Defining Semantic Variations of Diagrammatic Languages using Behavioral Programming and Queries

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Behavioral Programming-based **code**.

*We also present a **tool** demonstrating this approach using Live Sequence Charts (LSC).*

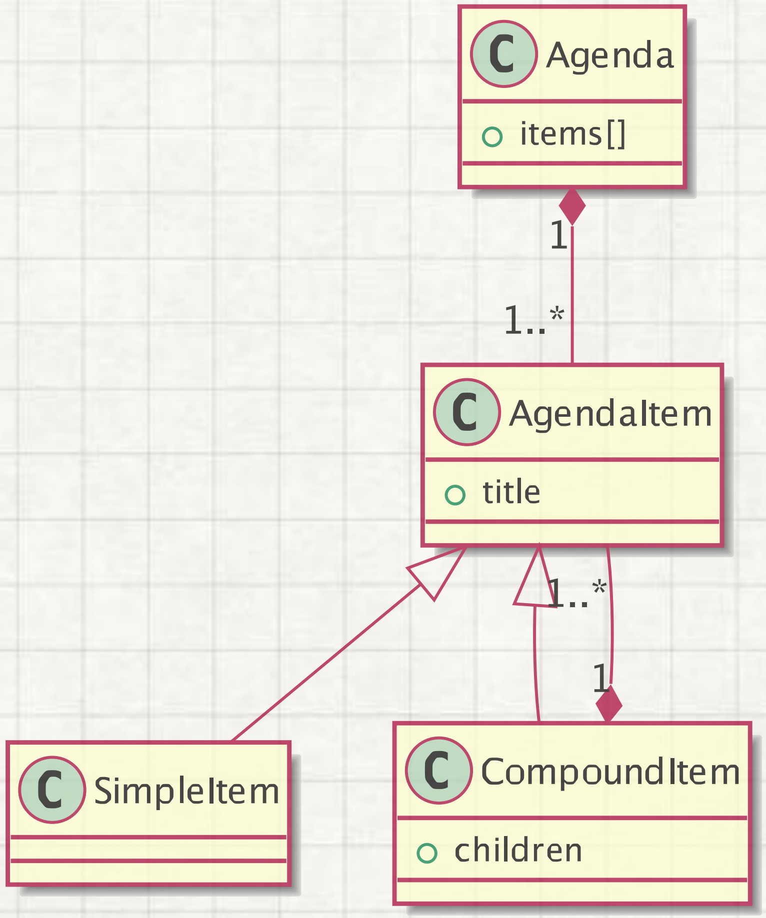
Problem Statement

- Diagrammatic programming languages hold great promise for software engineering
    - Have been holding this promise for a while
- Mostly not adopted by industry
    - Lack of approachable semantic definitions
    - Interoperation with existing tools and coding methodologies limited.

This paper focuses on languages with operations semantics; supporting languages with structural semantics is left to (near?) future work

Agenda

- Concept Overview
- Behavioral Programming 101
- Semantic Mapping to BP
- Discussion
- Case-Study: LSC
    - LSC 50
    - Visual Dictionaries
    - Implementation
    - Semantic Variations
- Related Work



Behavioral Programming 101 [1,2]

- Embedding scenario-based programming [3] concept in procedural languages
- A programming paradigm:
  compose a complex reactive system by interweaving threads of behavior (BThreads)
- An interaction protocol:
  BThreads can Request, Wait-for, and Block events
- A simple execution mechanism:
  Select event that is requested but not blocked, publish to all BThreads. Repeat.

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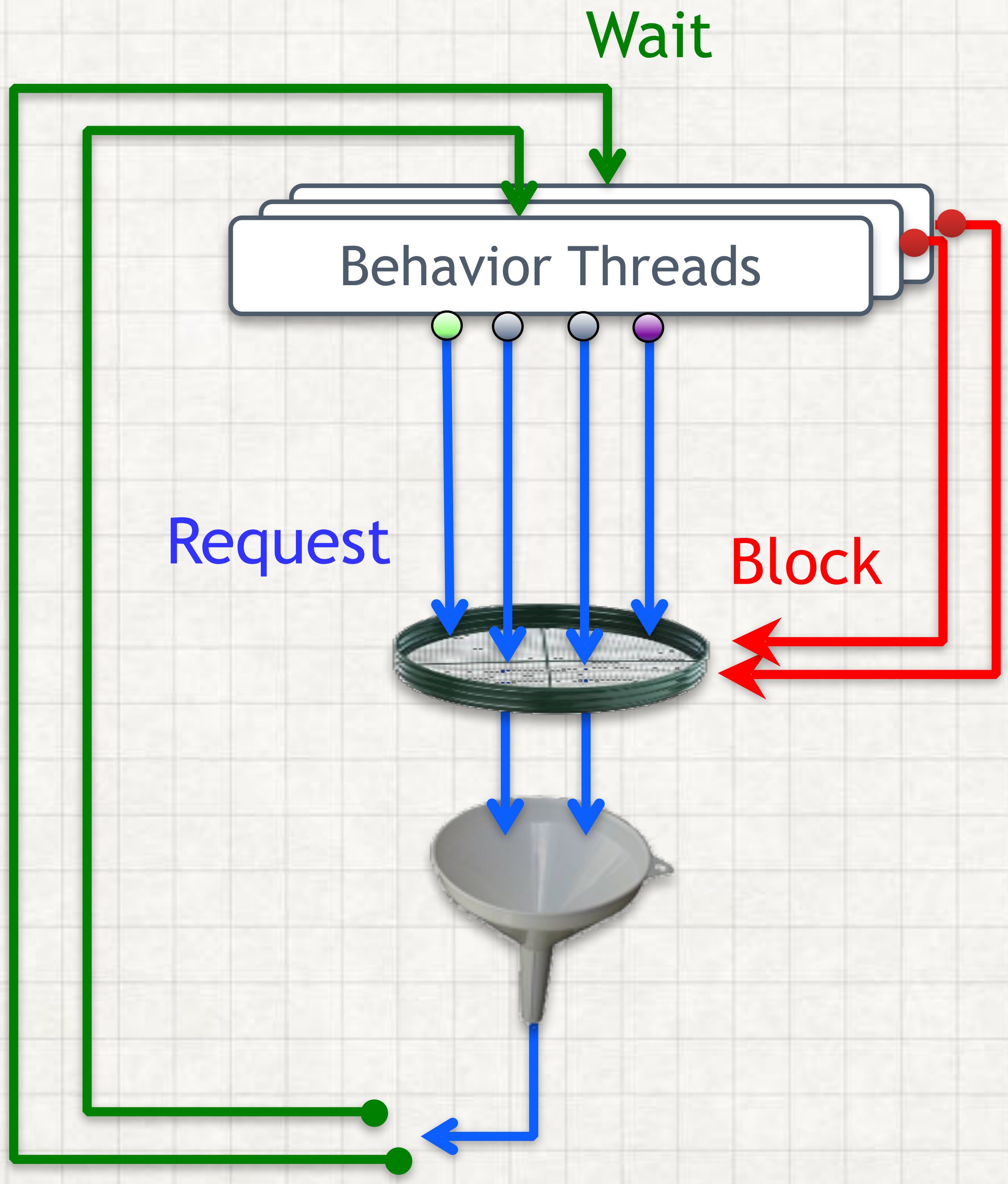
[1] D. Harel, A. Marron, and G. Weiss. Programming Coordinated Scenarios in Java. In Proc. 24th European Conf. on Object-Oriented Programming (ECOOP), pages 250–274, 2010.

[2] D. Harel, A. Marron, and G. Weiss. Behavioral Programming. Communications of the ACM, July 2012.

[3] W. Damm and D. Harel. LSCs: Breathing Life into Message Sequence Charts. J. on Formal Methods in System Design, 19(1):45–80, 2001.

The BP Execution Cycle



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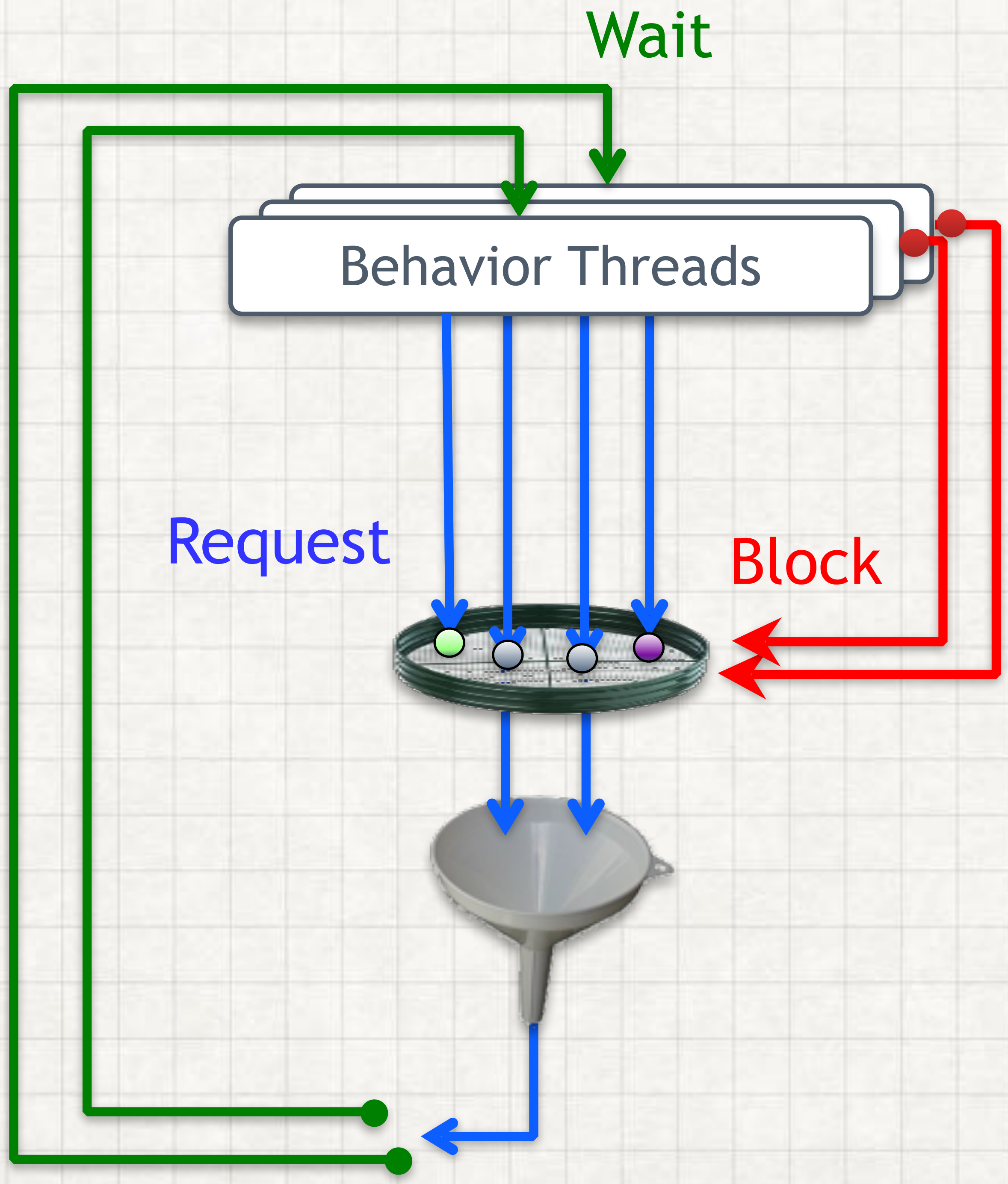

