Linking Programs to Architectures: An Object-Oriented Hierarchical Software Model based on Boxes

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Expertise

- Strong Experience
  - Design and Implementation of Programming Languages
  - Specification and Verification of OOLs
  - Compiler Construction, Verification, and Optimization
  - Component-Oriented Development
  - Theorem Provers
  - Type Systems
- Gaining Experience
  - Adaptive and Reconfigurable Systems
  - Concurrent and Distributed Systems
  - Software Architectures

Outline

Our Approach for CoCoME

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Common Component Modeling Example

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Common Component Modeling Example

Why do we need components?

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To enable reuse and substitution of software artifacts

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To enable reuse and substitution of software artifacts

... and modular verification

What are reuse and substitution?

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Reuse means to use one component in multiple environments.

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Substitution means to replace a component by another component in one environment.

What are reuse and substitution?

Reuse means to use one component in multiple environments.

one component – multiple environments

Substitution means to replace a component by another component in one environment.

multiple components – one environment

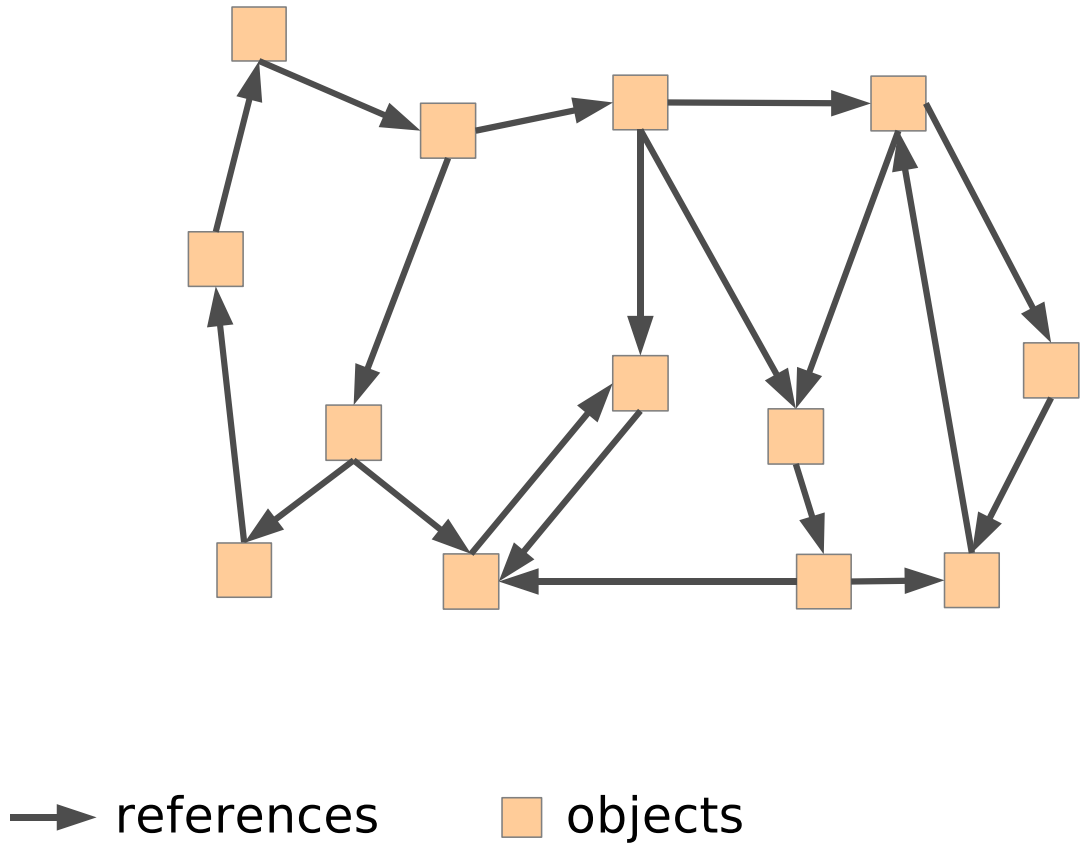
When are reuse and substitution possible?

When are reuse and substitution possible?

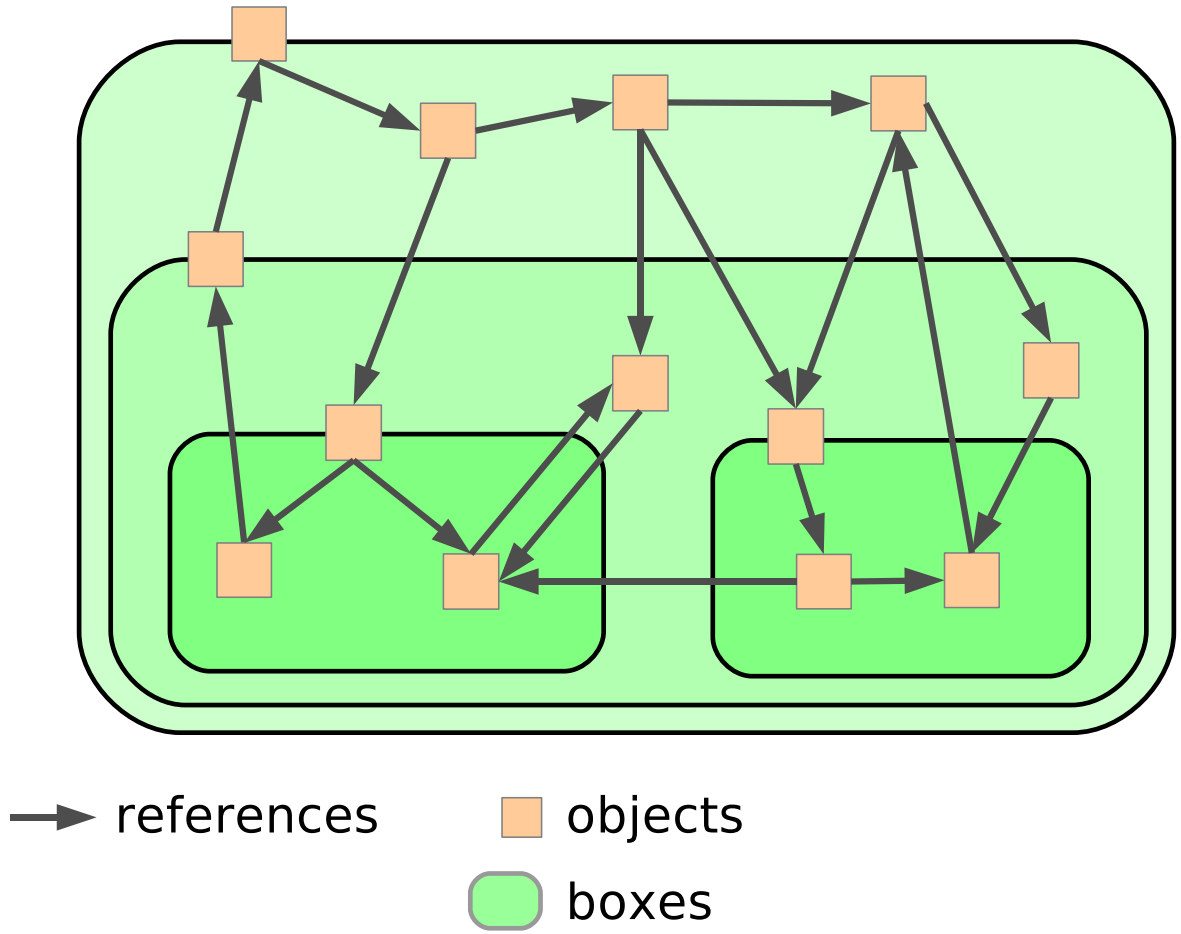
We have to understand

- compatibility of interfaces
- compatibility of behaviors
- what constitutes a component
  - statically
  - dynamically

