CoBoxes: Distributed Heaps with Cooperative Tasks

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JCoBox

Main Features

- Object-Oriented
- Class-Based
- Cooperative tasks
- Asynchronous method calls
- Futures
- Distributed object heaps (CoBoxes)

Main Language Mechanism

- CoBox classes

JCoBox

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Why CoBoxes?

Unit of Behavior (Runtime Component)

- Creol: Object
- JCoBox: CoBoxes (hierarchical object groups)

Advantages

- Complex mutable state (with atomic access)
- Multiple interface objects
- Hierarchical structure
  - Abstraction from internal details
  - Internal concurrency
  - Modular semantics for runtime components
- Active Objects are a special case
- Sequential OOP is a special case

Advantages by Example

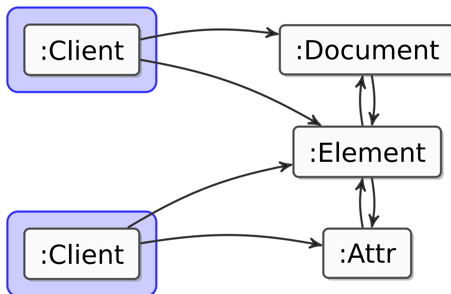
Example: org.w3c.dom.Document

DOM Document Component

```
interface Document {
  Attr createAttribute(String name);
  Element createElement(String tagName);
  ...
}
interface Node {
  Document getOwnerDocument(); ...
}
interface Element extends Node {
  Attr getAttributeNode(String name); ...
}
interface Attr extends Node {
  Element getOwnerElement(); ...
}
```

- Implement as a single active object?

Example: org.w3c.dom.Document (2)



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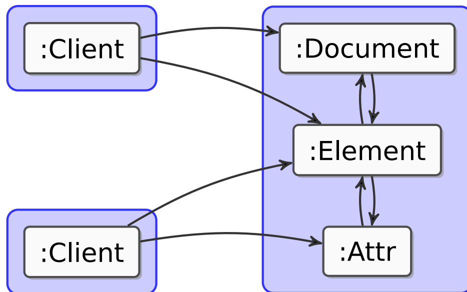


Example: SwitchGroup

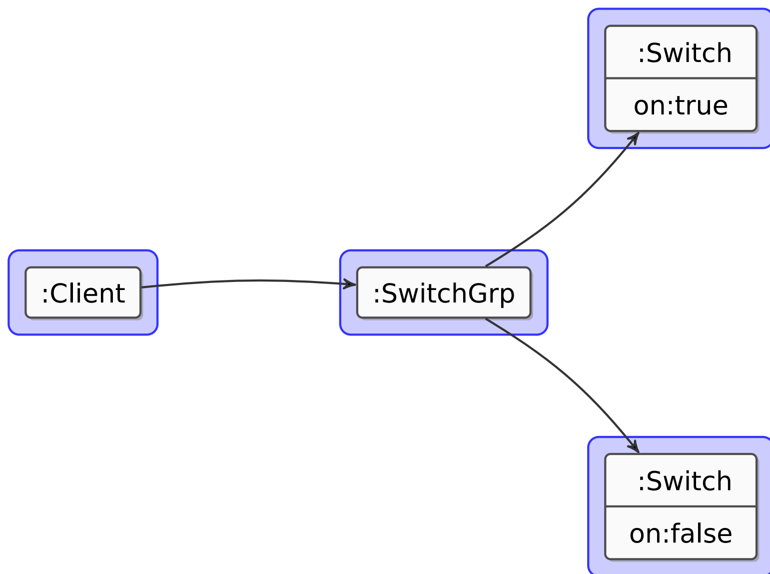
SwitchGroup - Specification

- A component which guarentees mutal exclusion for a set of *switches*, such that only one switch is *on* and all others are *off*
- If a switch in a switch group is turned on all other switches in that group are turned off
- Switches can only be directly turned on by the client

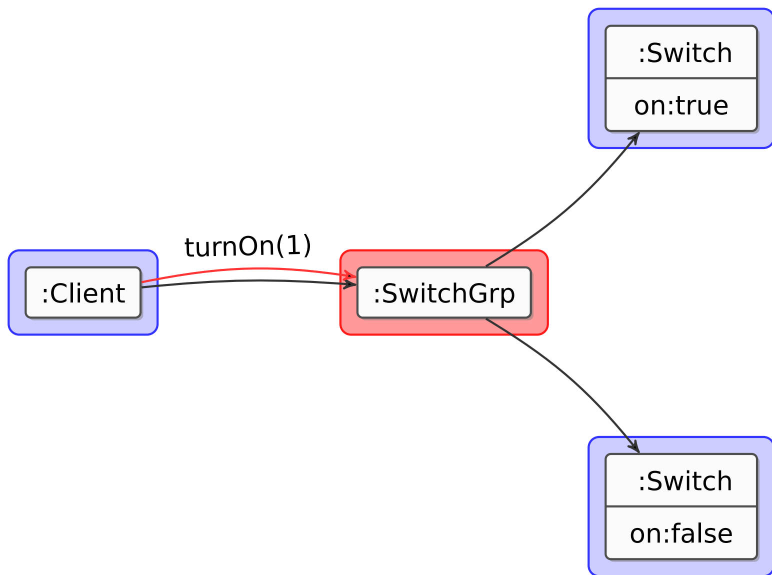
Problem

How to guarantee that invariant and allow direct access to switch objects?