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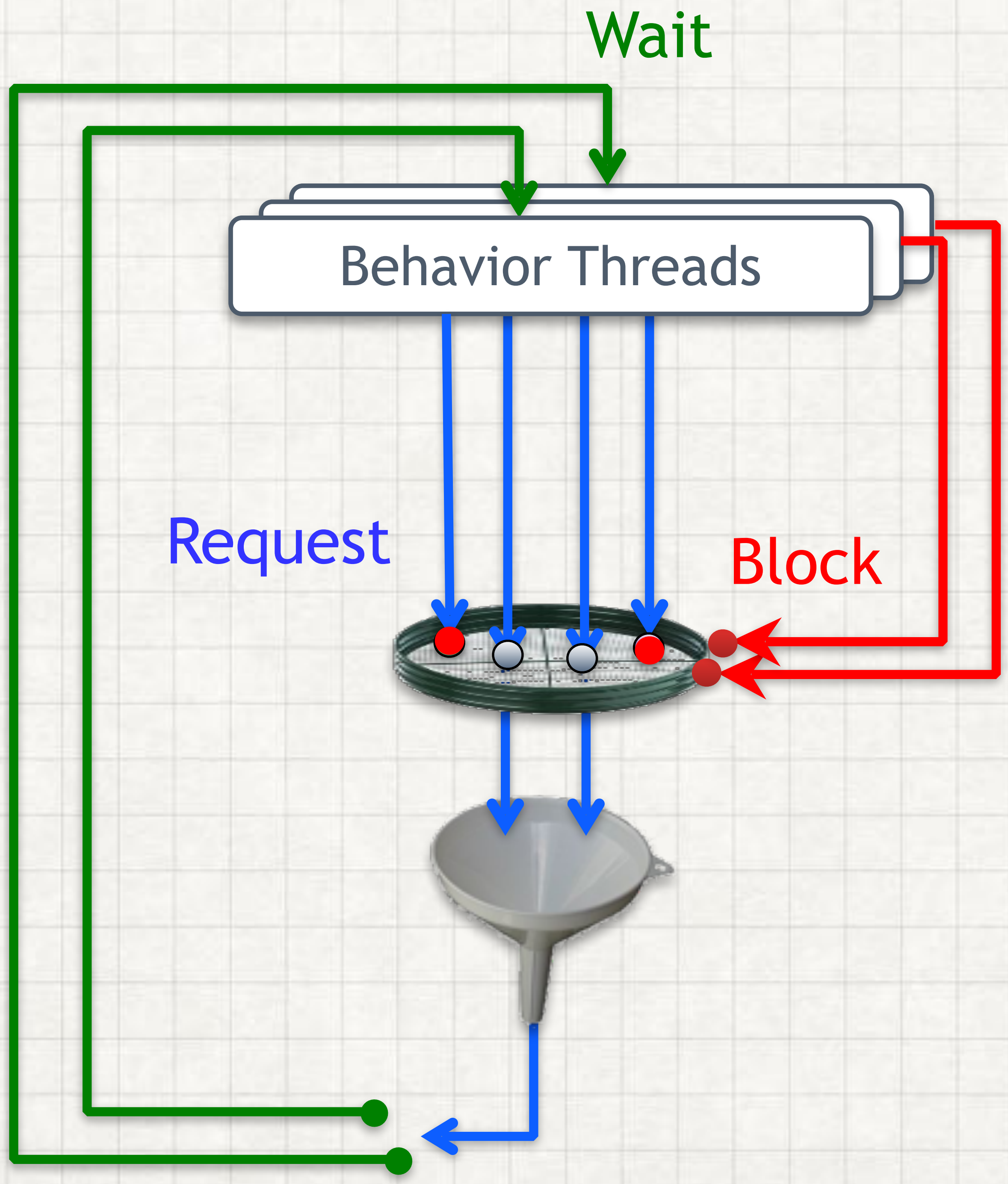

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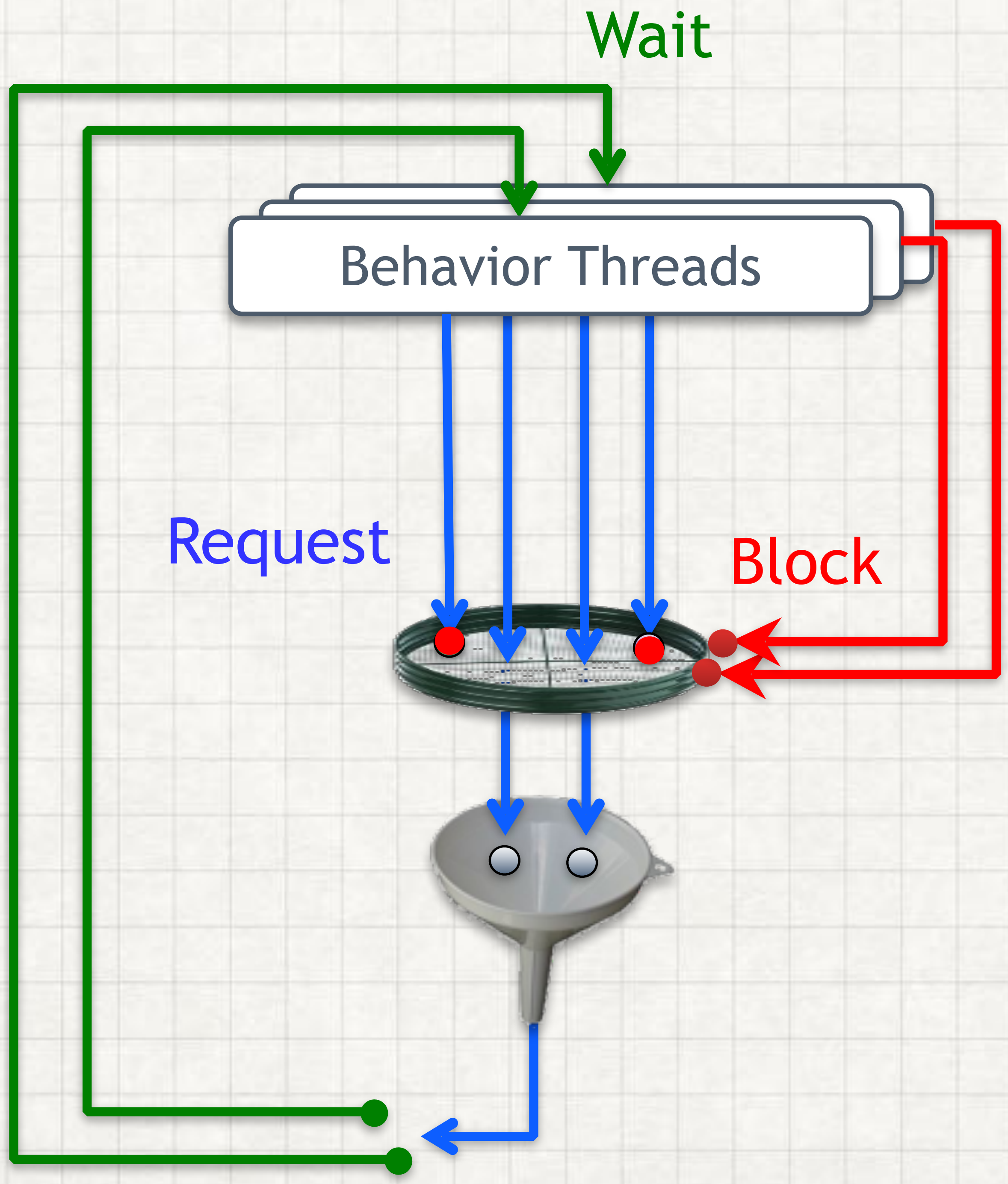

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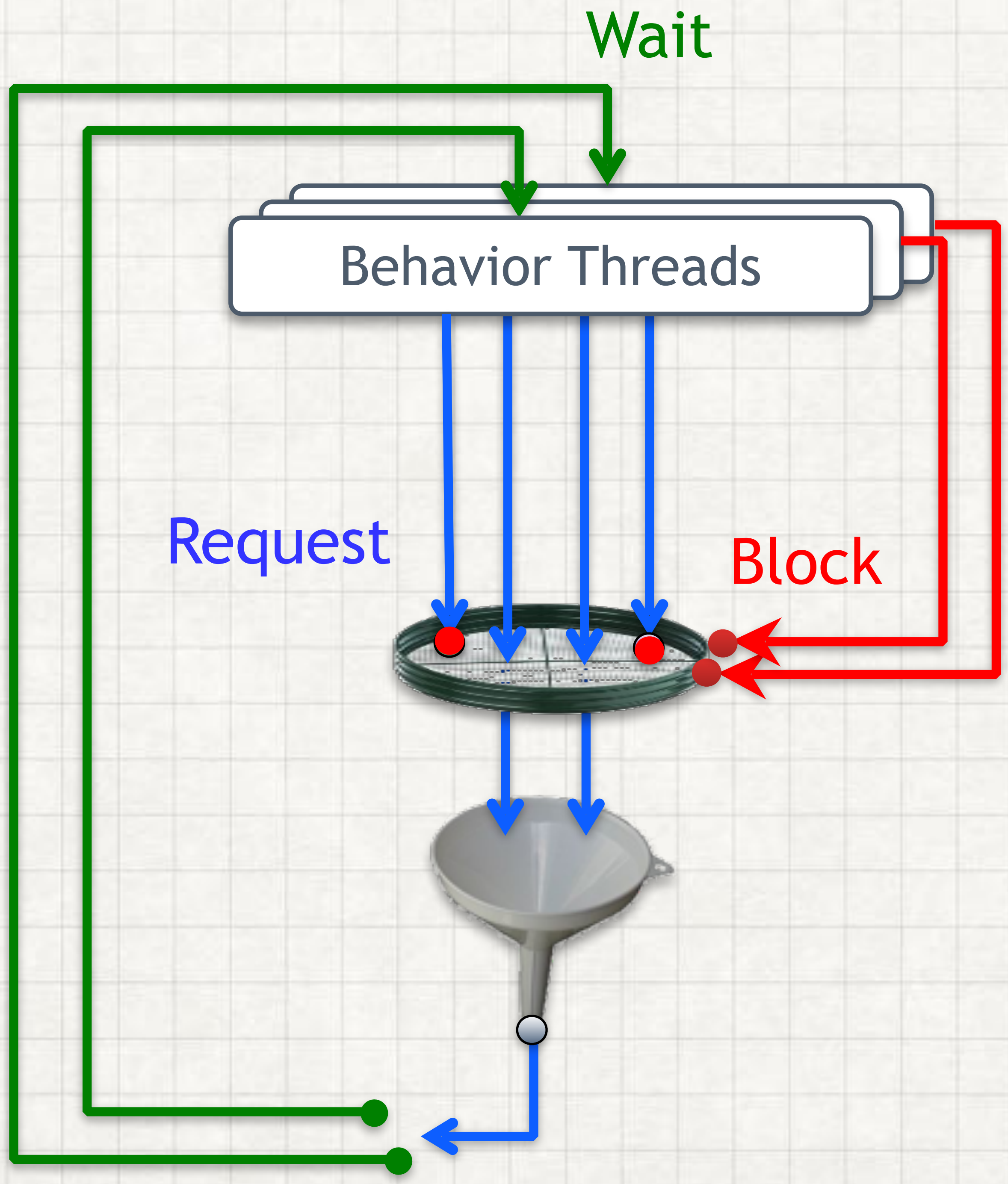