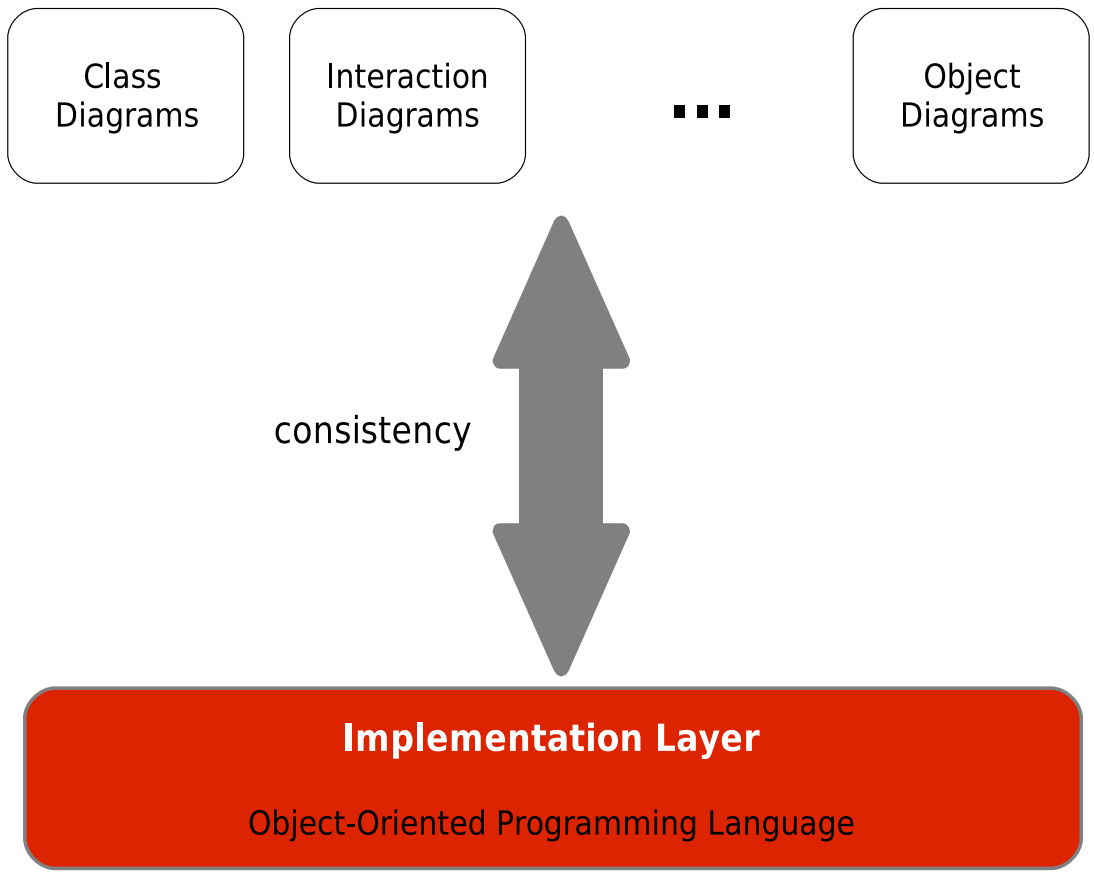
Unstructured Object-Heap



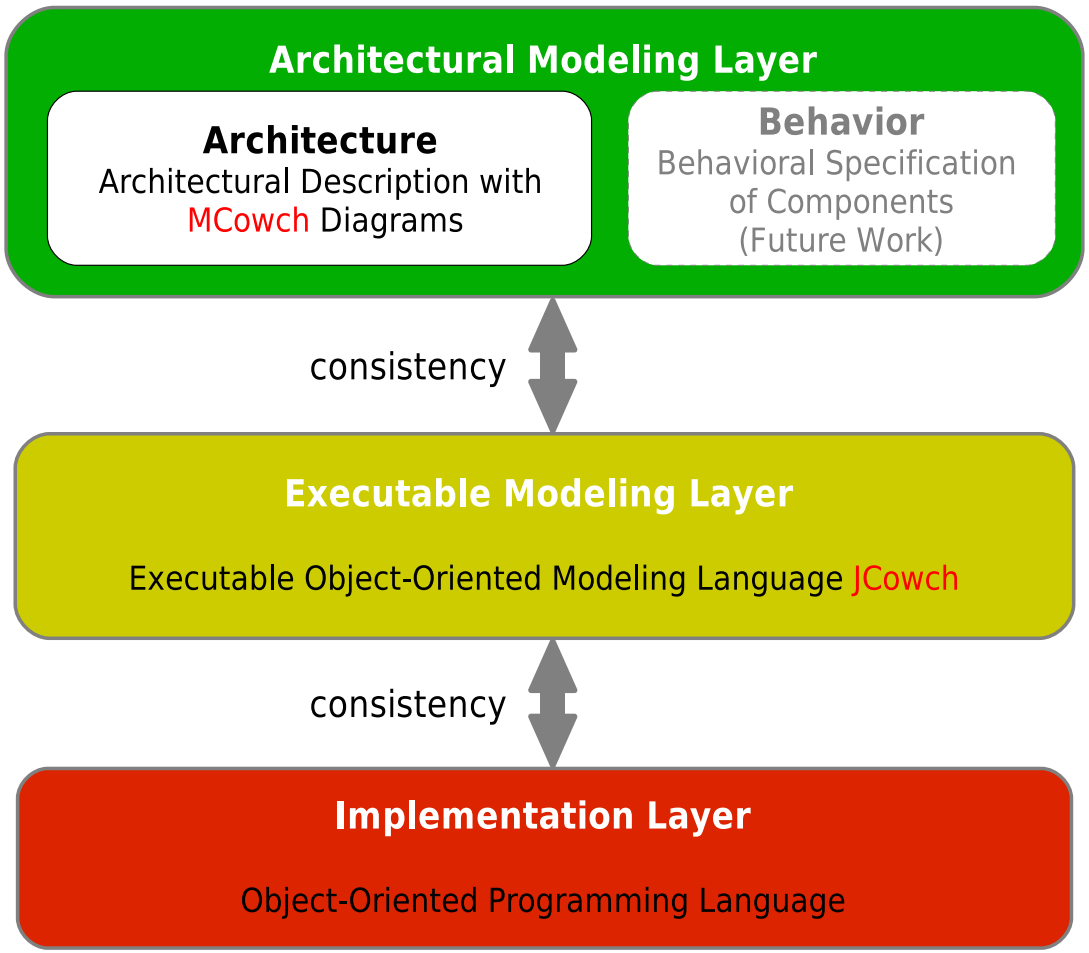
Heap structured with Boxes



Standard Approach: UML



Our Approach: Cowch

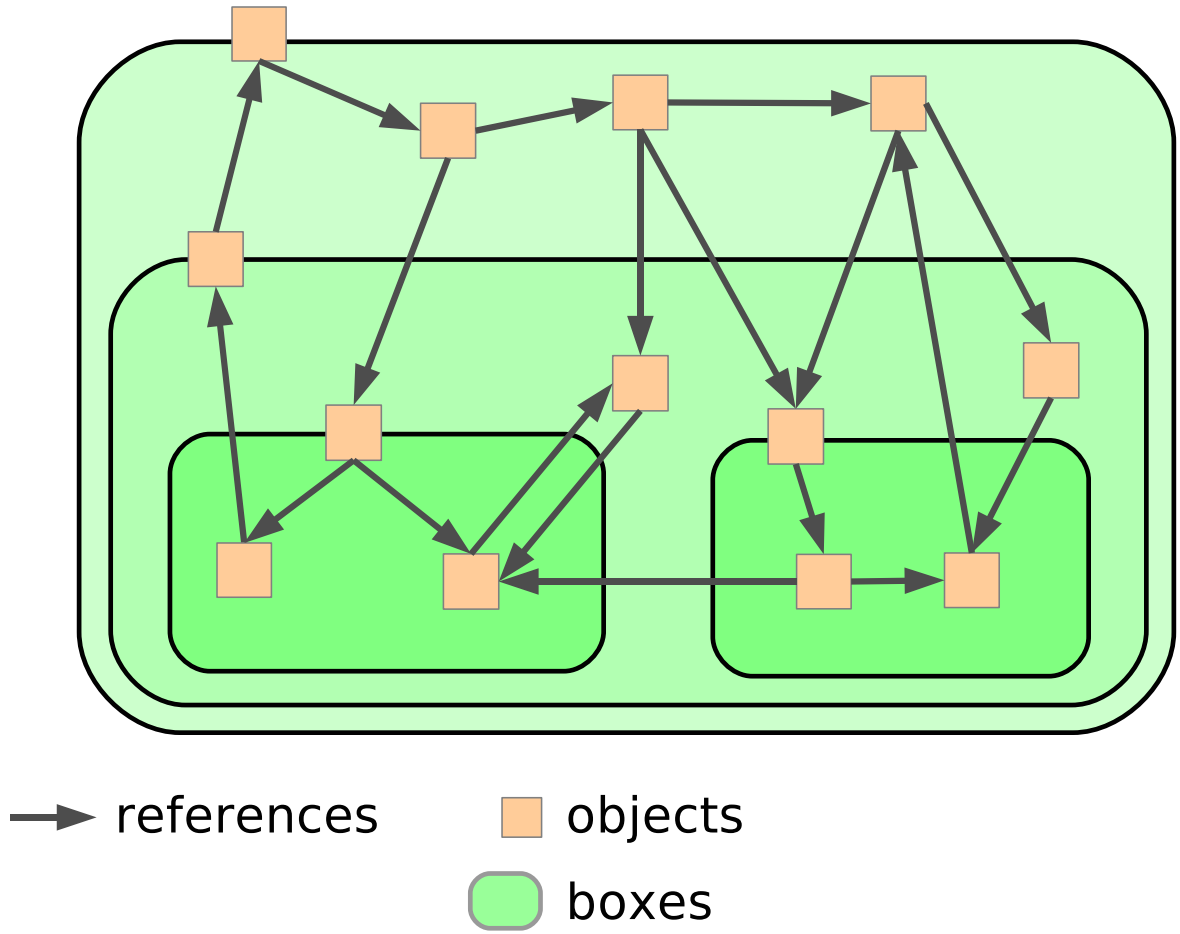


Executable Modeling Layer

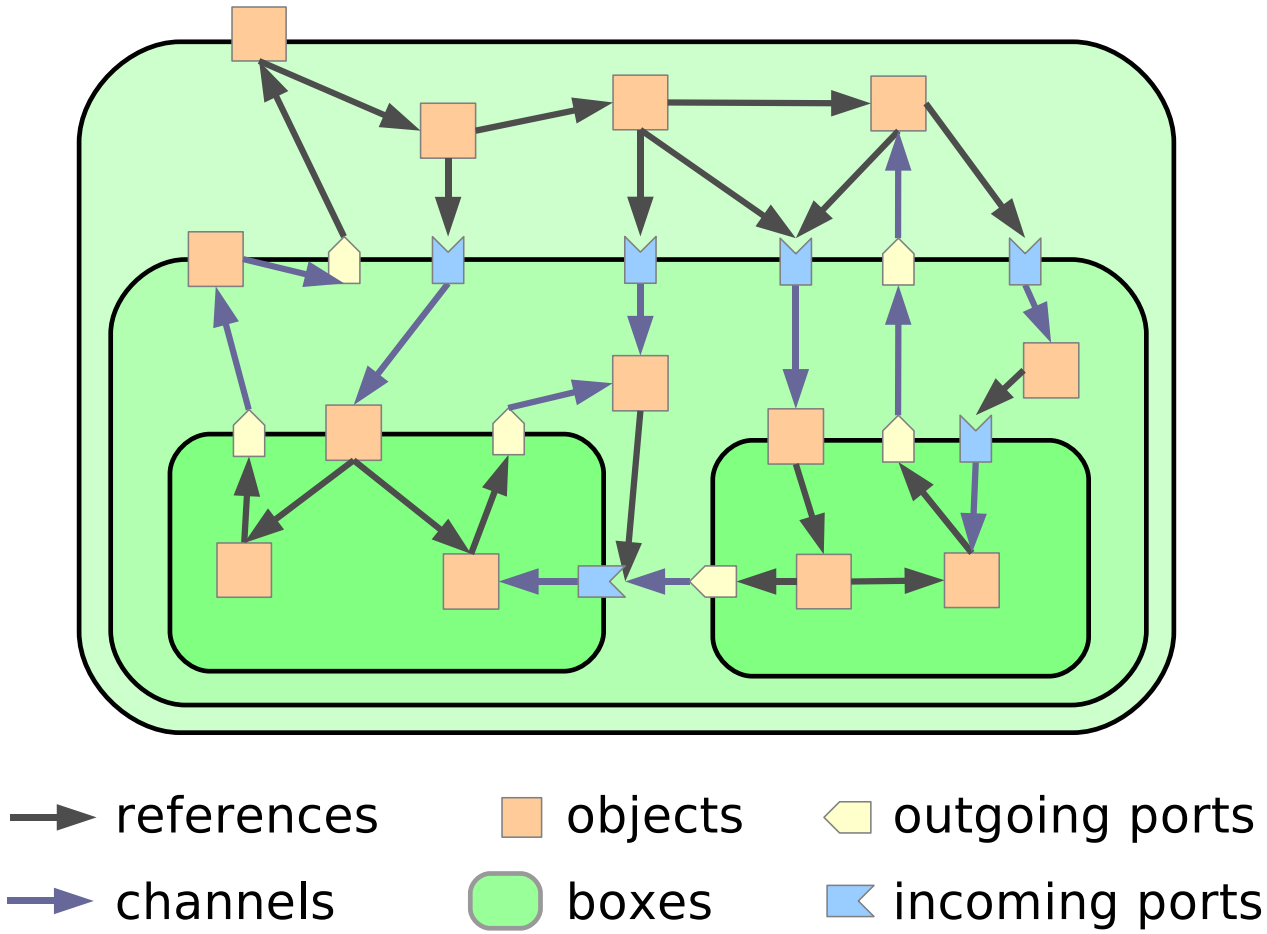
JCowch

- Executable Language
- Object-Oriented
- Classes and Interfaces
- Components and Boxes
- Ports and Channels
- High-Level Concurrency Model

Heap structured with Boxes



Heap structured with Boxes, Ports, and Channels



Ports and Channels

Ports

- Explicitly named interfaces at the boundary
- Outgoing or incoming
- Typed by interfaces
- Referenceable like ordinary objects

Channels

- Connect ports/ports and ports/objects
- Explicit creation/destruction
- Method-level channels possible

Concurrency

Based on the Join Calculus

- Asynchronous methods
- Join Patterns
- No explicit thread creation
- No explicit locks

JCowch Example

Producer–Consumer

```
box class Producer {
  outport StringBuffer buffer;
  async run() {
    while (true) {
      String s = "Hello World";
      buffer.put(s);