SwitchGroup - With Active Objects - No Direct Access



SwitchGroup - With Active Objects - No Direct Access



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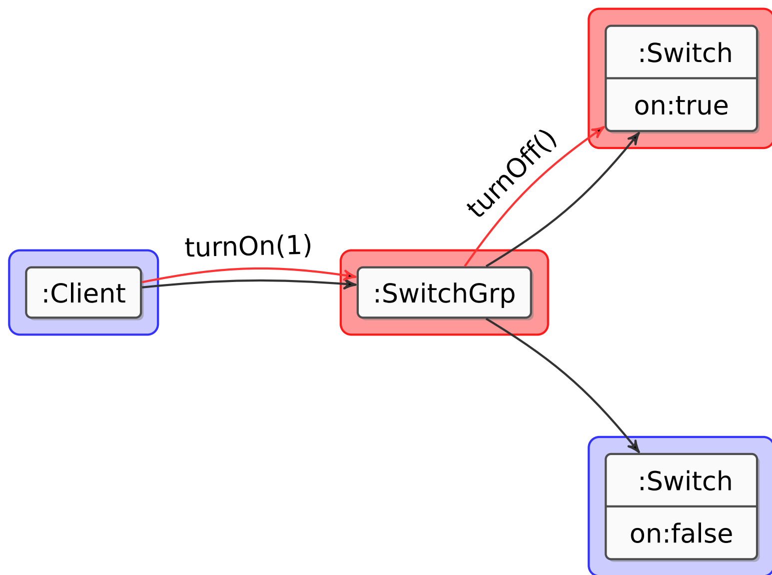

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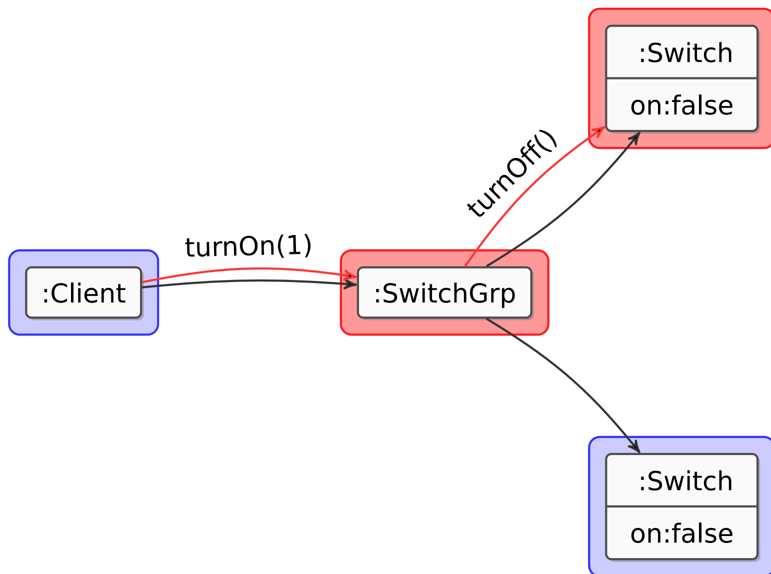

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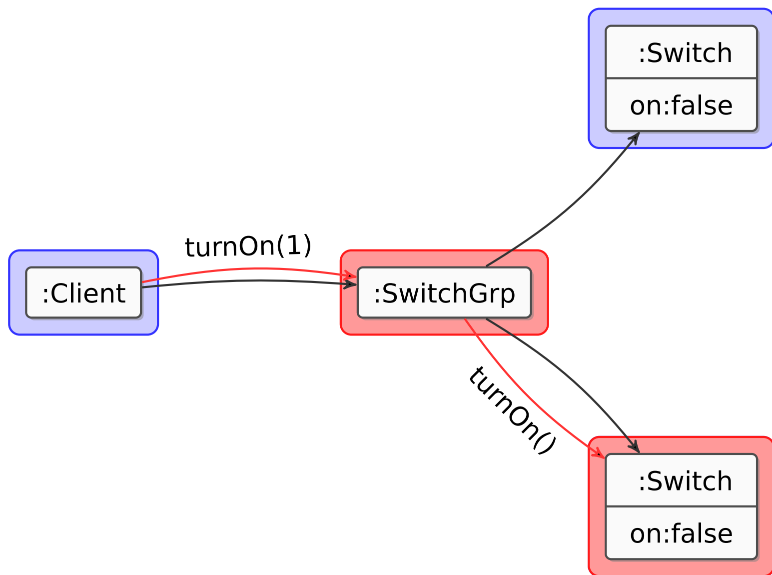

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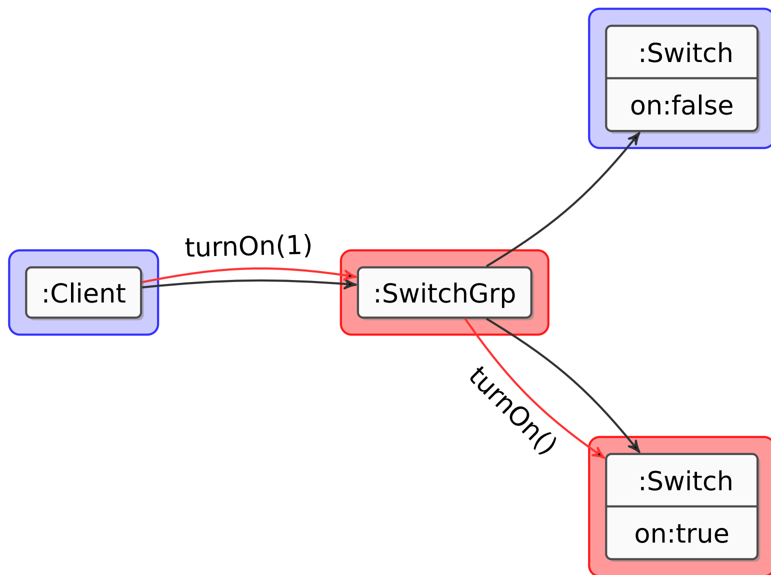