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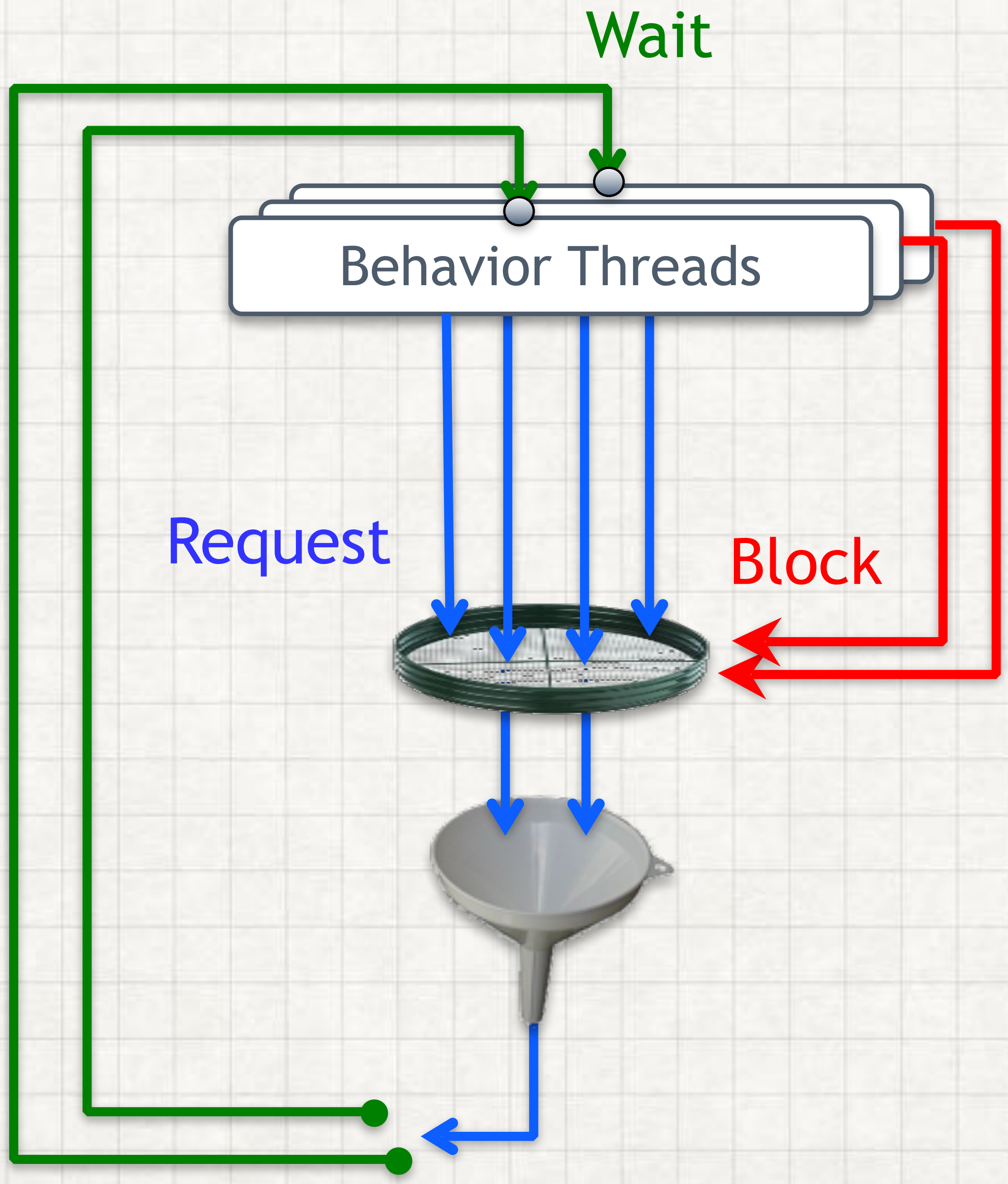
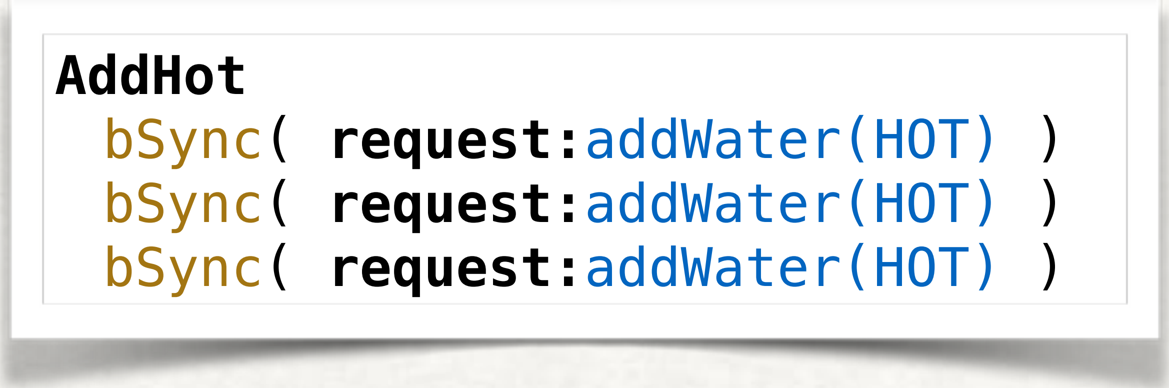
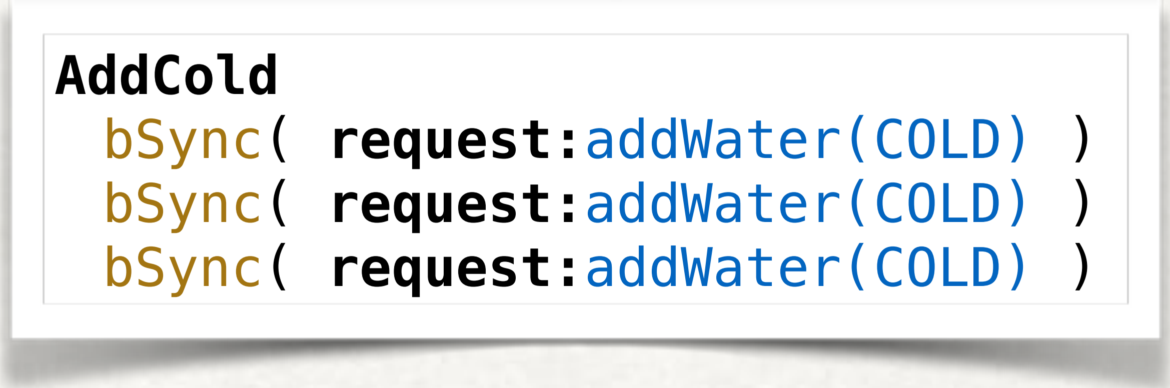


BP in action

Example: Fill a Bath



```
AddHot
  bSync( request:addWater(HOT) )
  bSync( request:addWater(HOT) )
  bSync( request:addWater(HOT) )
```



```
AddCold
  bSync( request:addWater(COLD) )
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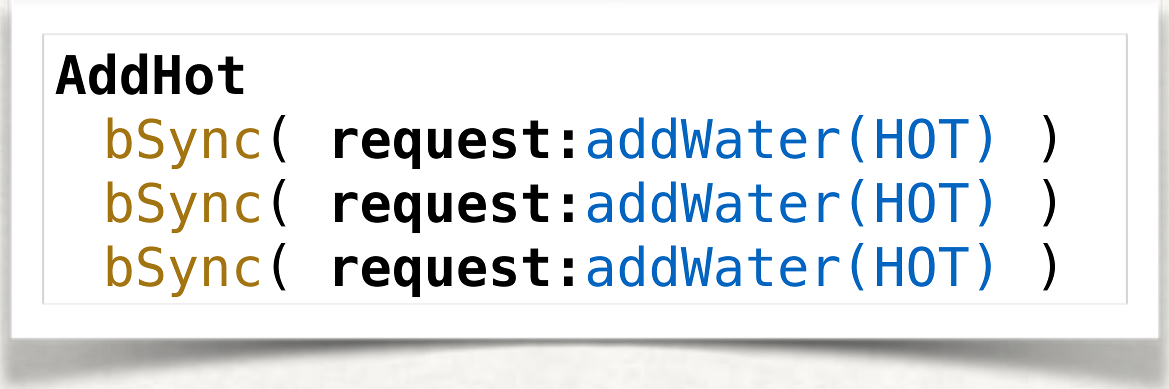
```

BP in action

Example: Fill a Bath



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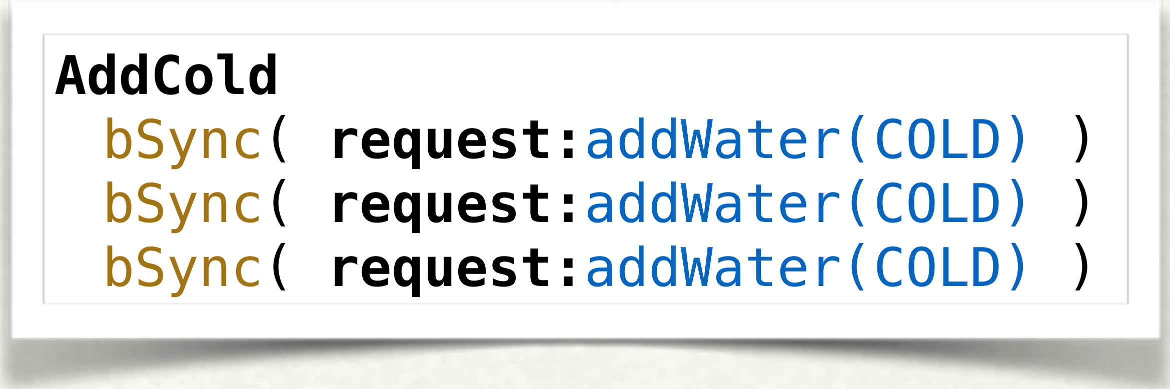


```
AddCold
  bSync( request:addWater(COLD) )
  bSync( request:addWater(COLD) )
  bSync( request:addWater(COLD) )
```

End result: Bath filled with lukewarm water.