    }
  }
}

box class Consumer {
  outport StringBuffer buffer;
  async run() {
    while (true) {
      String s = buffer.get();
      System.out.println(s);
    }
  }
}
```

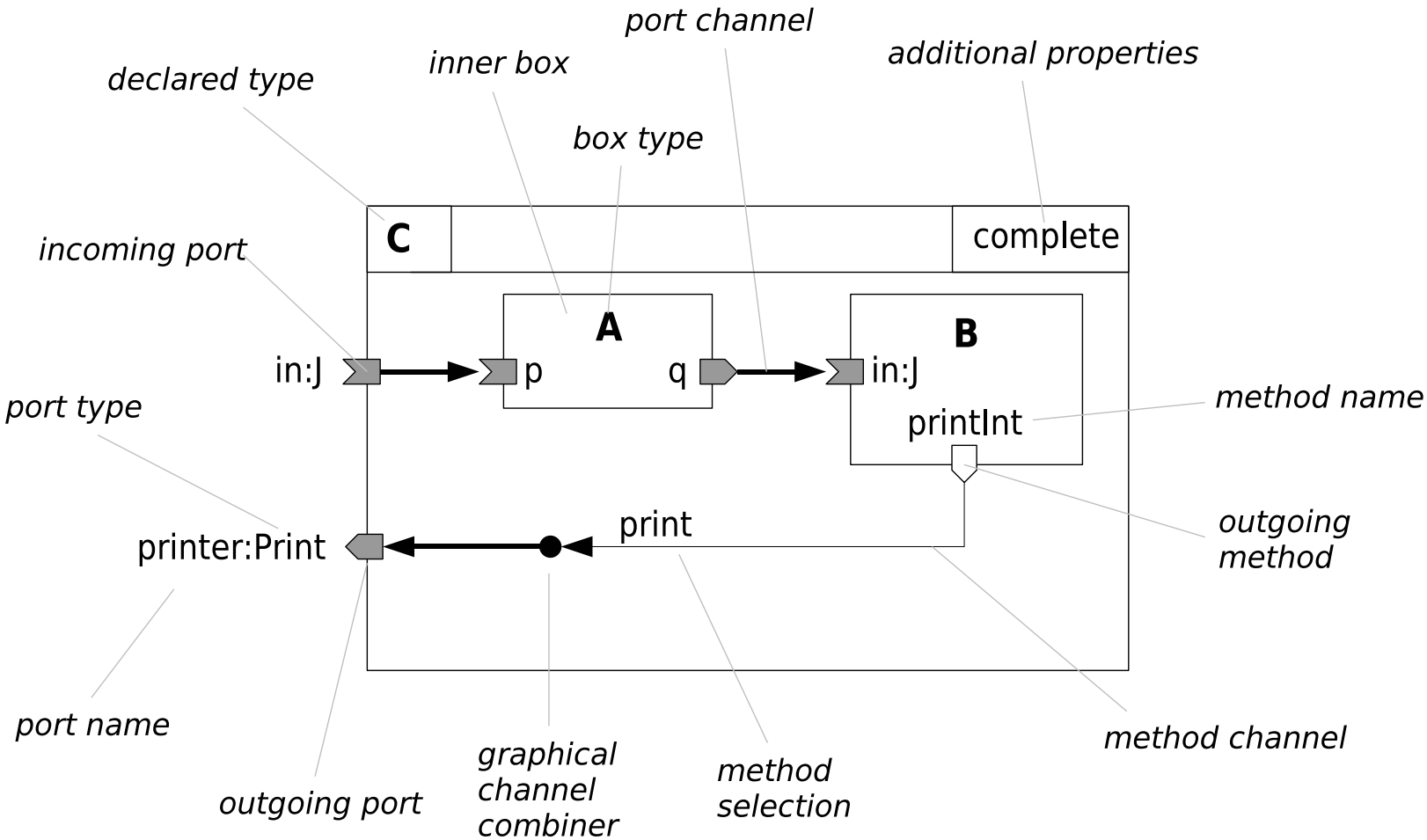
```
interface StringBuffer {
  async put(String s);
  String get();
}

box class StringBufferImpl implements StringBuffer {
  String get() & put(String s) { return s; }
}

box class Main {
  void main() {
    StringBuffer buff = new StringBufferImpl();
    Producer prod = new Producer();
    Consumer cons = new Consumer();
    connect prod.buffer to buff;
    connect cons.buffer to buff;
    prod.run(); cons.run();
  }
}
```

Architectural Modeling Layer

MCowch

- Graphical non-executable language
- Describes the statically determined box structure
  - Hierarchy
  - Channels
- Semantic-based consistency relation to executable modeling layer
- In general underspecified
  - Also fully specified models supported

MCowch Syntax



Additional Properties

Complete Diagrams

- Fully specified models
- Architecture model $\widehat{=}$ Executable model
- Allows code generation