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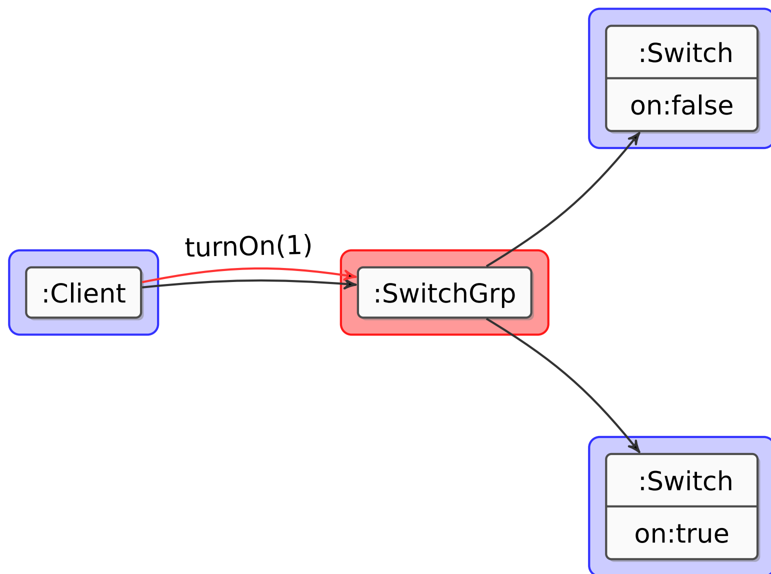

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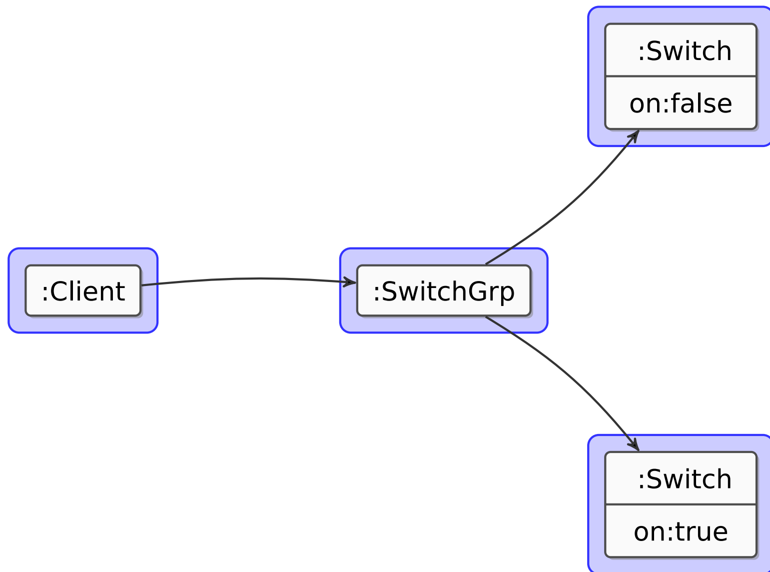

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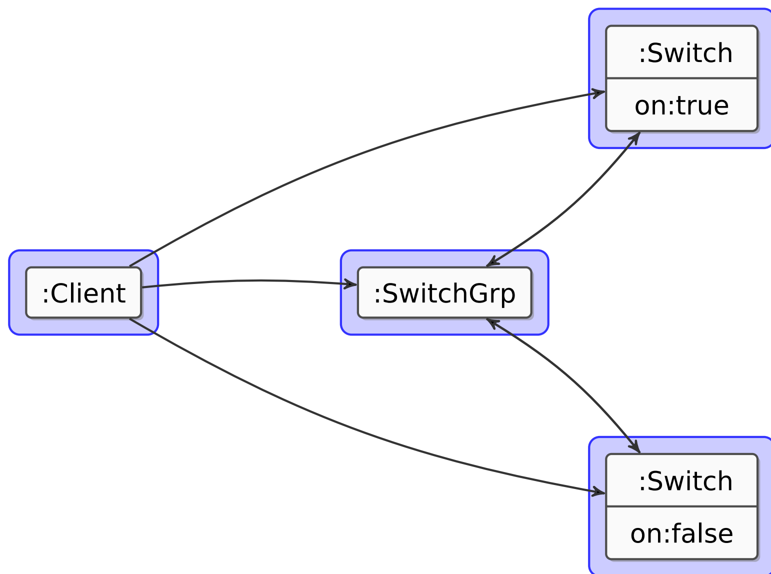

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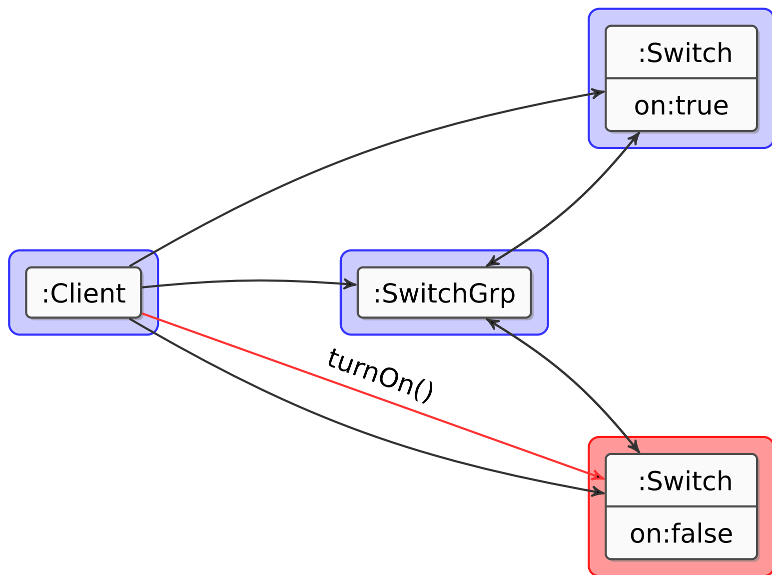