Intermediate results: May vary

BP in action

Example: Fill a Bath

```
MaintainSaneTemp
  for ( i=1..3 ) {
    bSync( waitFor:addWater(_), block:addWater(HOT) )
    bSync( waitFor:addWater(_), block:addWater(COLD) )
  }
```

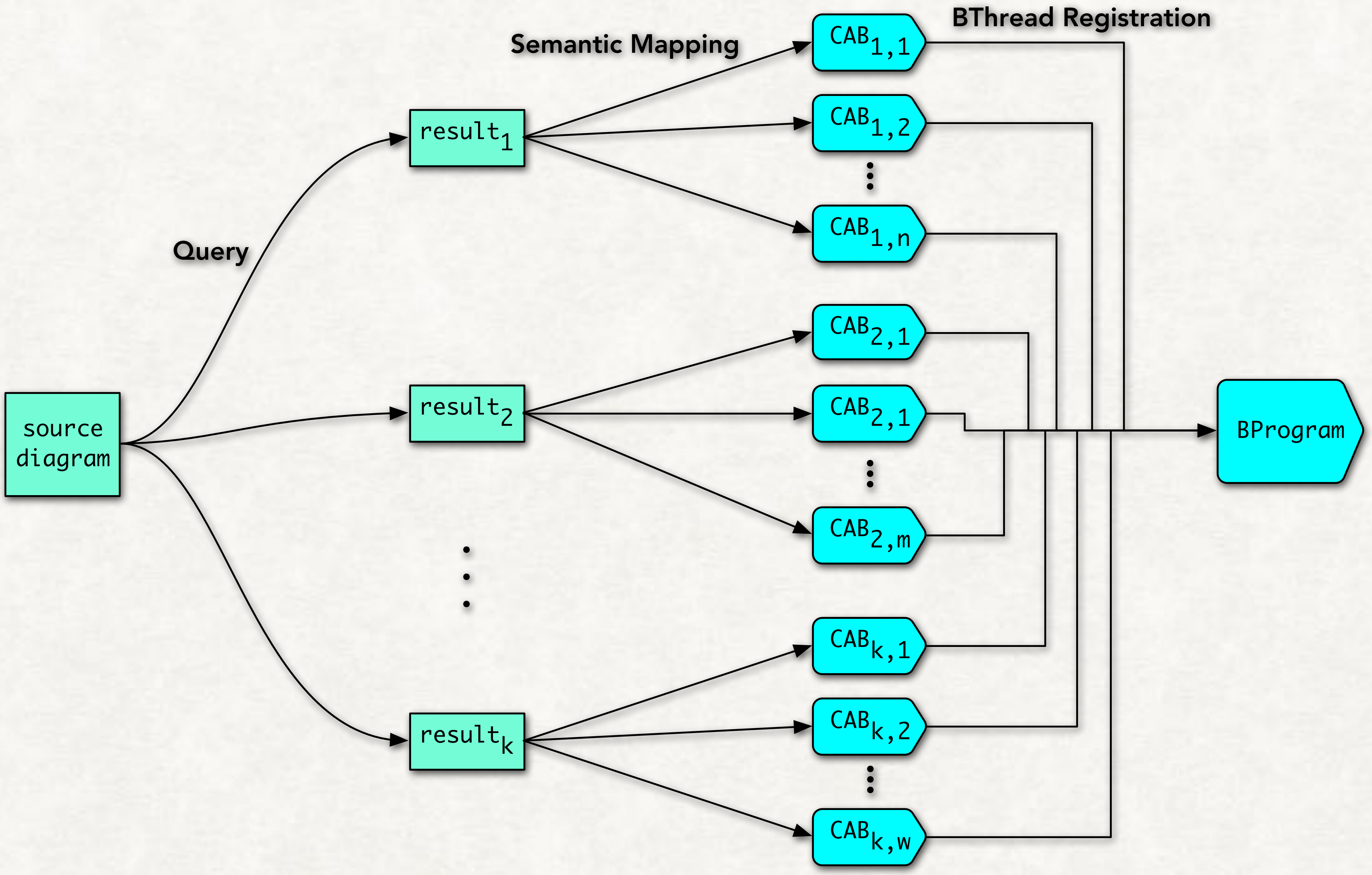
```
AddHot
  bSync( request:addWater(HOT) )
  bSync( request:addWater(HOT) )
  bSync( request:addWater(HOT) )
```

```
AddCold
  bSync( request:addWater(COLD) )
  bSync( request:addWater(COLD) )
  bSync( request:addWater(COLD) )
```

End result: Bath filled with lukewarm water.

Intermediate results: May vary

Concept Overview: Semantic Mapping



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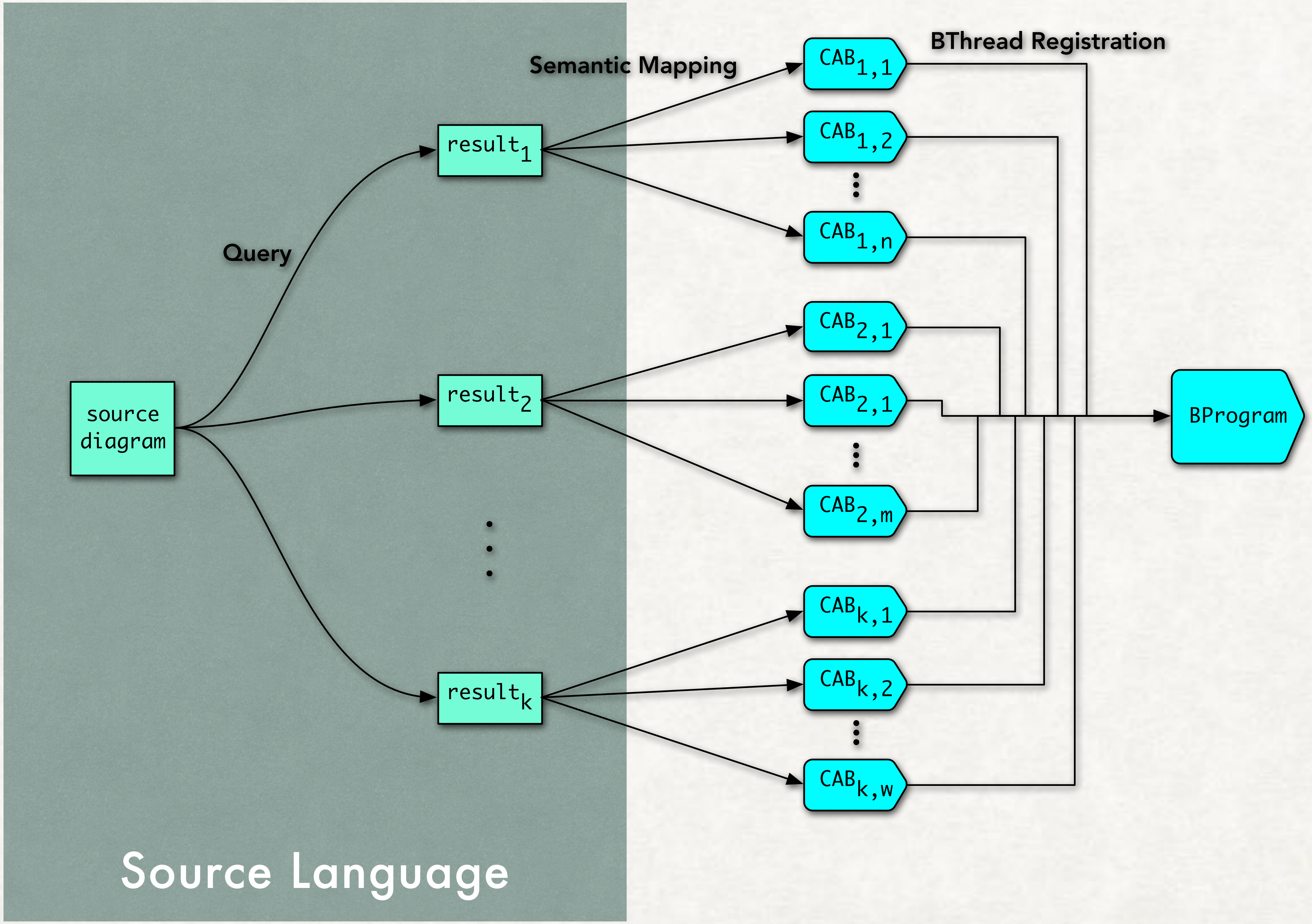

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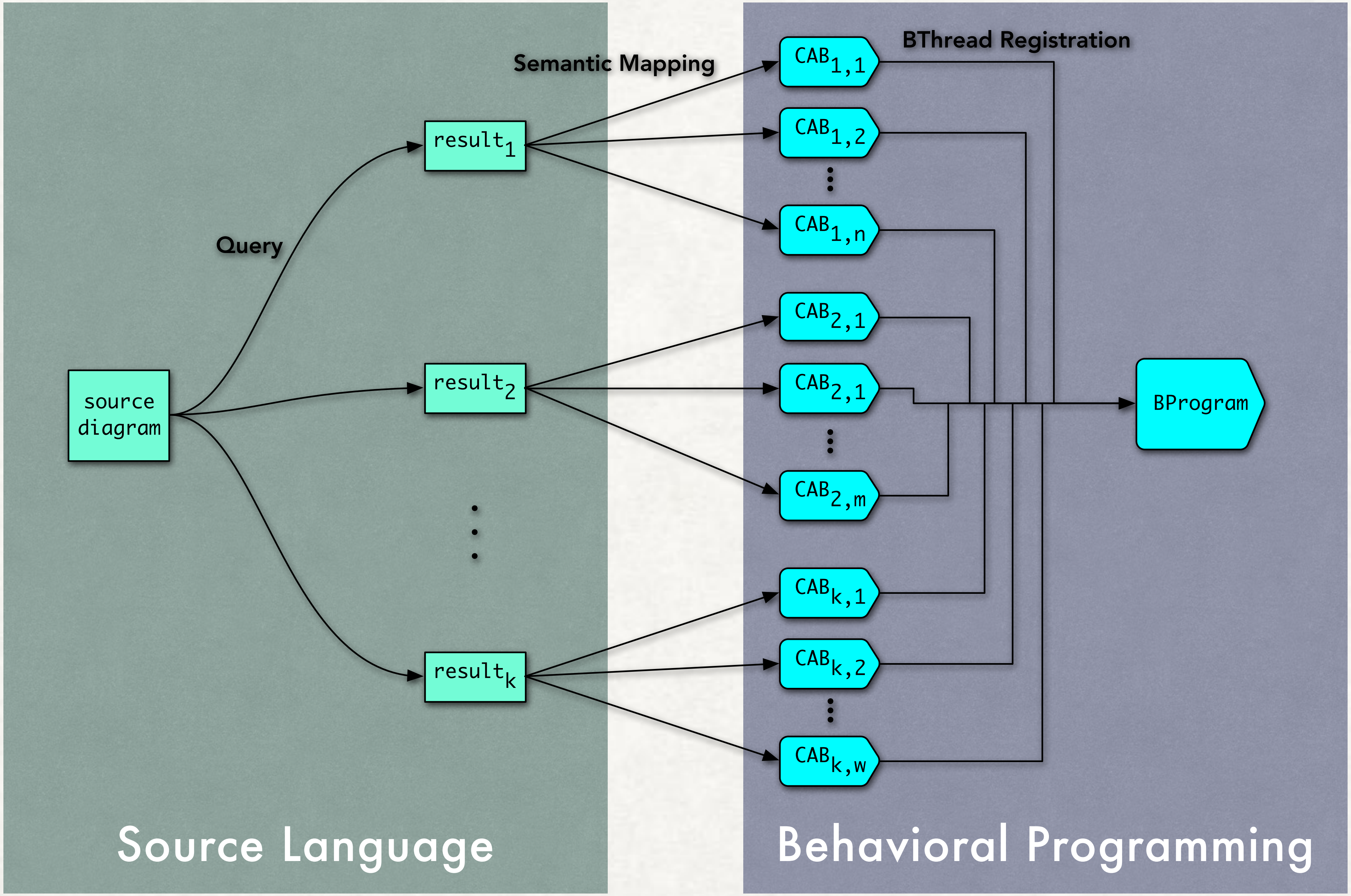