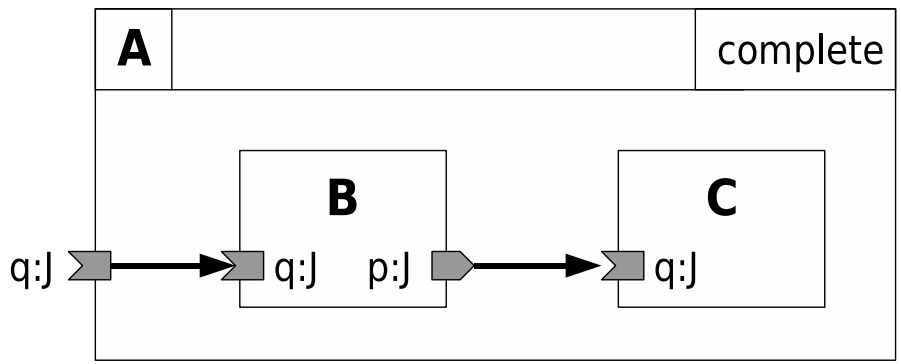
Active/Reactive Boxes

- Active Boxes
  - May spontaneously emit messages
- Reactive Boxes
  - Require external stimulation

Consistency Relation between MCowch and JCowch

Example 1/2

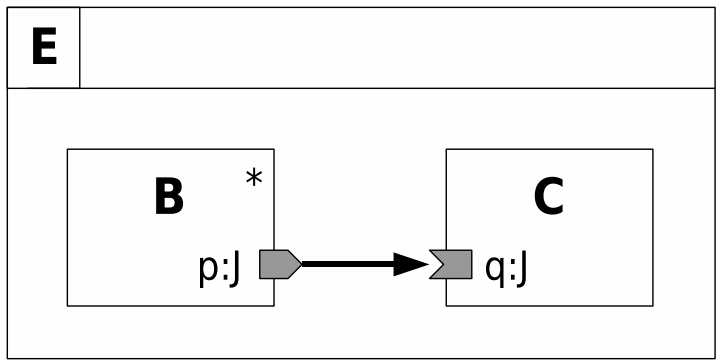
```
box class A {
  inport J q;
  B b; C c;
  A() {
    b = new B();
    c = new C();
    connect this.q to b.q;
    connect b.p to c.q;
  }
}
```



Consistency Relation between MCowch and JCowch

Example 2/2

```
box class E {
  C c;
  B[] b;
  E(int numB) {
    c = new C();
    b = new B[numB];
    for (int i=0; i <numB; i++) {
      b[i] = new B();
      connect b[i].p to c.q;
    }
  }
}
```



Summary (1)

Notion of a component

Which allows to define

- the constituting elements
- the interface
- the behavior

$\Rightarrow$ safe reuse and substitution come into reach

Modeling approach

- Two-Layered approach
- Consistency relation

Summary (2)

Scope

Distributed concurrent object-oriented systems

Focus

Structural and behavioral aspects

Our CoCoME Model

The Modeled Part of CoCoME

We provide

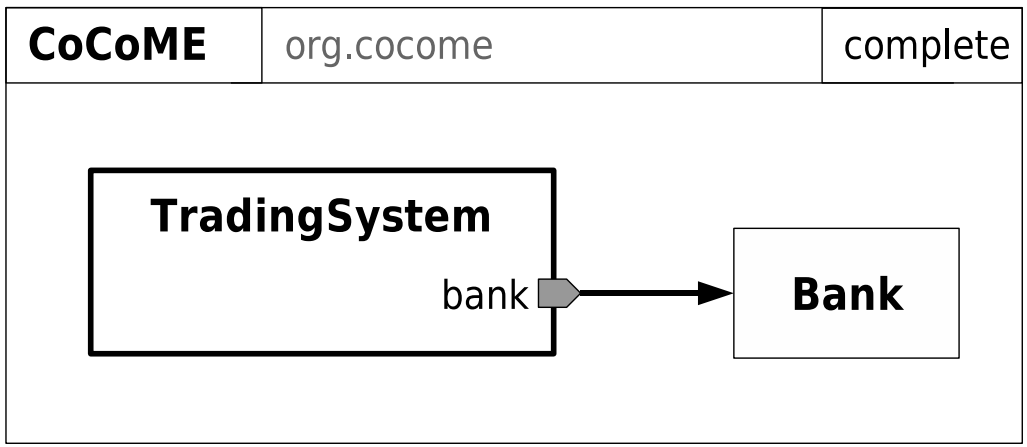
- Architectural Model
  - Most parts
    - No Inventory
    - No GUI
- Executable Model
  - Only exemplarily
    - Coordinator Component

We abstracted from

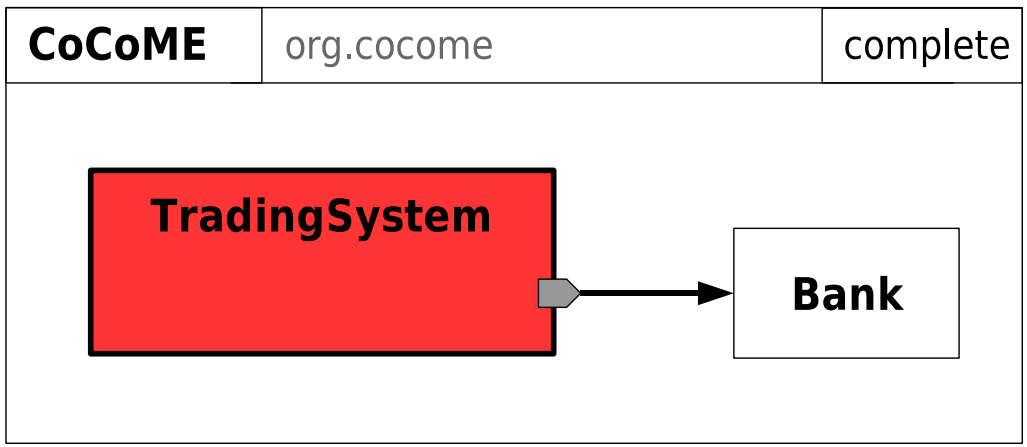
- Technologies
  - Hibernate, RMI, ActiveMQ, ...