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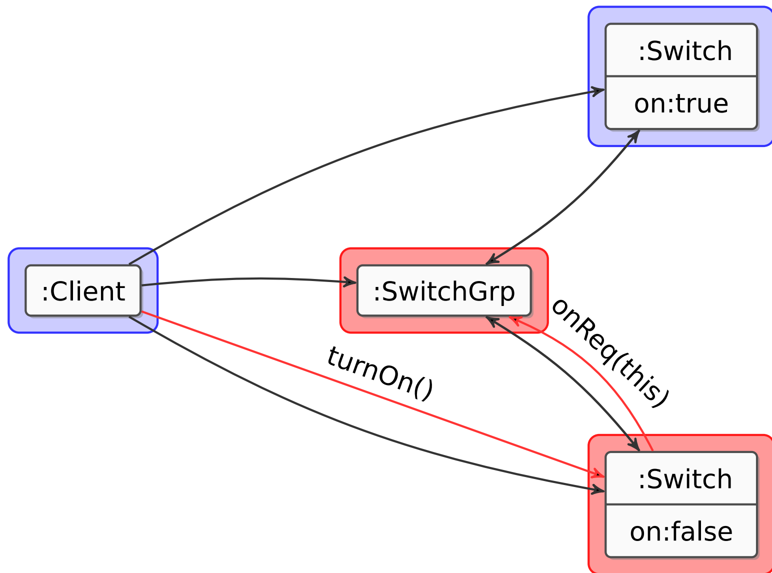

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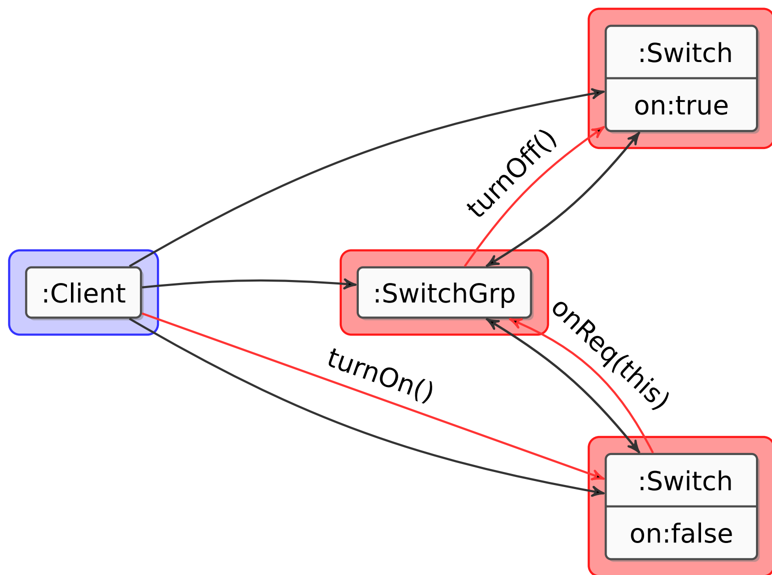

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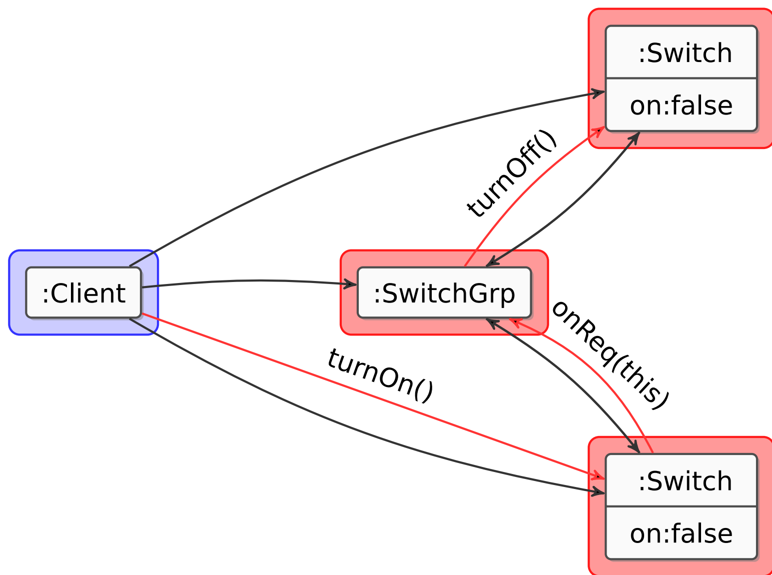

