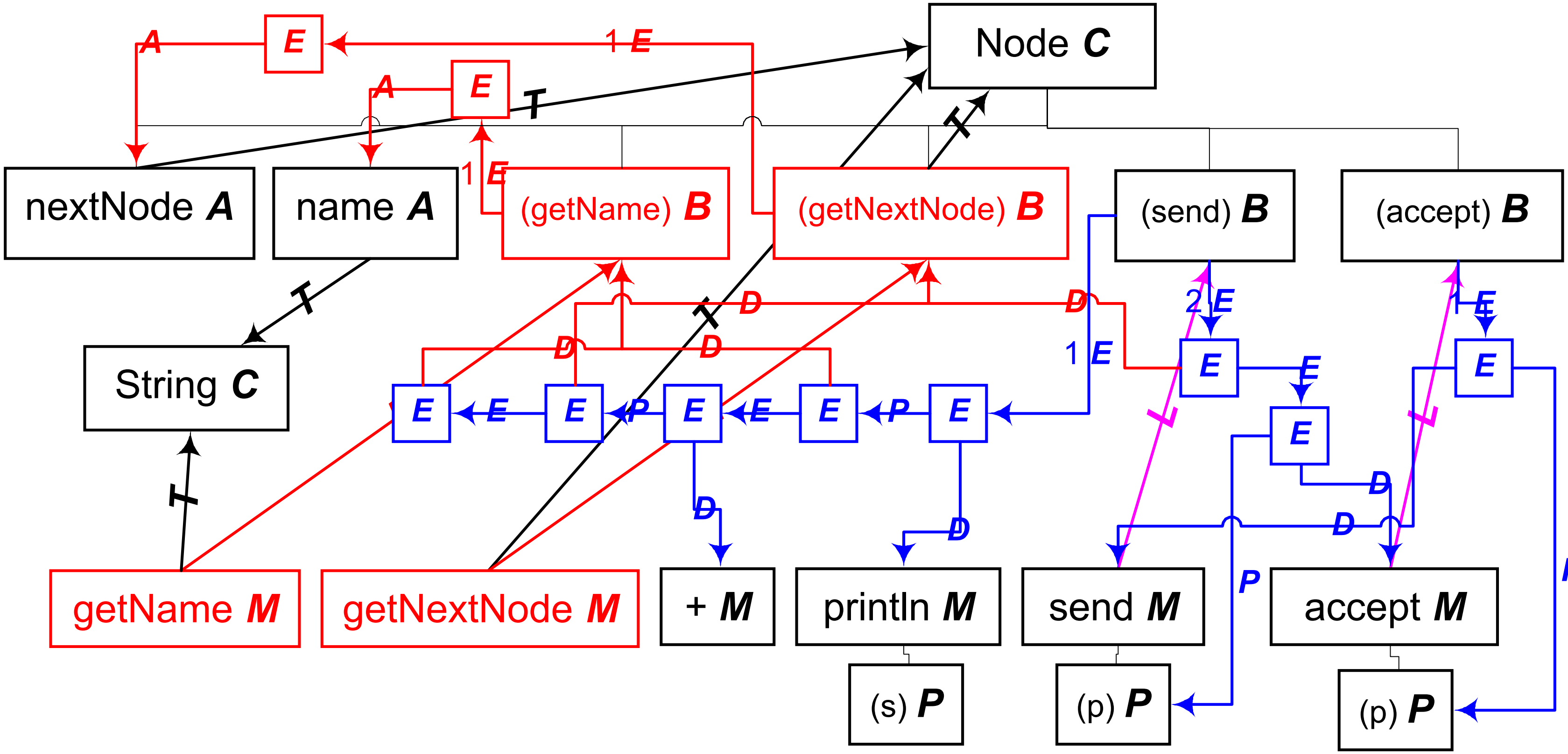
Refactoring – Encapsulate Field

- before the refactoring



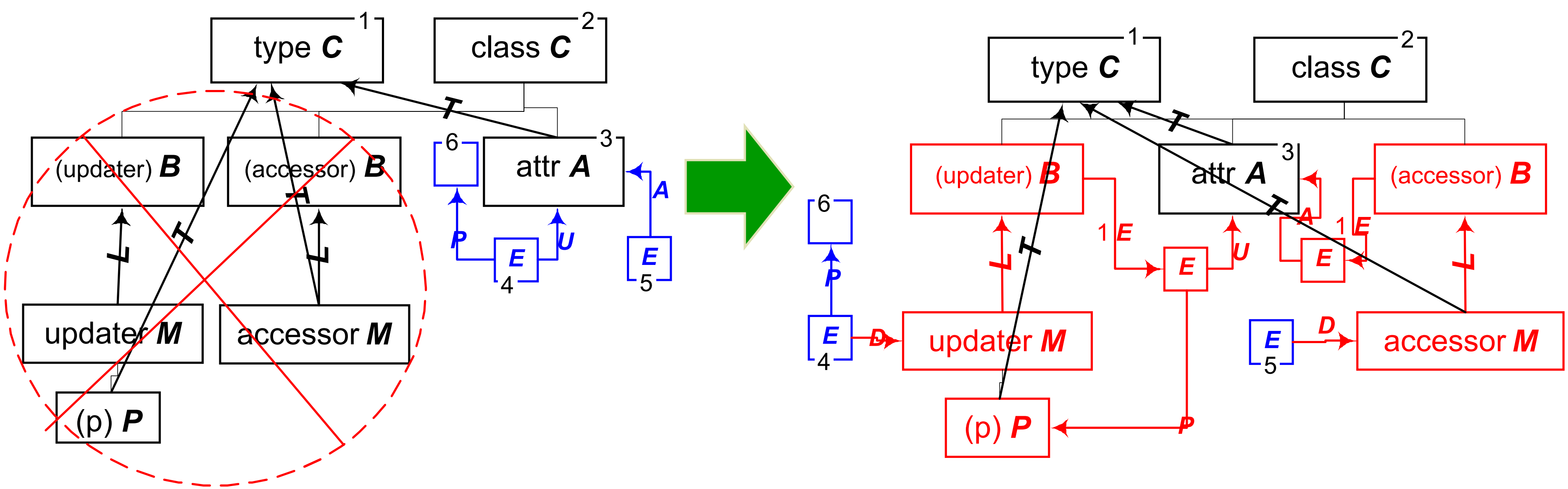
Refactoring – Encapsulate Field

- after the refactoring



Graph transformation – Encapsulate Field

- refactoring is achieved by applying two occurrences of production *EncapsulateField(class,attr,type,accessor,updater)*
  - EncapsulateField(Node,name,String,getName,setName)
  - EncapsulateField(Node,nextNode,Node,getNextNode,setNextNode)



Behaviour preservation invariants

- Access preservation
  - each method body (indirectly) performs at least the same attribute accesses as it did before the refactoring
- Update preservation
  - each method body (indirectly) performs at least the same attribute updates as it did before the refactoring
- Statement preservation
  - each method (indirectly) performs at least the same statements as it did before the refactoring
- Type preservation
  - each statement in each method body still has the same result type or return type as it did before the refactoring

Behaviour preservation invariants

- EncapsulateField preserves behaviour
  - *access preserving*: all attribute nodes can still be accessed via a transitive closure

  - *update preserving*: all attribute nodes can still be updated via a transitive closure

Behaviour preservation invariants can be detected by **graph patterns**

Conclusion

- Graph rewriting seems a useful and promising formalism to provide support for refactoring
  - More practical validation needed
  - Current experiment only focuses on behaviour preservation
  - A formalism can assist the refactoring process in many other ways
  - Proposed FWO research project (4 years / 3 persons)

Open questions

- Which program properties should be preserved by refactorings?
  - input/output behaviour, timing constraints, static versus dynamic behaviour
- What is the complexity of a refactoring?
  - complexity of applicability / complexity of applying the refactoring
- How do refactorings affect quality factors?
  - increase/decrease complexity, understandability, maintainability, …
- How can refactorings be composed/decomposed?
  - composite refactorings / extracting refactorings from successive releases
- How do refactorings interact?
  - parallel application of refactorings may lead to consistency problems
- How to provide support for non-behaviour-preserving refactorings?
- Co-evolution: How do refactorings affect design models?
- Language-independent formalism for refactoring?