Architectural Model

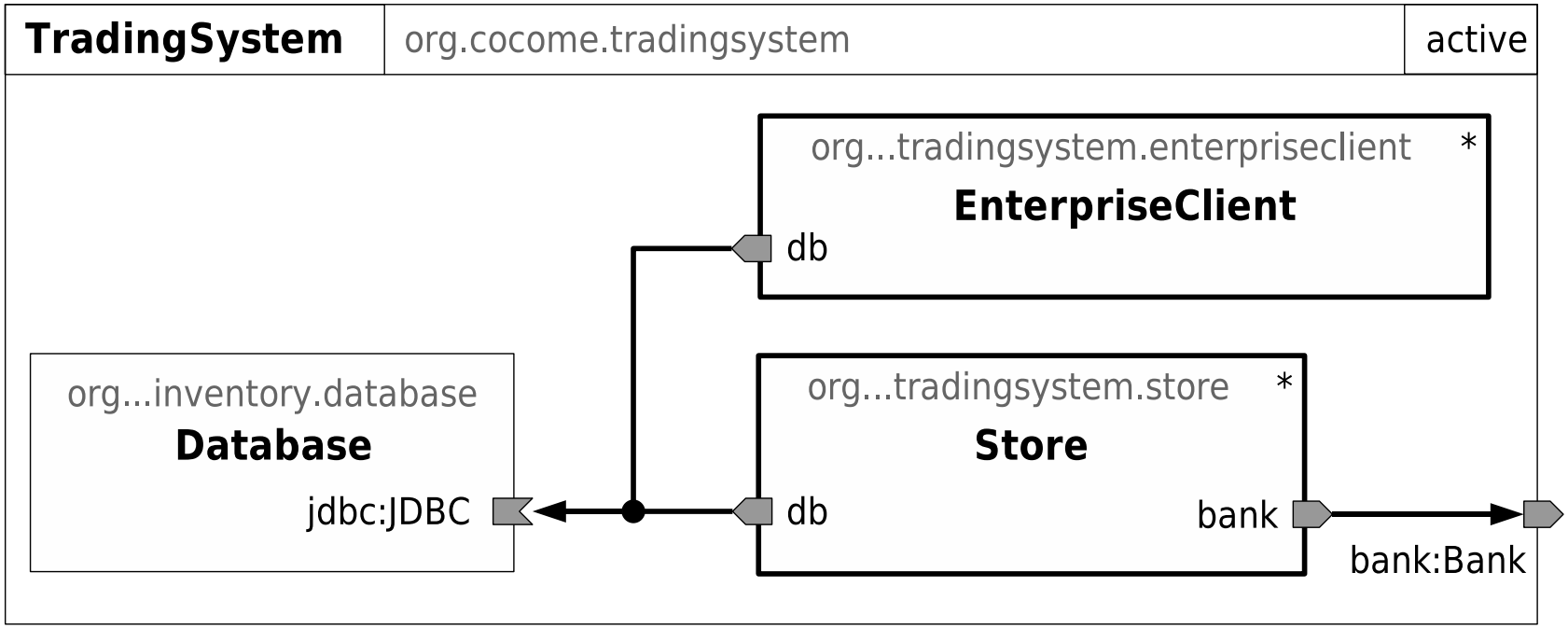
Top-Level View

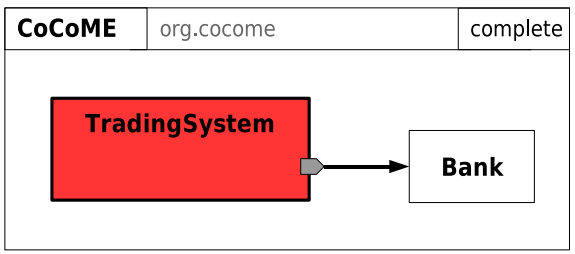


Top-Level View



The TradingSystem Component





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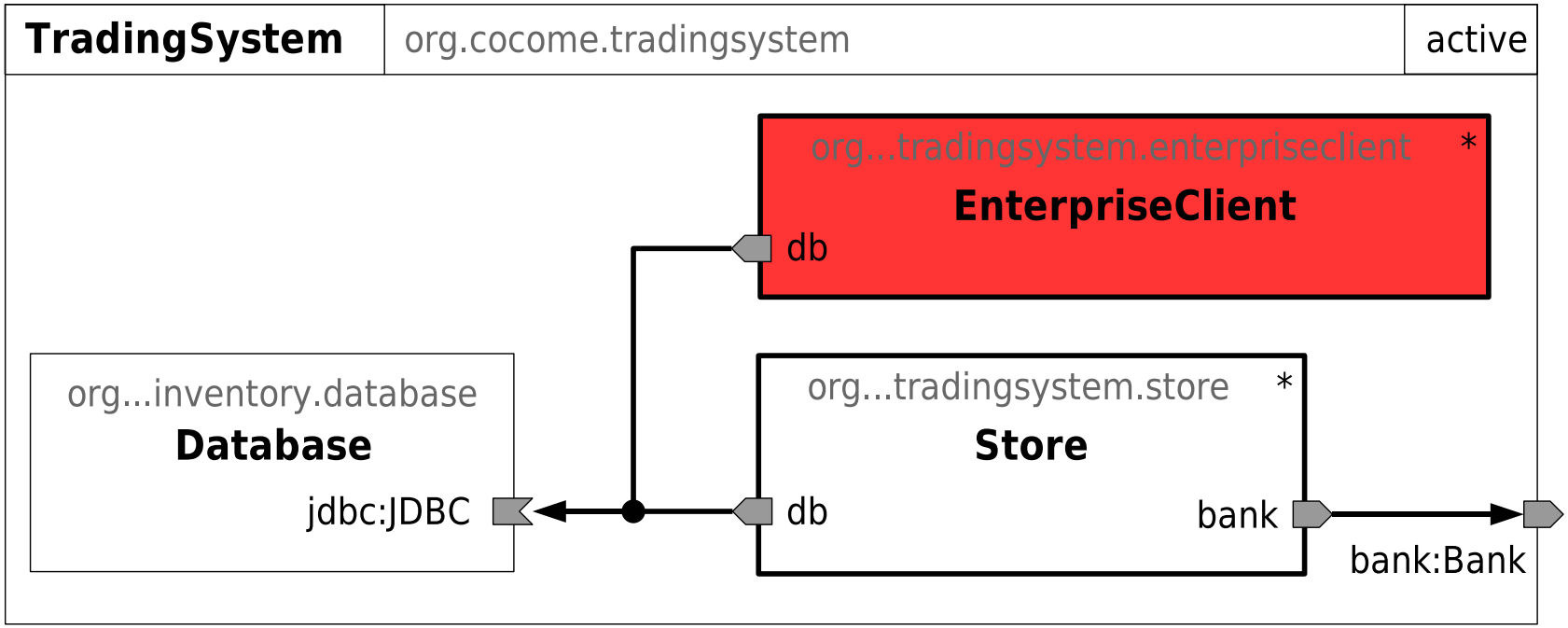
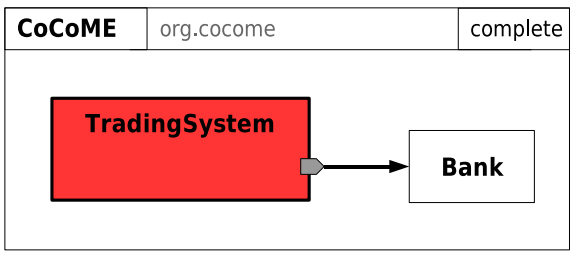
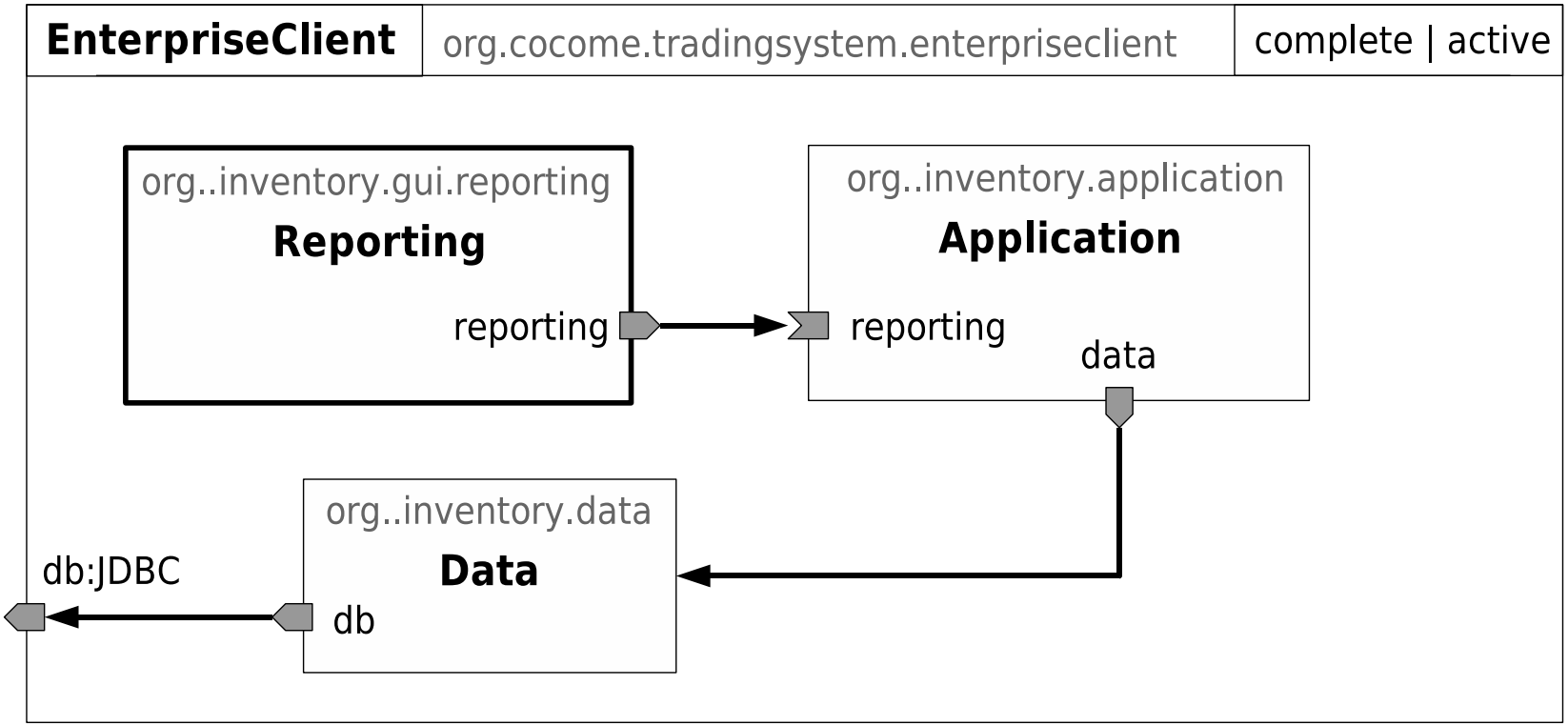
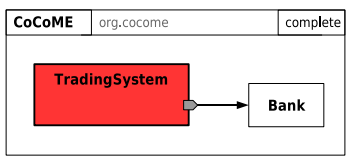
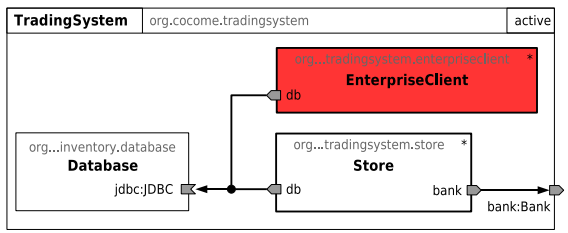