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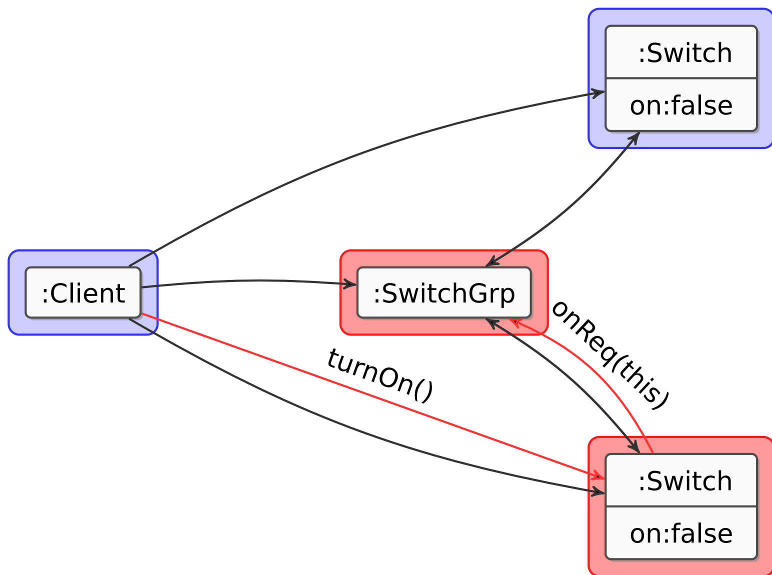

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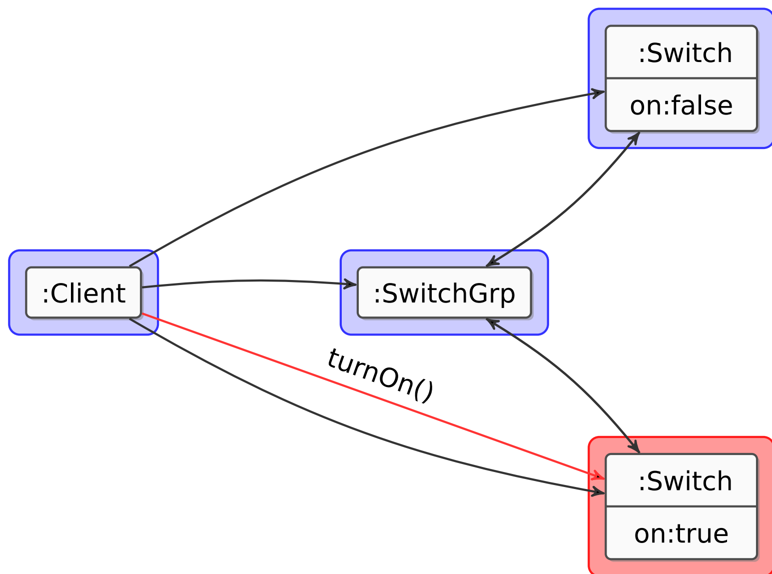

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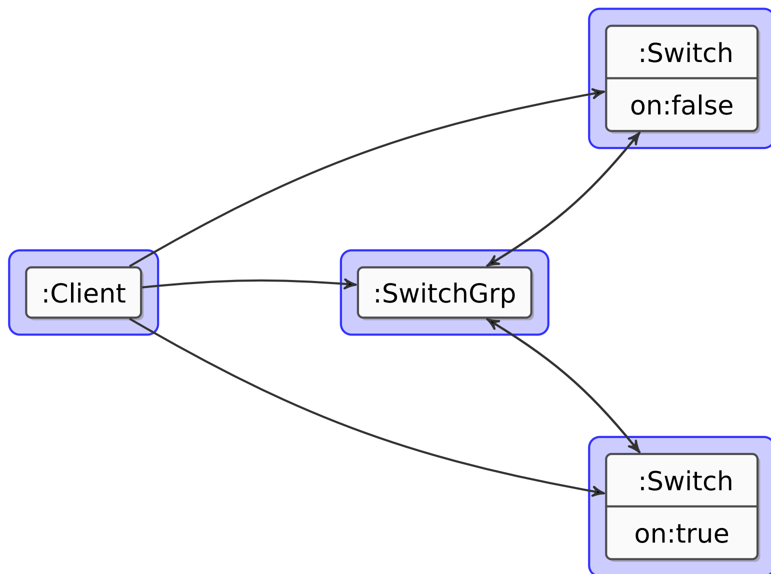
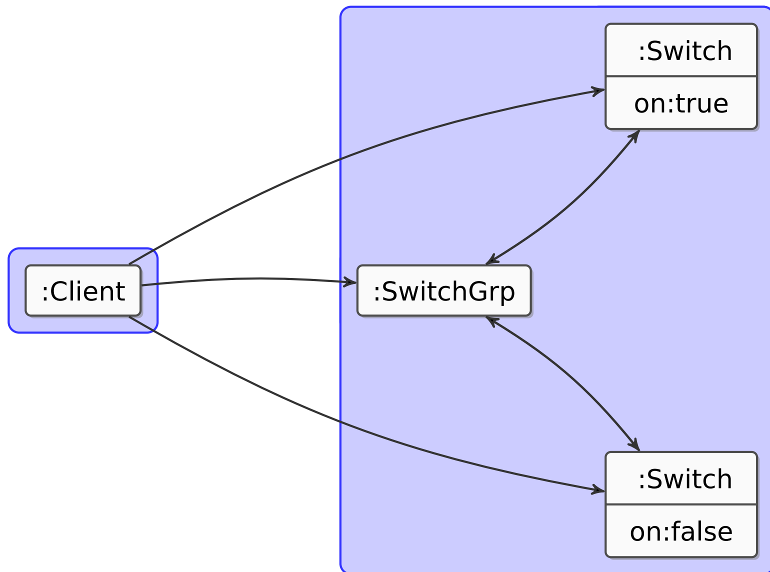