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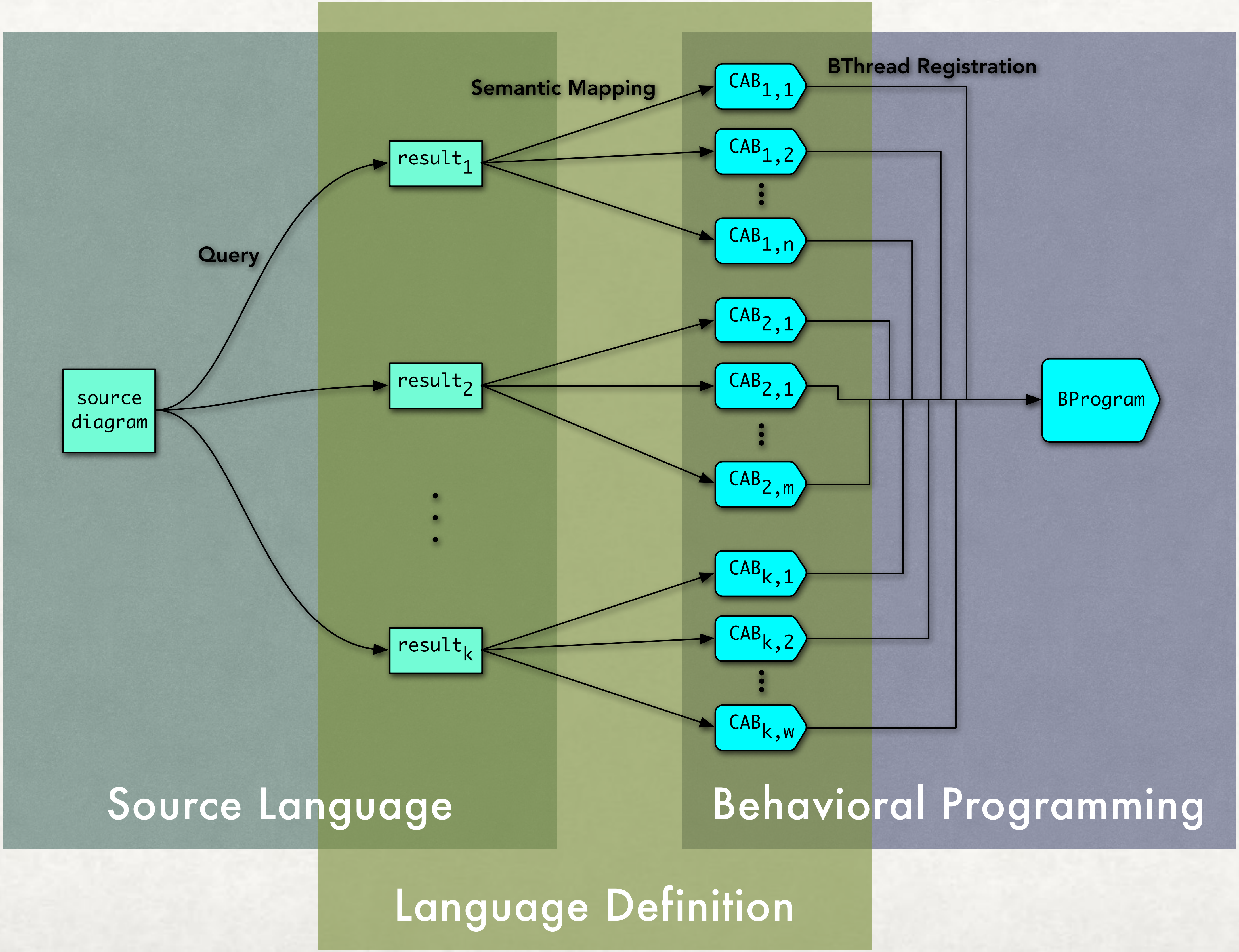

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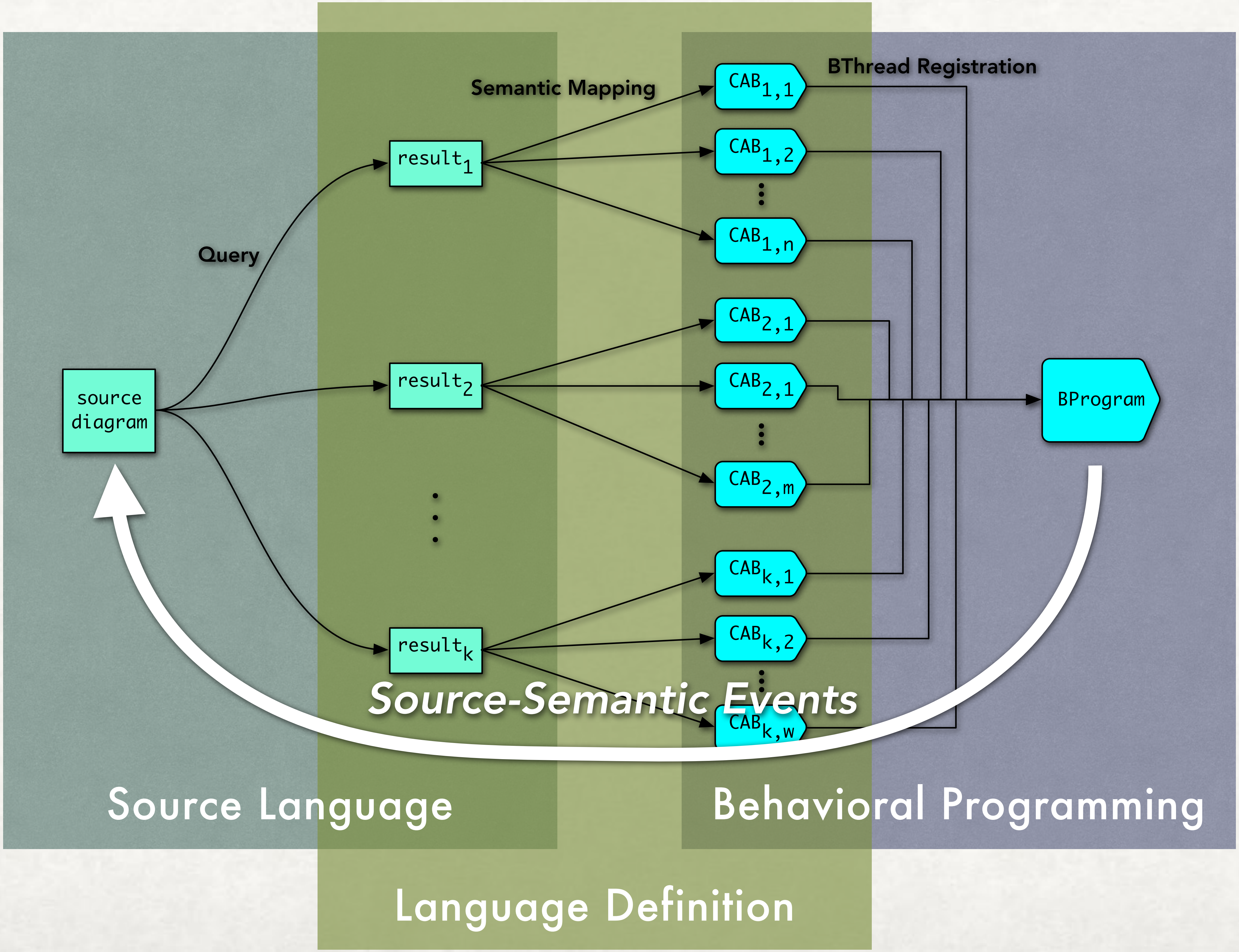


Proposed Methodology in Action

Define Language *L*:

- **Decide** what are the syntactic building blocks of programs in the language (e.g. squares and ovals, connected by green arrows or red arrows).
- **Define** a set of queries over programs in L.
- For each query, **define** a set of *BThread templates*, parametrized by query results.
    - Each BThread templates defines some of the executable semantics of its parameters. Together, the templates define the full executable semantic of the construct returned from the query.

Write Programs *P* in *L*:

- **Draw** the program's diagrams
- **Load** L's language definition into an execution tool.
- **Load** the diagrams into the tool.
- **Press** the *Run* button.
- The tool runs the queries in L's definition against *P*'s diagrams. It then uses the BThread templates and the query results to generate a BP-program, and executes it.

So, Is this a Good Idea?

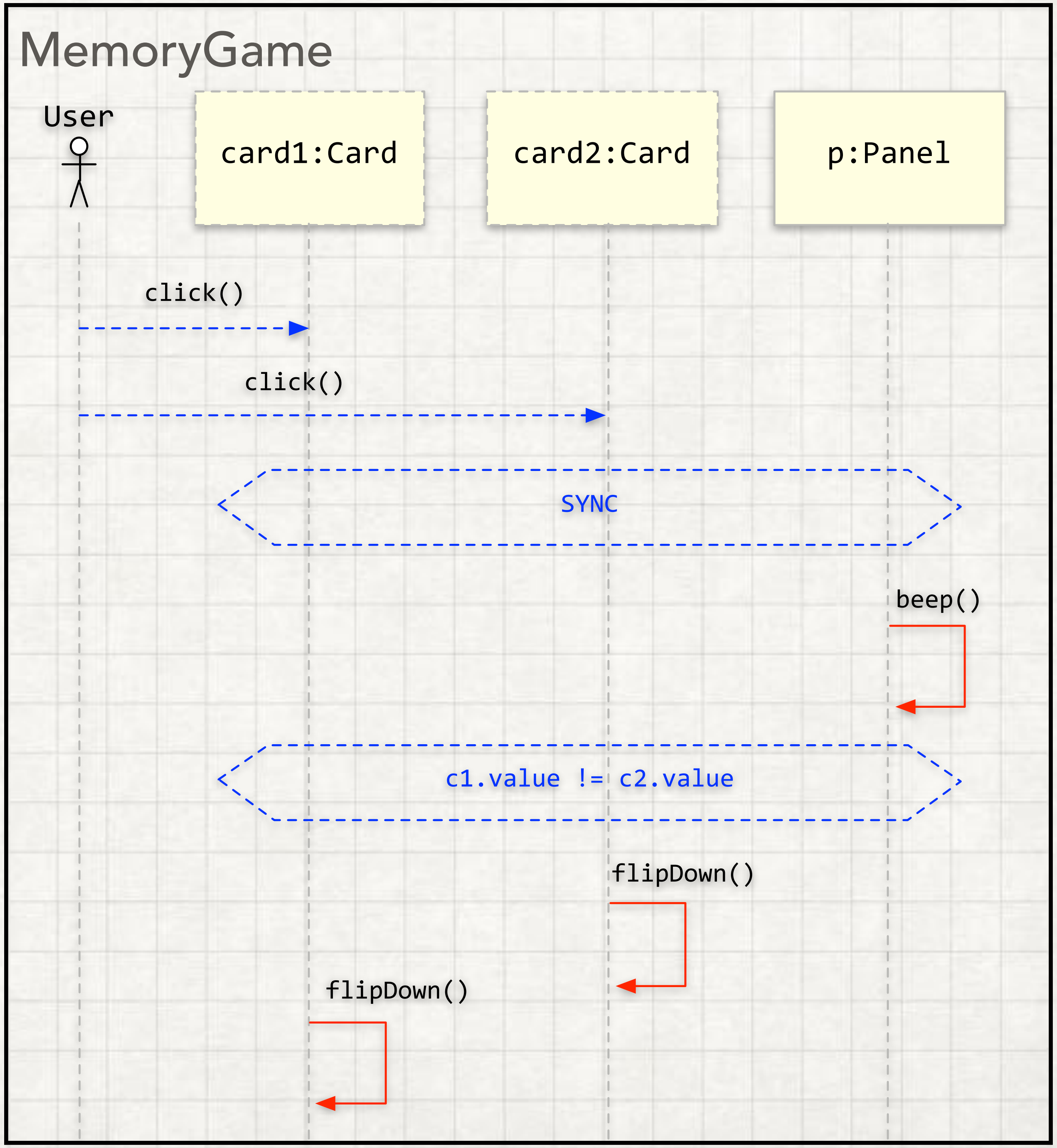
- Reader needs to remember multiple CABs for understanding a single construct
- BP not widely known
- Too many BThreads might cause performance issues