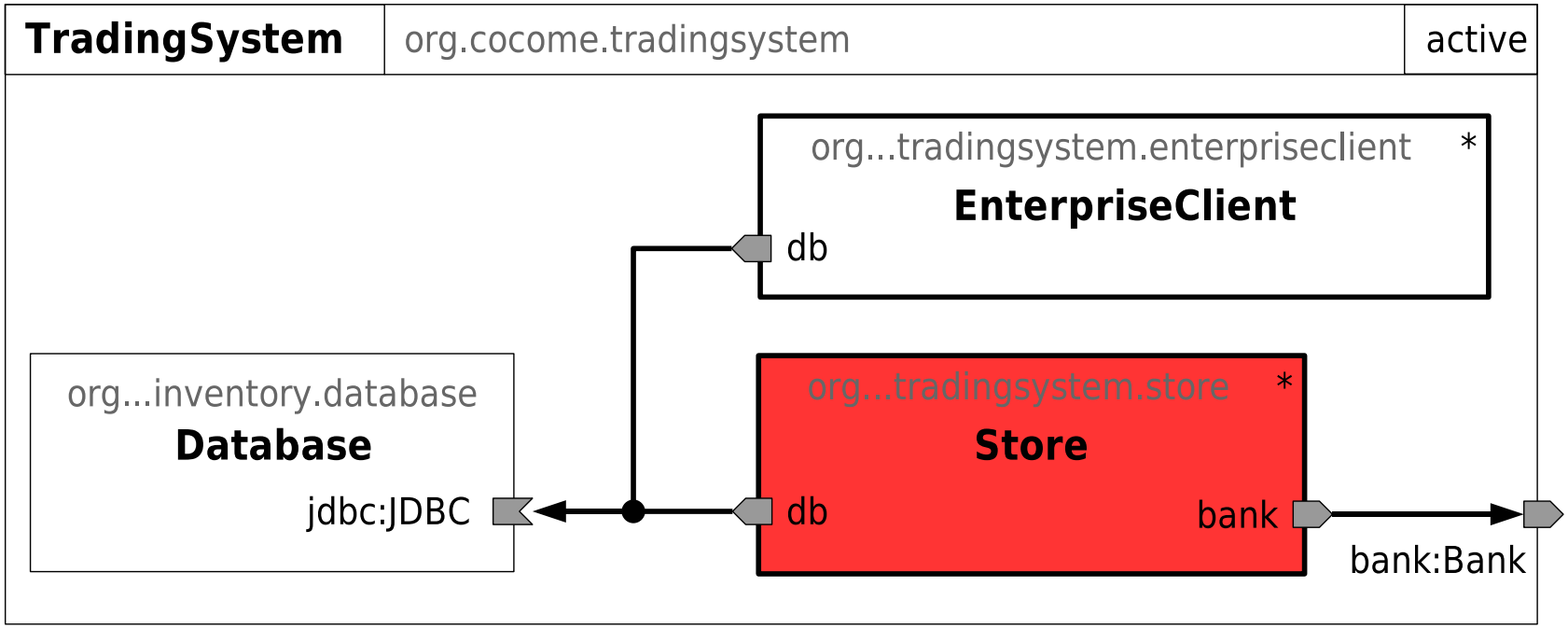
The EnterpriseClient Component

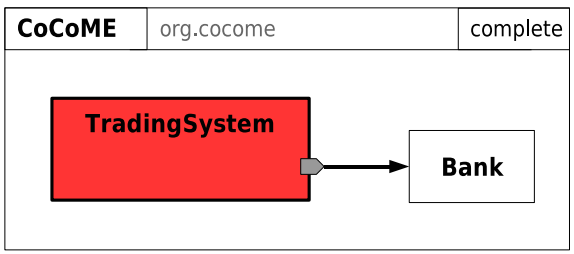






The Store Component





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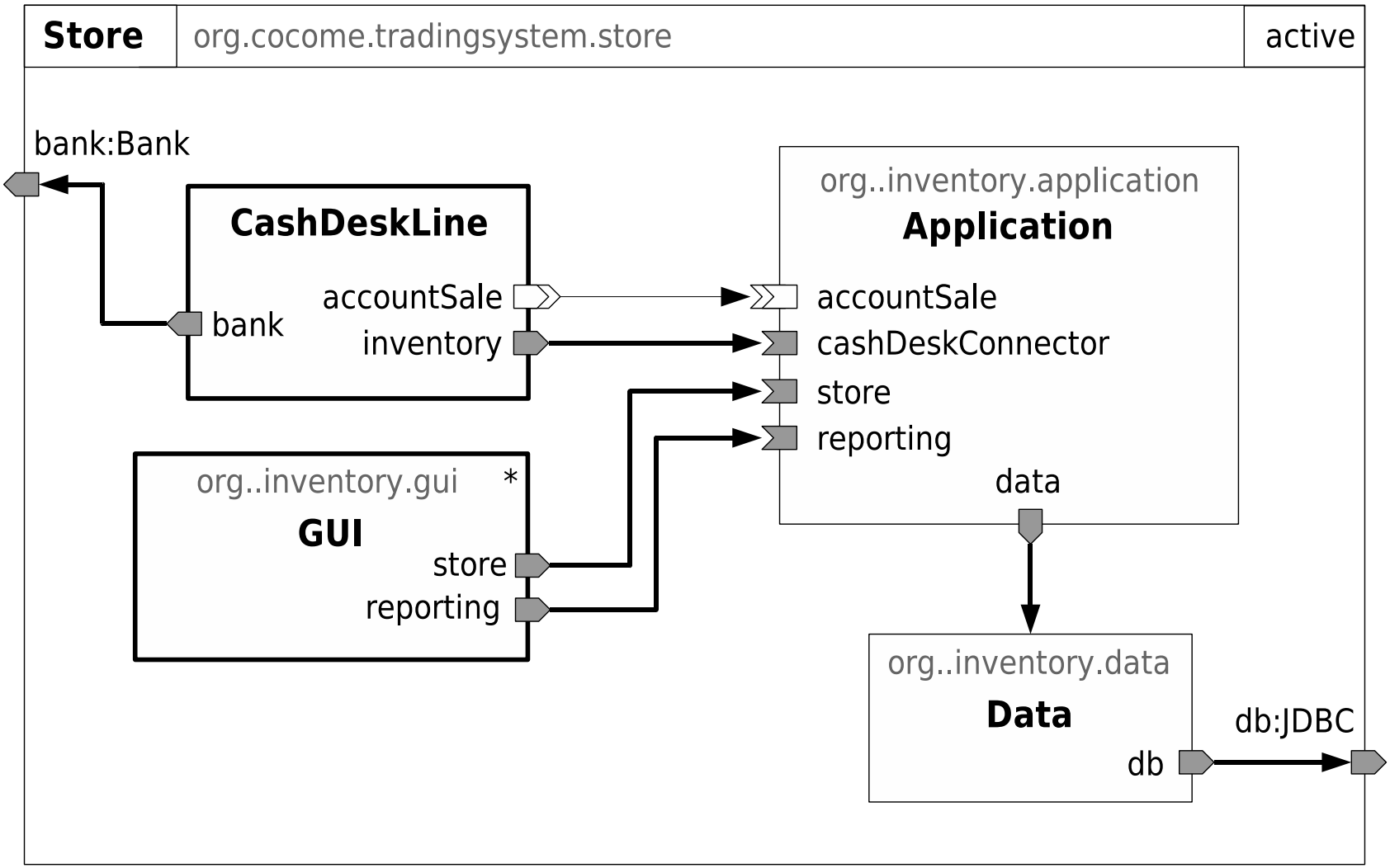
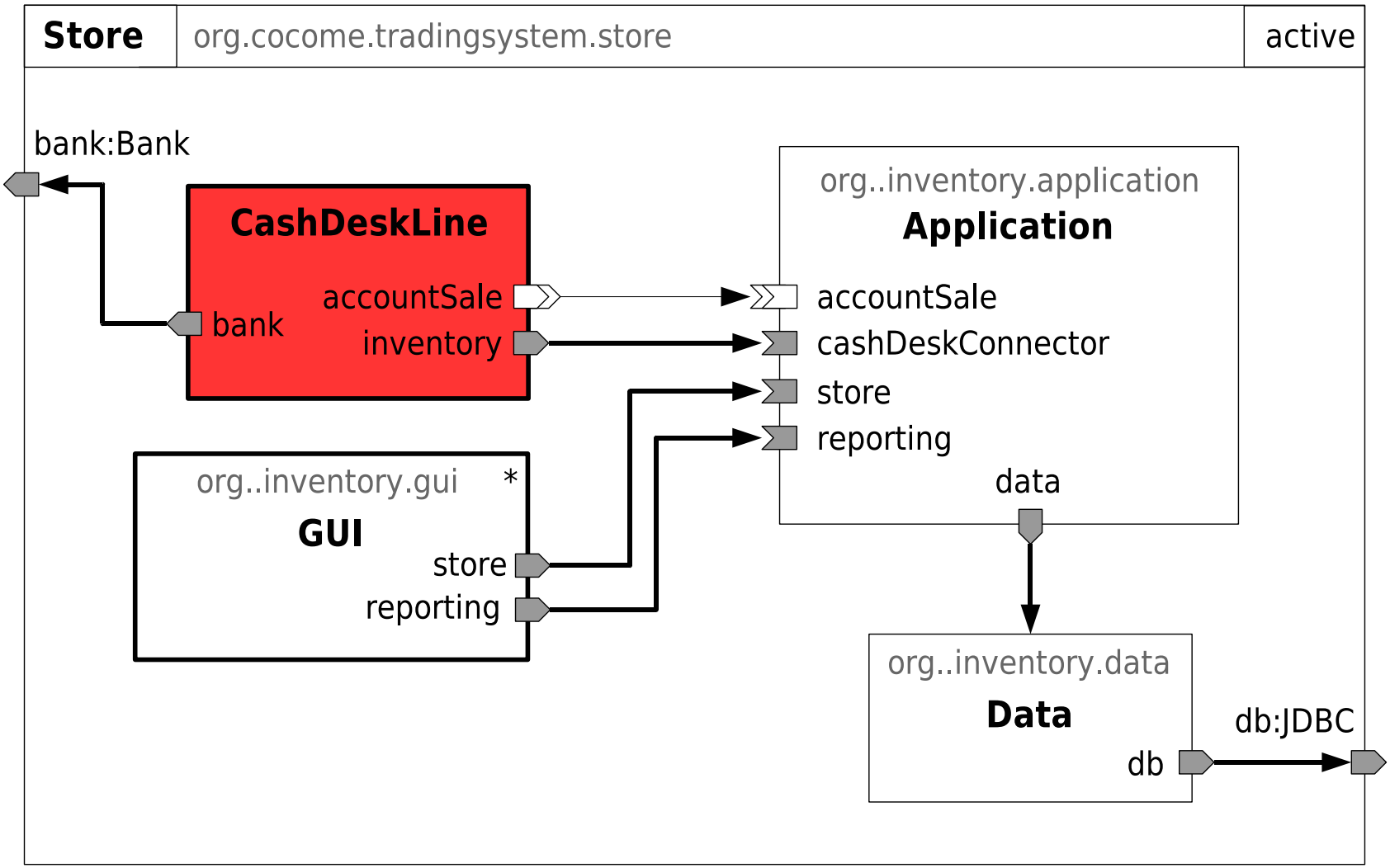