SwitchGroup - With CoBoxes



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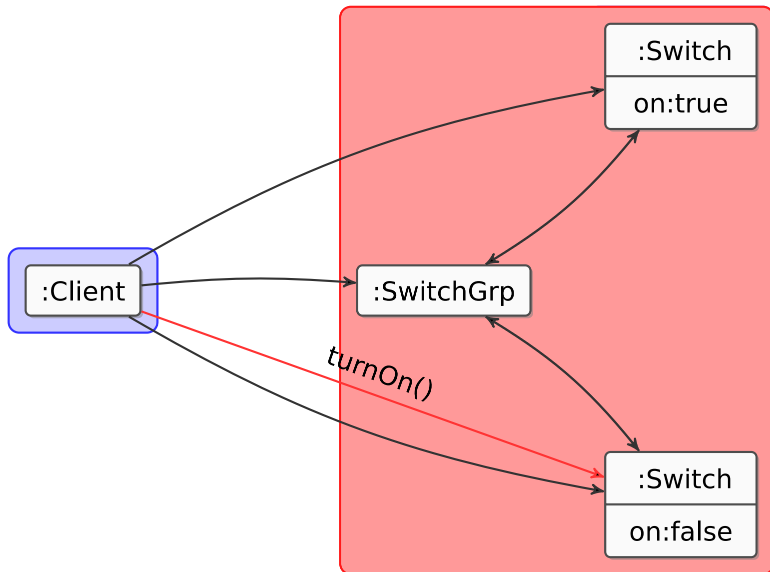

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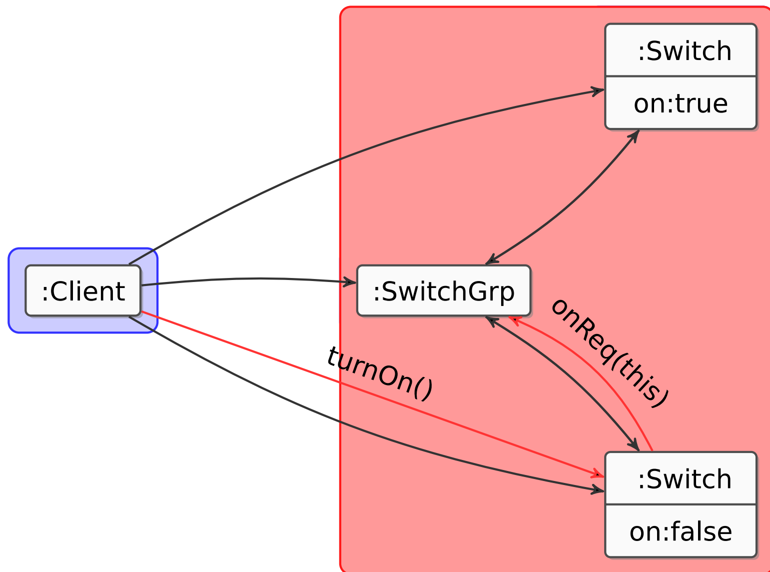

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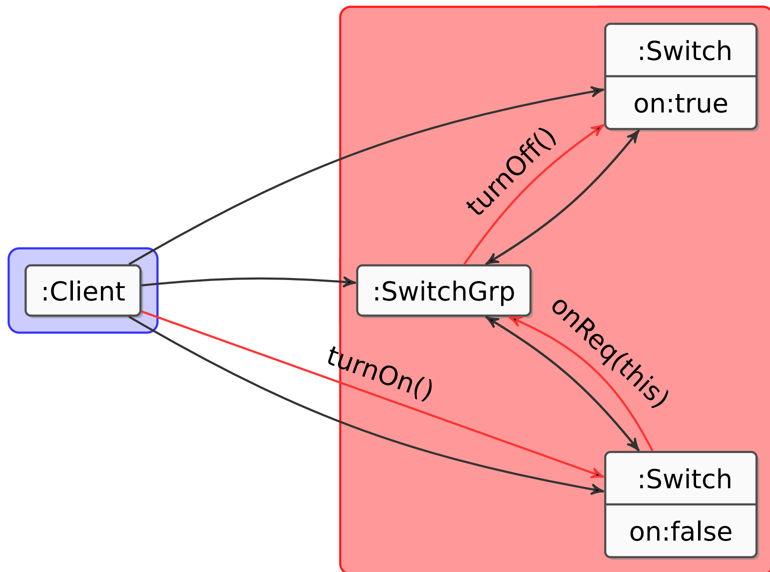
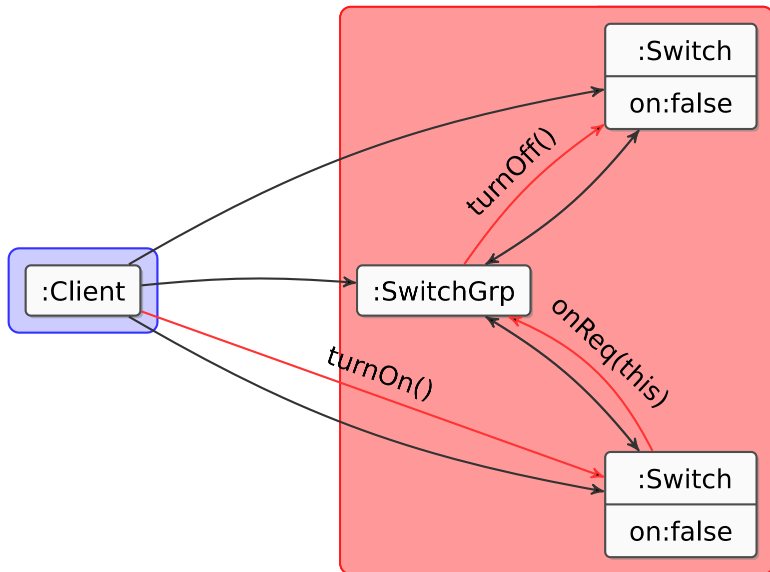
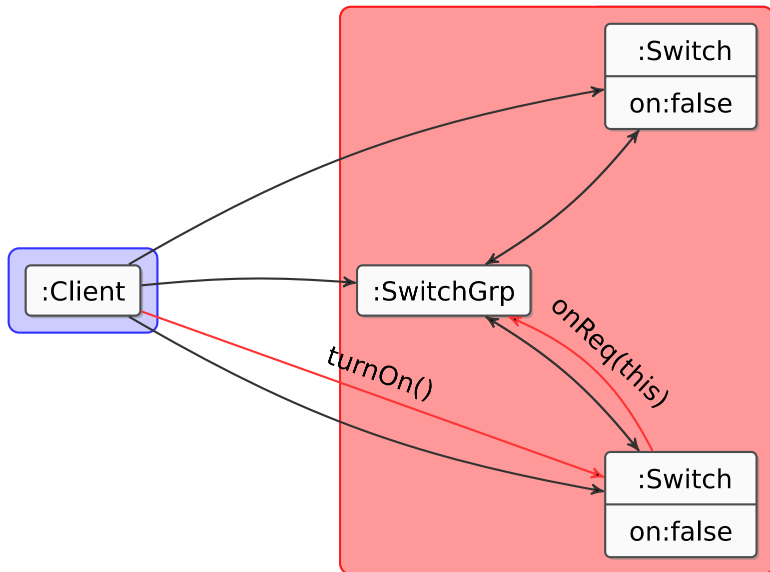