- Generated definitions are:
  - Formal
  - Accessible
  - Executable
  - Verifiable (e.g. BPMC)
- Mix and match semantics and constructs by adding/removing relevant queries and mappers only.
- Use BP as common execution environment for heterogeneous specifications

Case Study:
Semantic Variations of
Live Sequence Charts

Live Sequence Charts (LSC) - a Quick Intro

- Damm and Harel, 2001
- Diagrammatic programming language, extending classical message sequence charts, mainly with a universal interpretation and must/may, monitor/execute modalities
- Rich set of features: concurrency, event unification, forbidden scenarios and more.
- Multiple Semantic Variations:
  - Original (PlayGo)
  - UML2 Compliant



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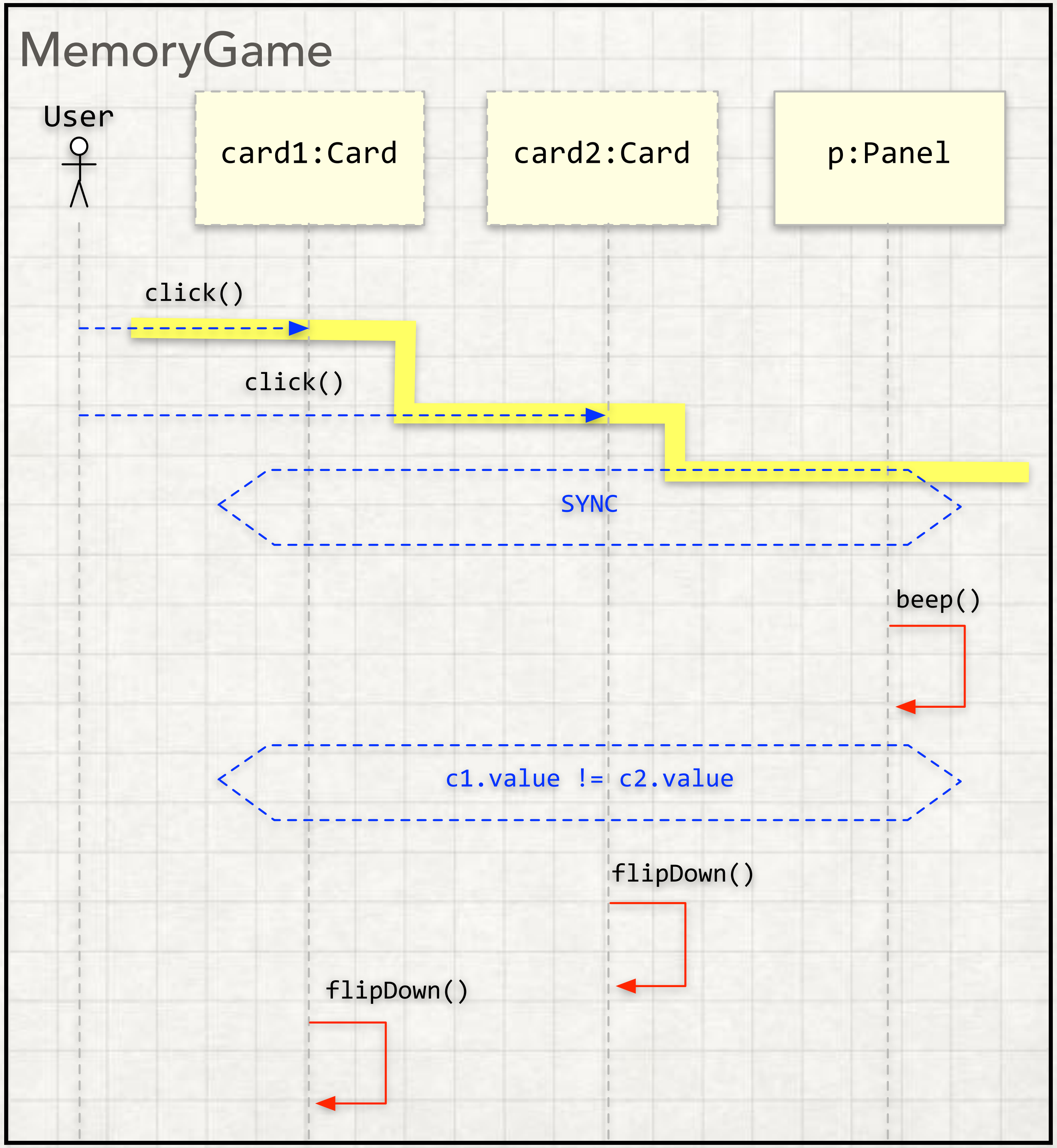

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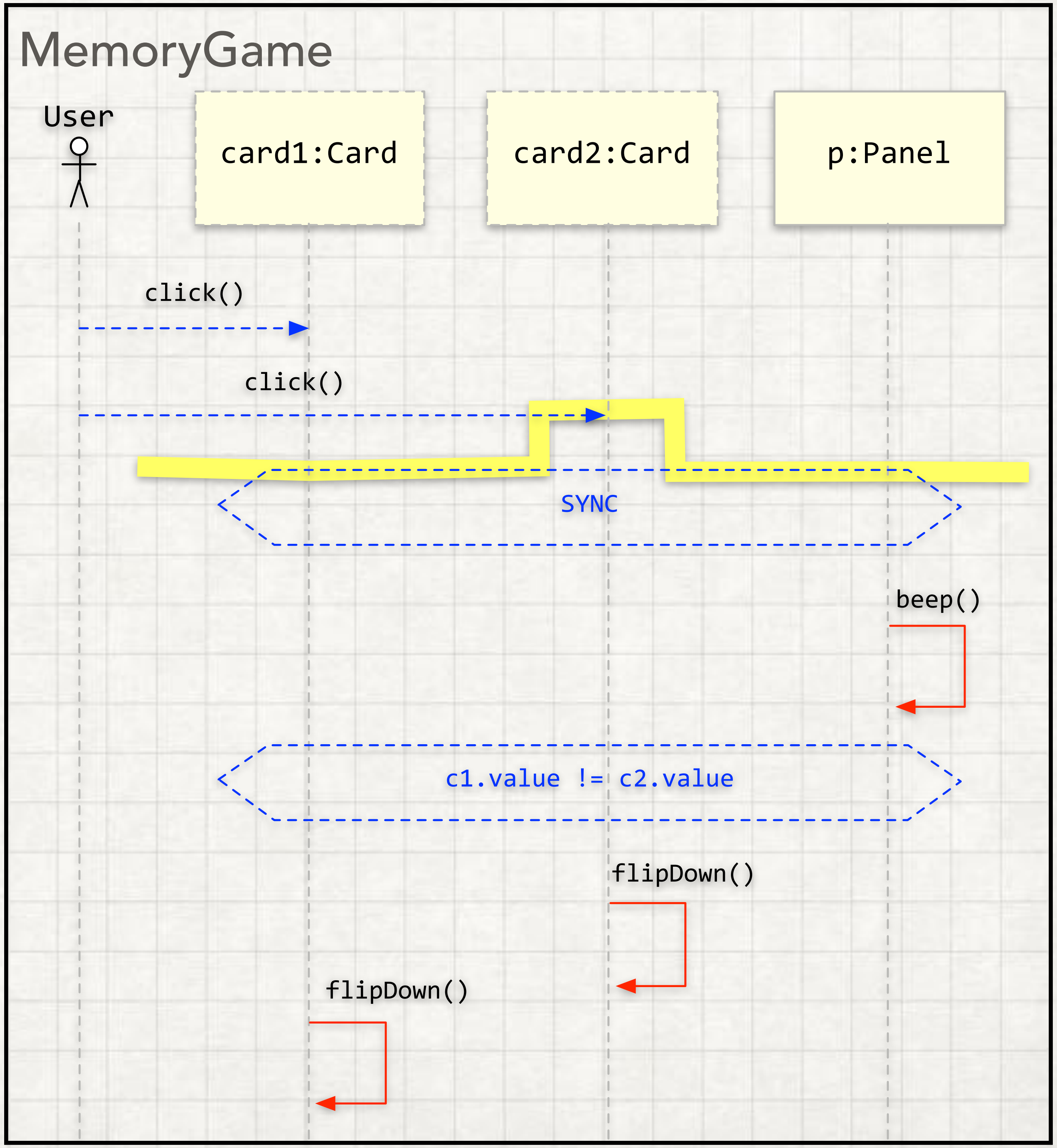