The CashDeskLine Component



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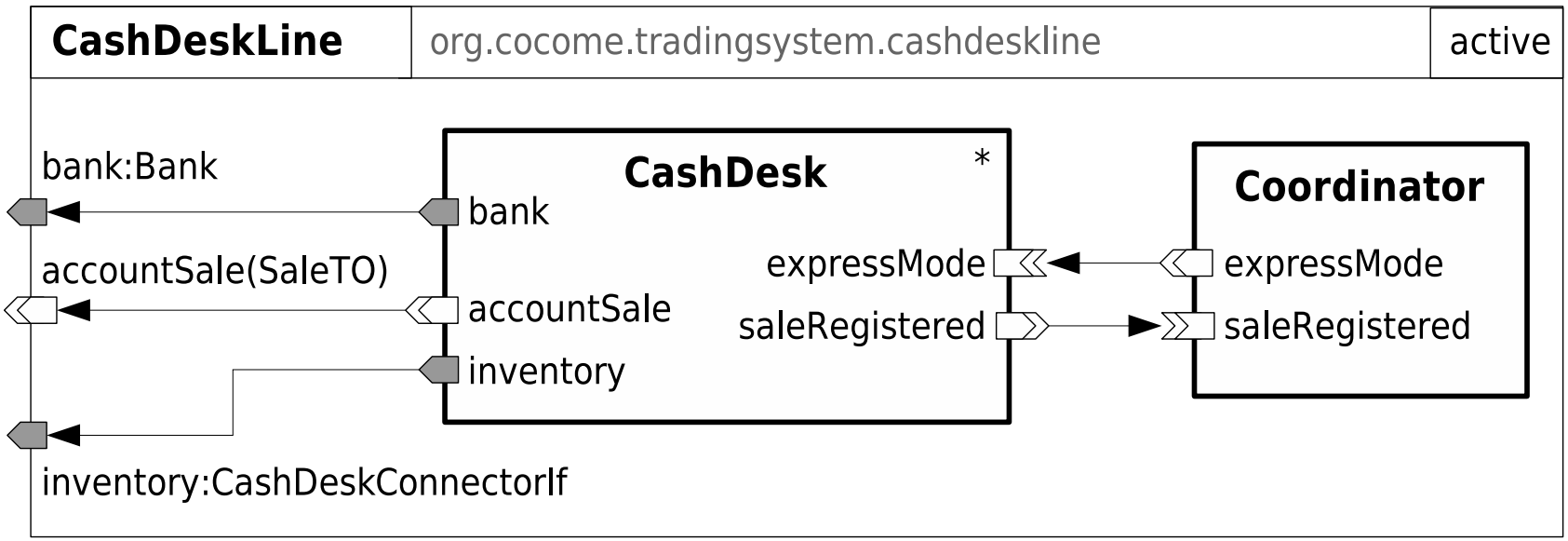
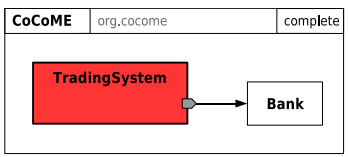
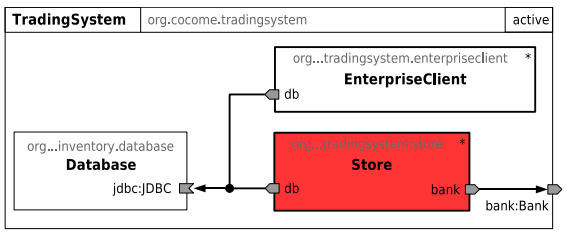
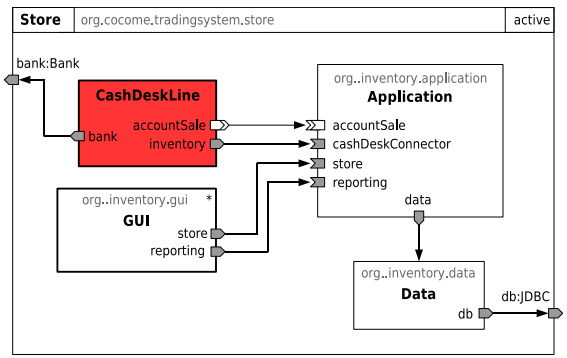
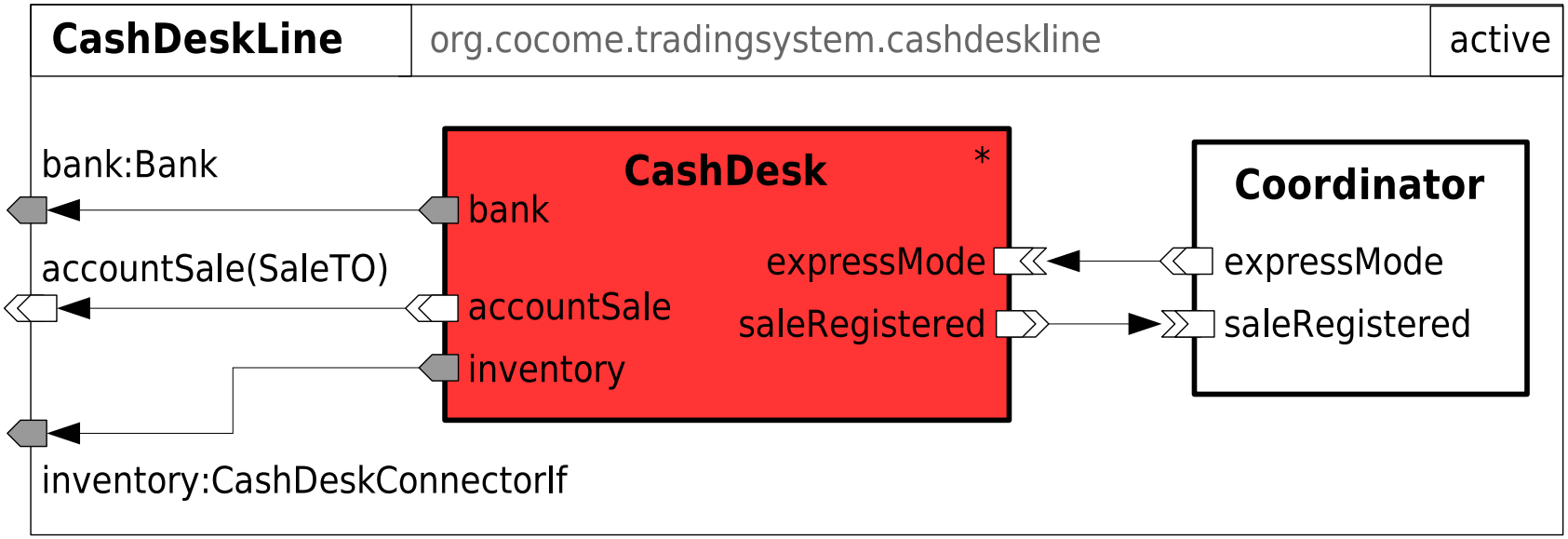