:Switch
on:false
turnOff()
:Client
:SwitchGrp
onReq(this)
turnOn()
:Switch
on:false

SwitchGroup - With CoBoxes



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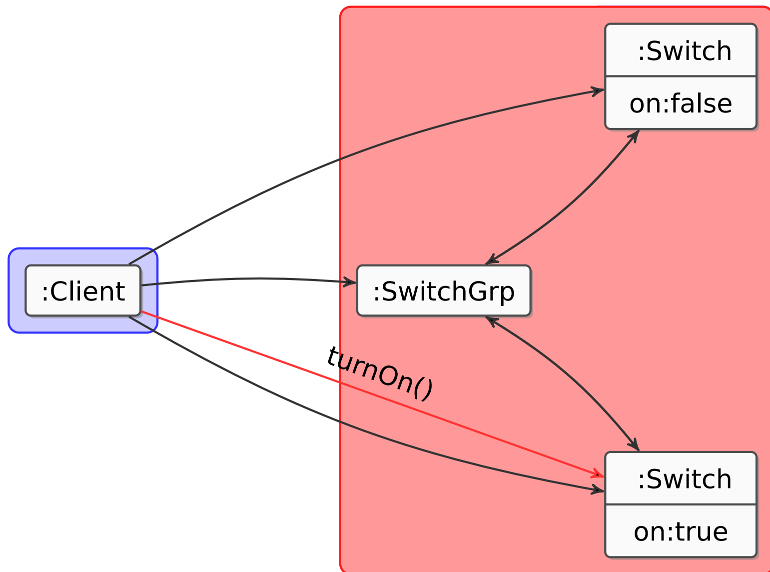

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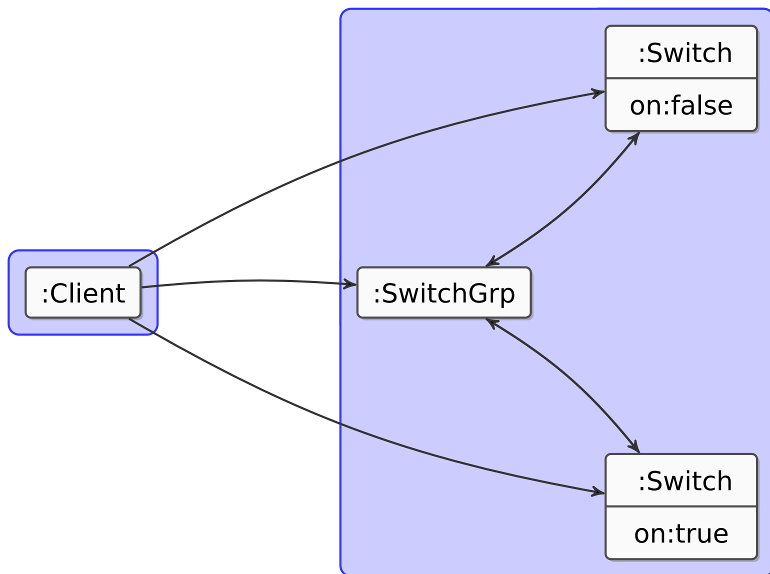
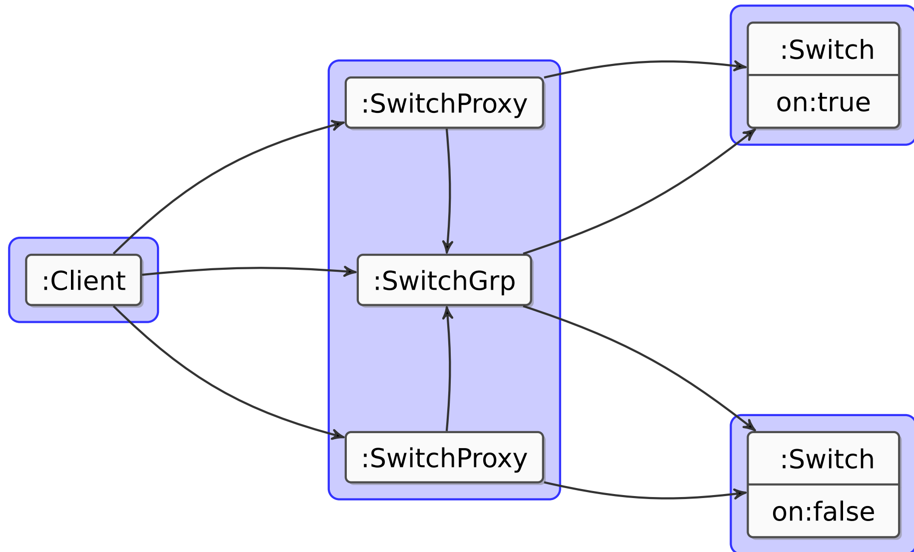
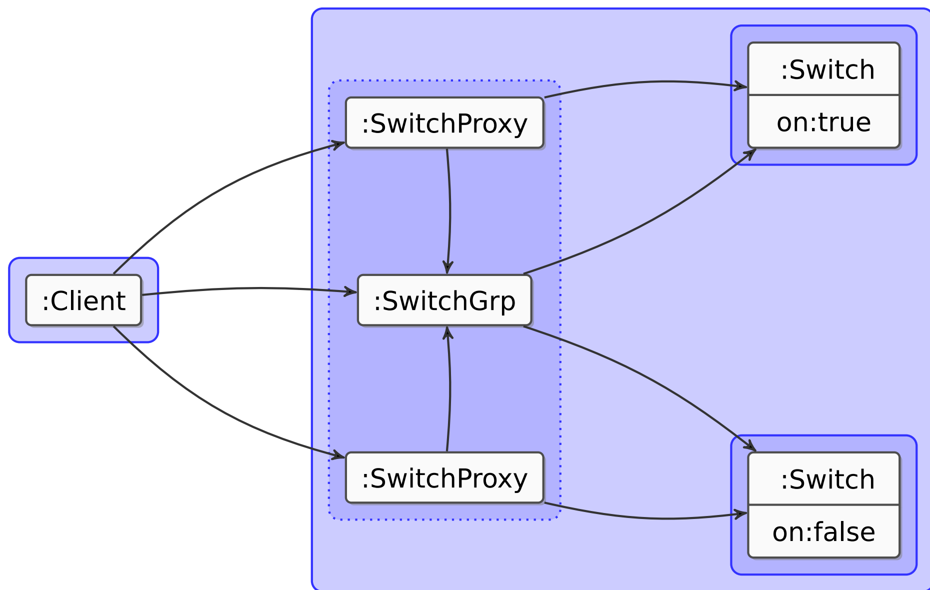