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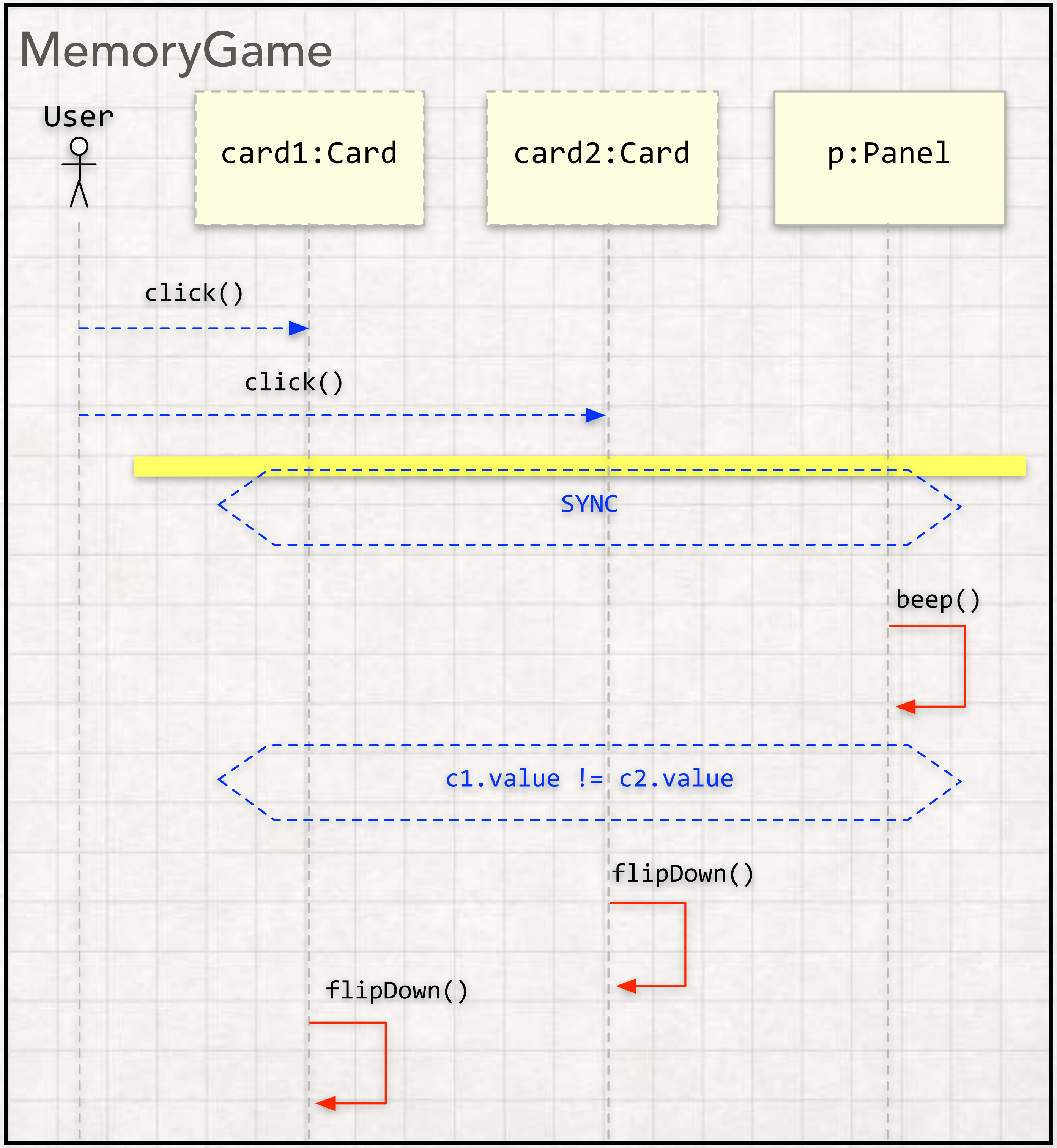

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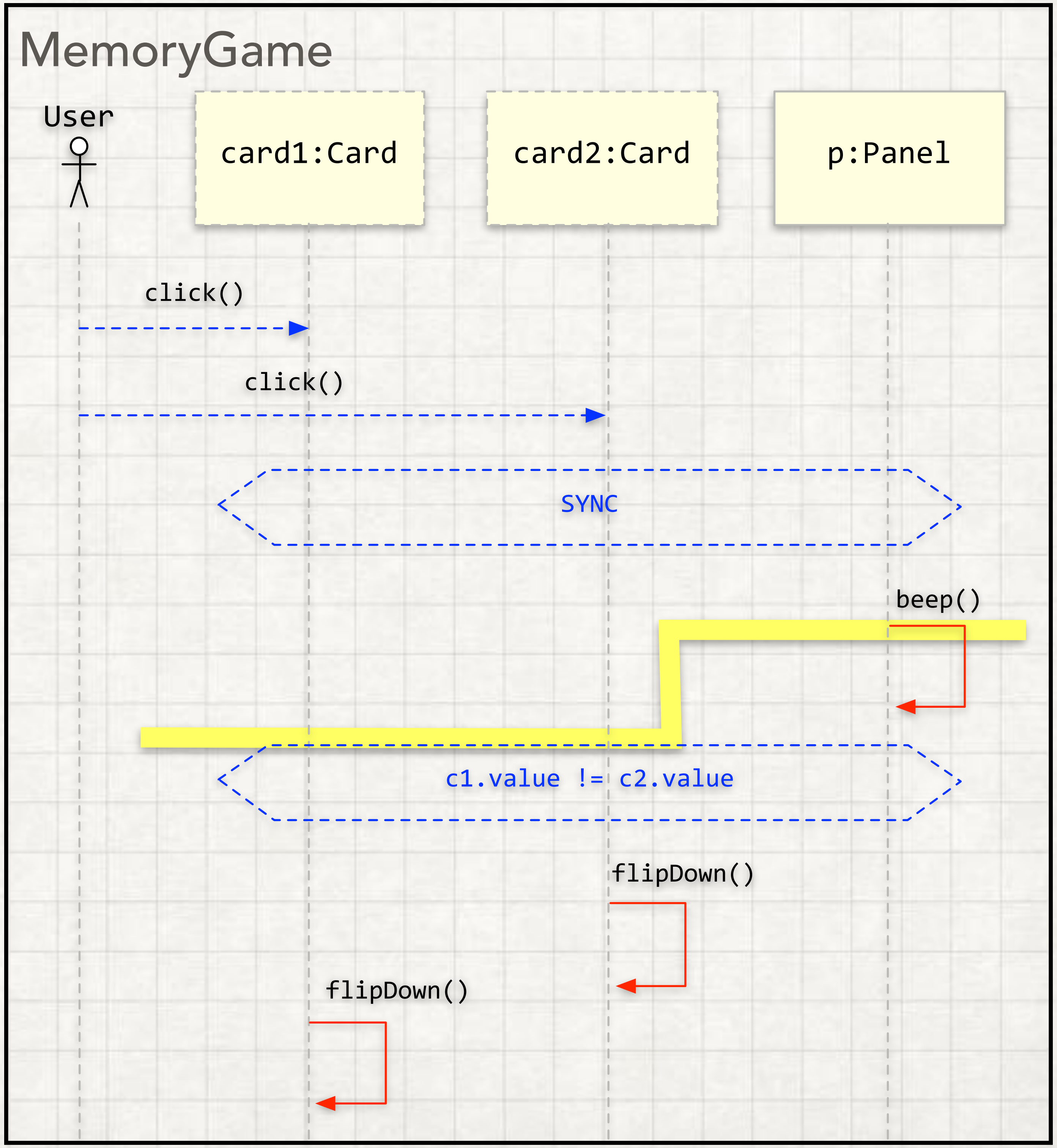

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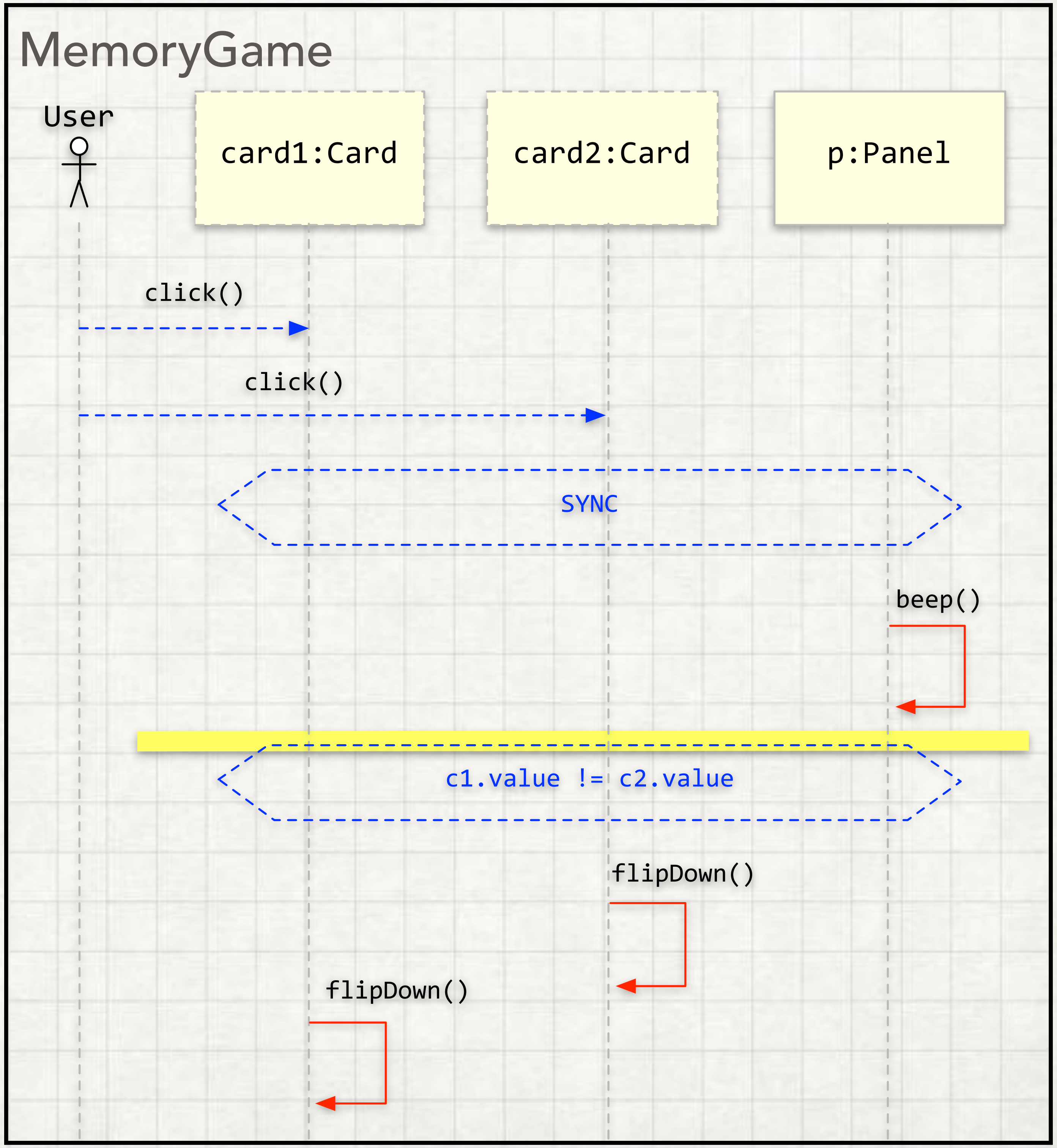