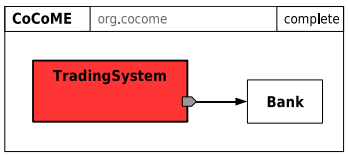


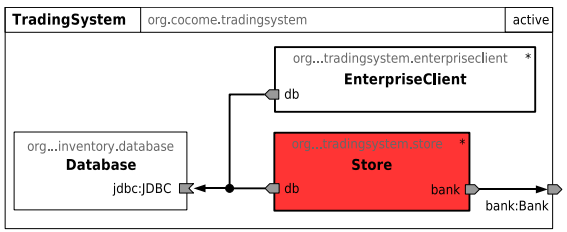


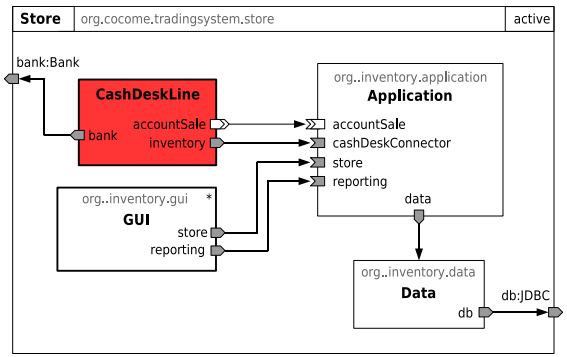


The CashDesk Component









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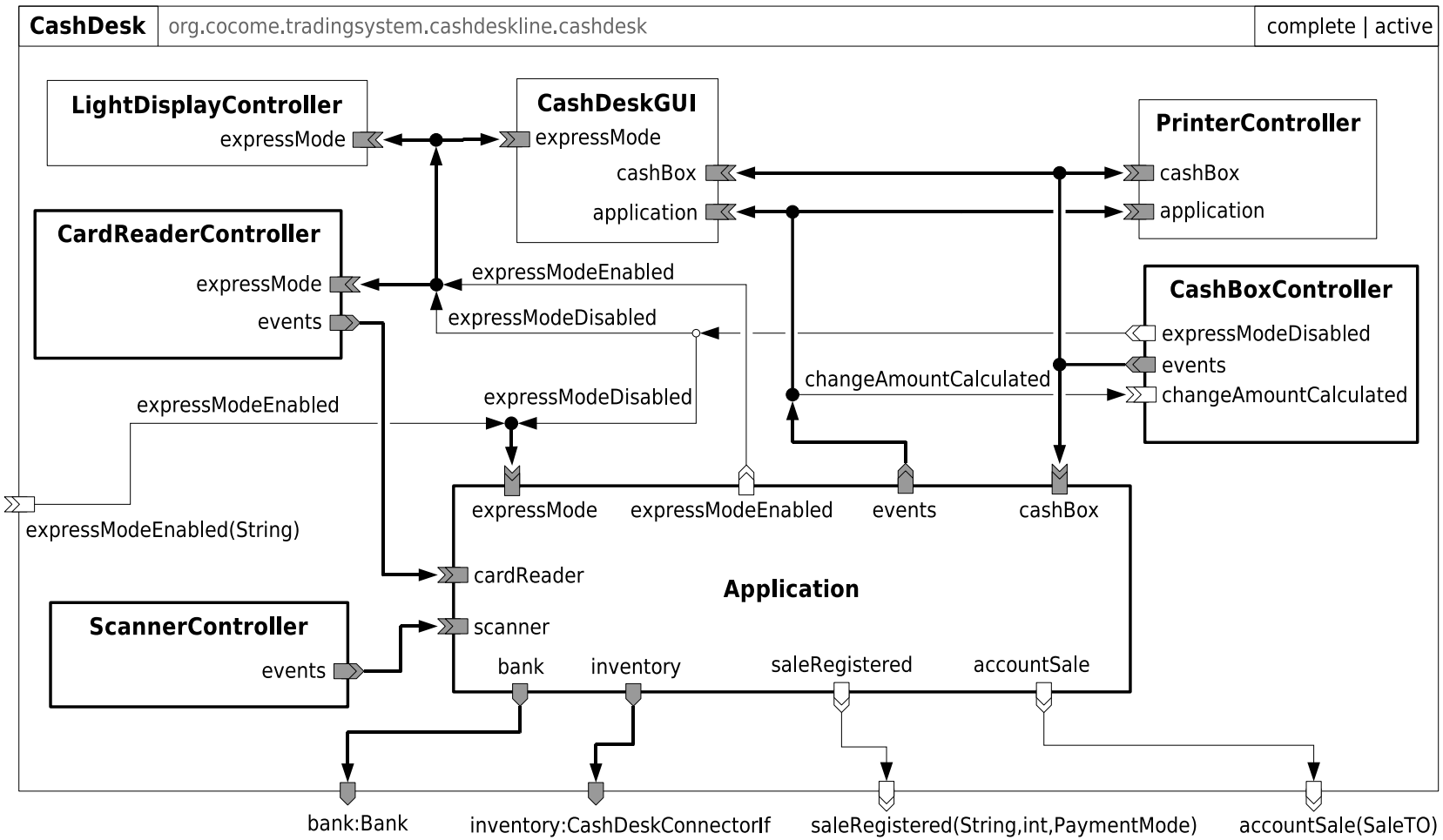
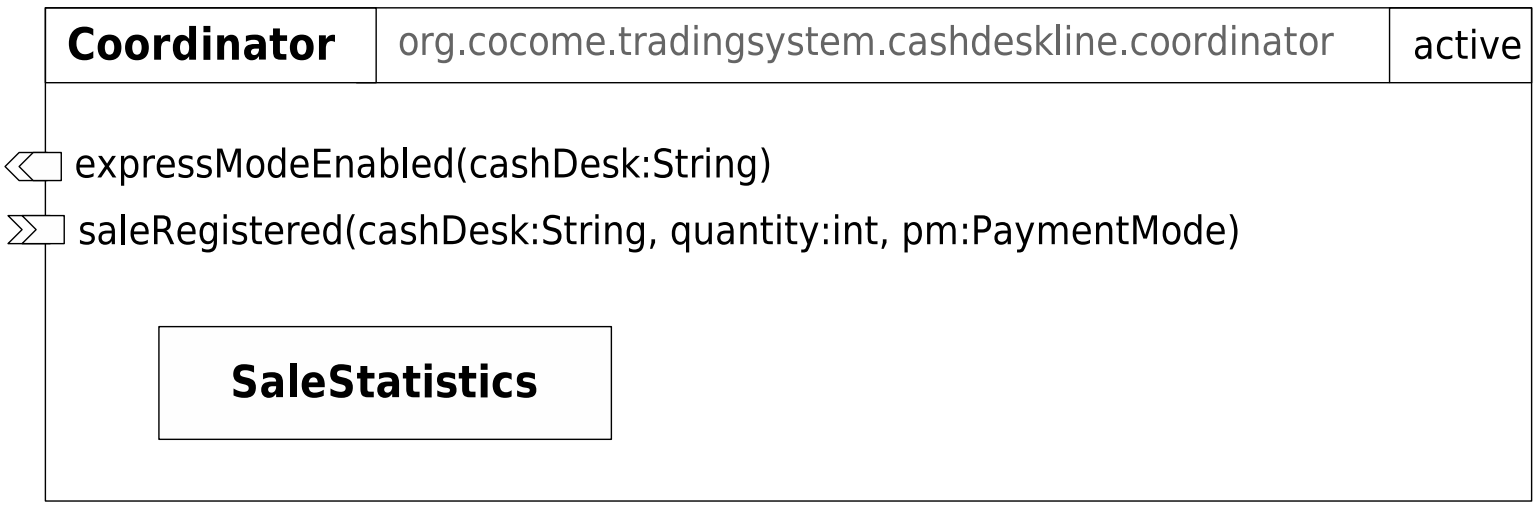
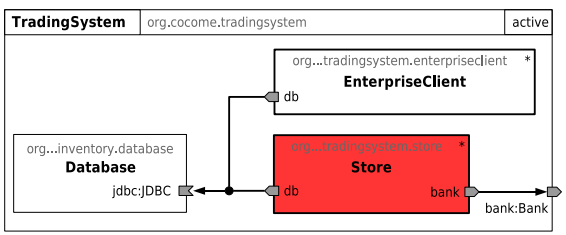


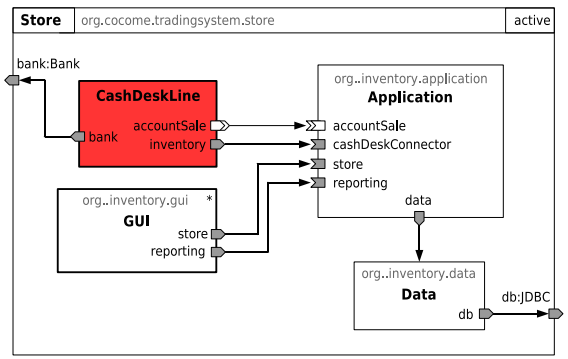
Executable Model

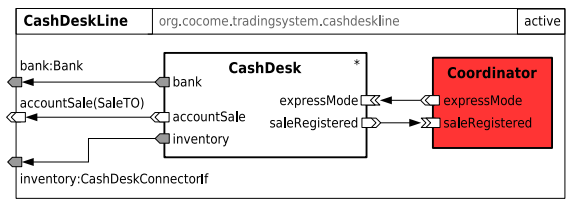
The Coordinator Component

MCowch Diagram









The Coordinator Component

JCowch Model

```
public box class Coordinator {
  public out async expressModeEnabled(String cashDesk);
  public async saleRegistered(String cashDesk, int quantity, PaymentMode pm);

  private SaleStatistics saleStats;

  public Coordinator() { saleStats = new SaleStatistics(); loop(); }

  private void handleNext()
    & saleRegistered(String cashDesk, int quantity, PaymentMode pm)
  {
    saleStats.registerSale(quantity,pm);
    if (saleStats.isExpressModeNeeded())
      expressModeEnabled(cashDesk);
  }

  private async loop() { while (true) handleNext(); }
}
```

Conclusion

Conclusions

- Almost complete arch. model of the CoCoME system
- Architectural descriptions provide a concise overview
- Consistency relation to executable model
- Concurrency support should be refined

Present and Future Work

Short-Term (This Year)

- Formal result to substitutability of OO-components
- Formal semantics for JCowch
- Concurrency model improvements
  - Apply ideas from Creol (cooperative multi-tasking)
  - Integrate Futures
- Tools
  - JCowch compiler
  - MCowch designer
  - Rudimentary automatic consistency checking

Future Work

Long-Term (Next Year(s))

- Full (semi-)automatic architectural consistency checking
- Integrated Development Environment for Cowch
- Behavioral specification and verification

Thank You!