SwitchGroup - With a CoBox Facade



SwitchGroup - Nested CoBoxes



Summary of Advantages

Complex Mutable State

Every non-trivial object has a logical state represented by further objects

In Creol

- represent the whole state as ADT
  - only functional programming inside an object
- use other active objects to hold state
  - more difficult because of distributed state
- sequential programming cannot be completely simulated
  - always use: x!m().get $\Rightarrow$ problems with reentrancy
  - always use: x!m().await $\Rightarrow$ problems with concurrent accesses

In JCoBox

- Sequential OOP within a single CoBox
- ADTs still useful!

Sequential OOP within a CoBox

- Well-known programming technique
- Easy for programmers
- Existing tools/knowledge
  - Analysis
  - Verification
  - ...
- Encapsulation of existing legacy code
  - Allows for a smooth migration path

Multiple Interface Objects

- Multiple objects as entry points to an object structure
- Very important for OOP
- Allows for scalable OO interfaces
- Examples
  - List: Iterator
  - DOM
  - File System
  - GUI-Frameworks

Hierarchical Structure

- Treat groups of CoBoxes semantically as a single unit of behavior
- Allows for a modular semantics of CoBoxes
- Does not influence the behavior of individual CoBoxes
  - Like Boxes for sequential OOP
  - Different to published paper version

Practical Experience

Additional Features

- Promises (explicitly resolvable futures)
- Immutable classes
- Transfer classes
- Java 5: Generics, annotations, ...
- Plain Java classes
- Static fields and methods
- Exceptions
- Configurable Task Scheduler (very limited)
- Configurable message ordering guarantees
- Distribution with RMI

Implemented Examples

- FourWins
  - Game with a Swing-GUI
  - Computer player utilizing multiple cores
- CoCoME
  - Distributed cash desk system
  - Implemented as a product line
- Classical Examples
  - Philosophers
  - Dating Service
  - ...

Experiences

- The CoBox model has proven to be useful in practice
- Deadlocks rarely occur and are easy to find
- High-Level data-races rarely occur and are easy to find
- Order guarantee very useful
- Immutable and Transfer objects are needed
  - ADTs could be used instead
- Design decisions usually clear
  - Which class should be plain, cobox, transfer, immutable?

Maude Specification

Maude Specification

- Goal: Executable paper rules
  - $\Rightarrow$ not optimized for performance
- Can be used to model-check simple programs
  - Found deadlock in 3-Philosopher example
- Currently very different to Maude specification of Creol
  - Integration of CoBoxes would be possible, however

Questions concerning ABS

Question Concerning Concurrency Model

- Futures yes, but Promises? Channels?
- Only ADTs, or also Transfer Objects?
- Message ordering guarantees?
- Configurable Scheduling?
  - specified by join patterns?

General Questions for the ABS (from our perspective)

- Process-independent data description
  - How to represent object references?
- Modularity (Notion of a component)
  - Clear behavioral interface description
    - declarative specification language
  - Notion of composition
- Notion of Refinement
  - Relation to implementation
  - Relation between different models (fully abstract?)
- Support for features/deltas on the modeling level
- Well-defined notion concurrency with a pluggable scheduling concept