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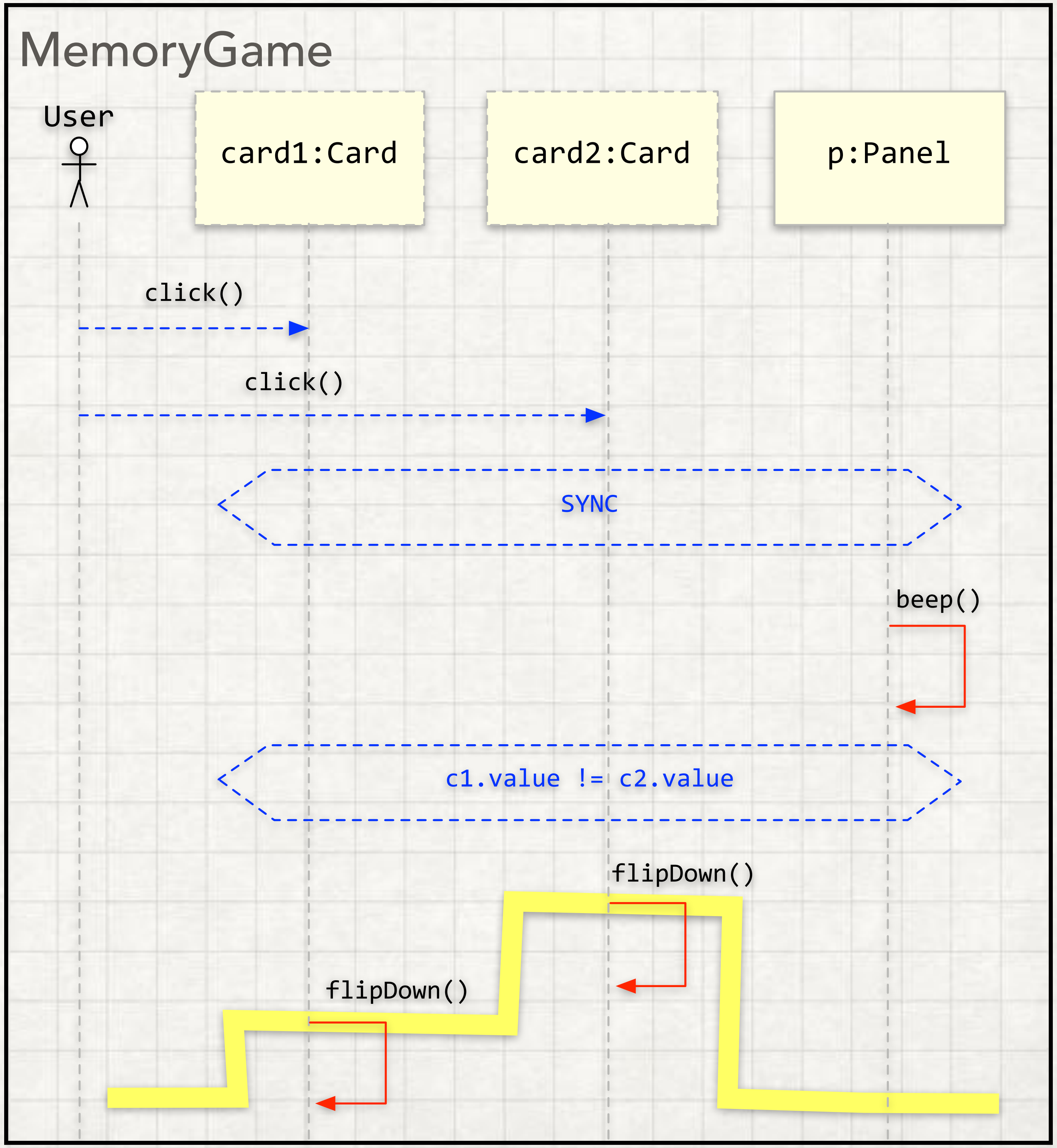

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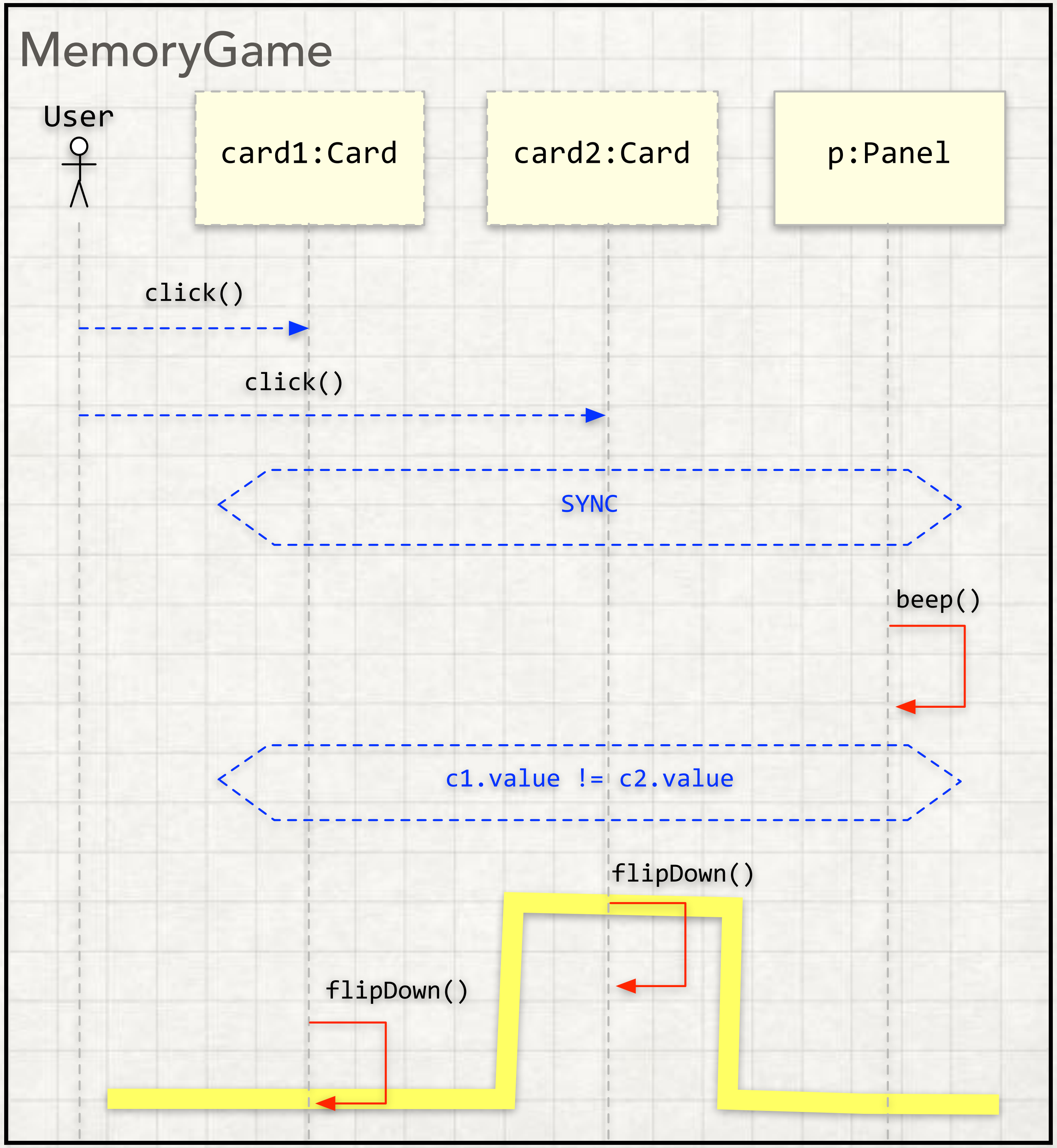

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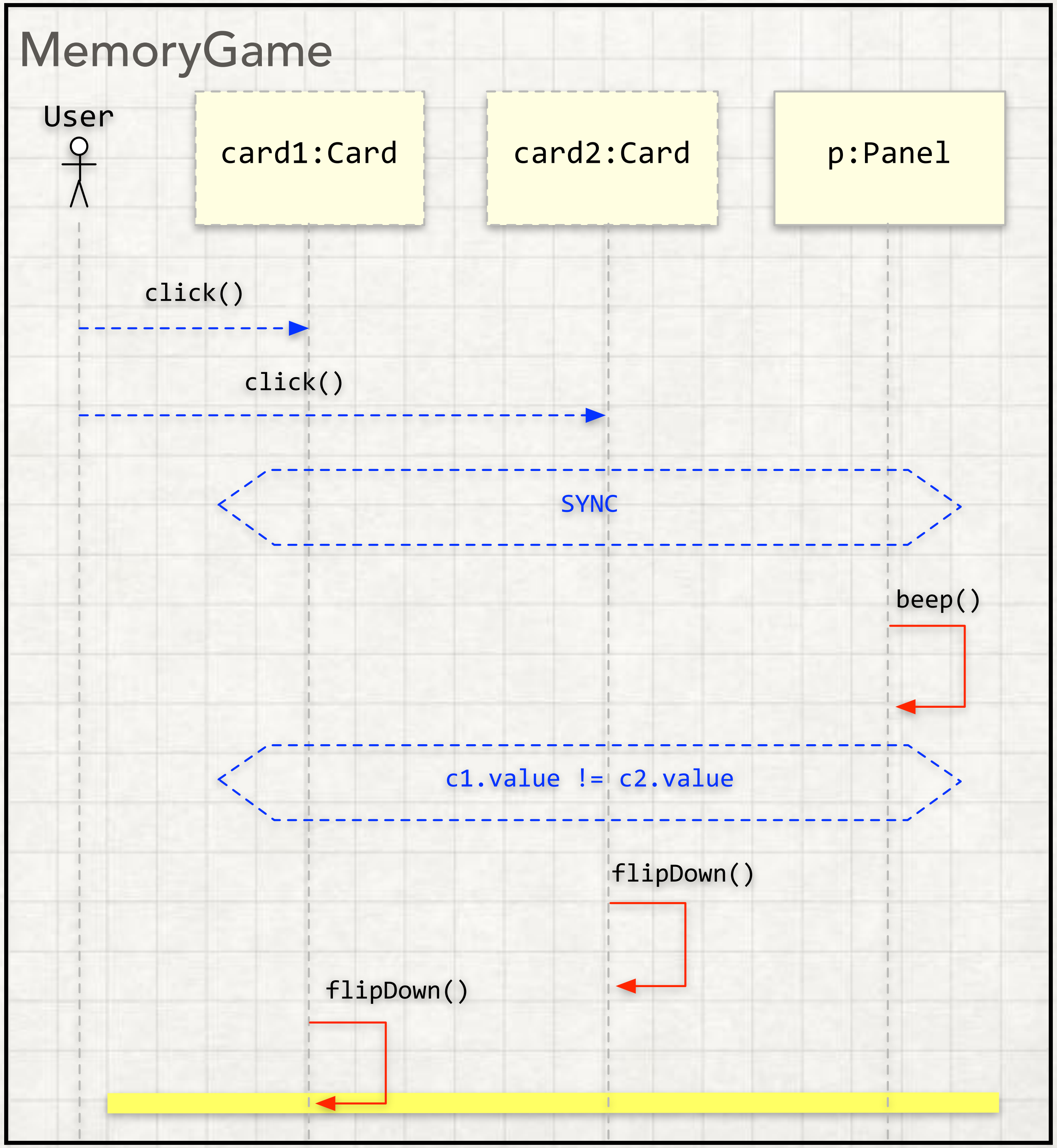

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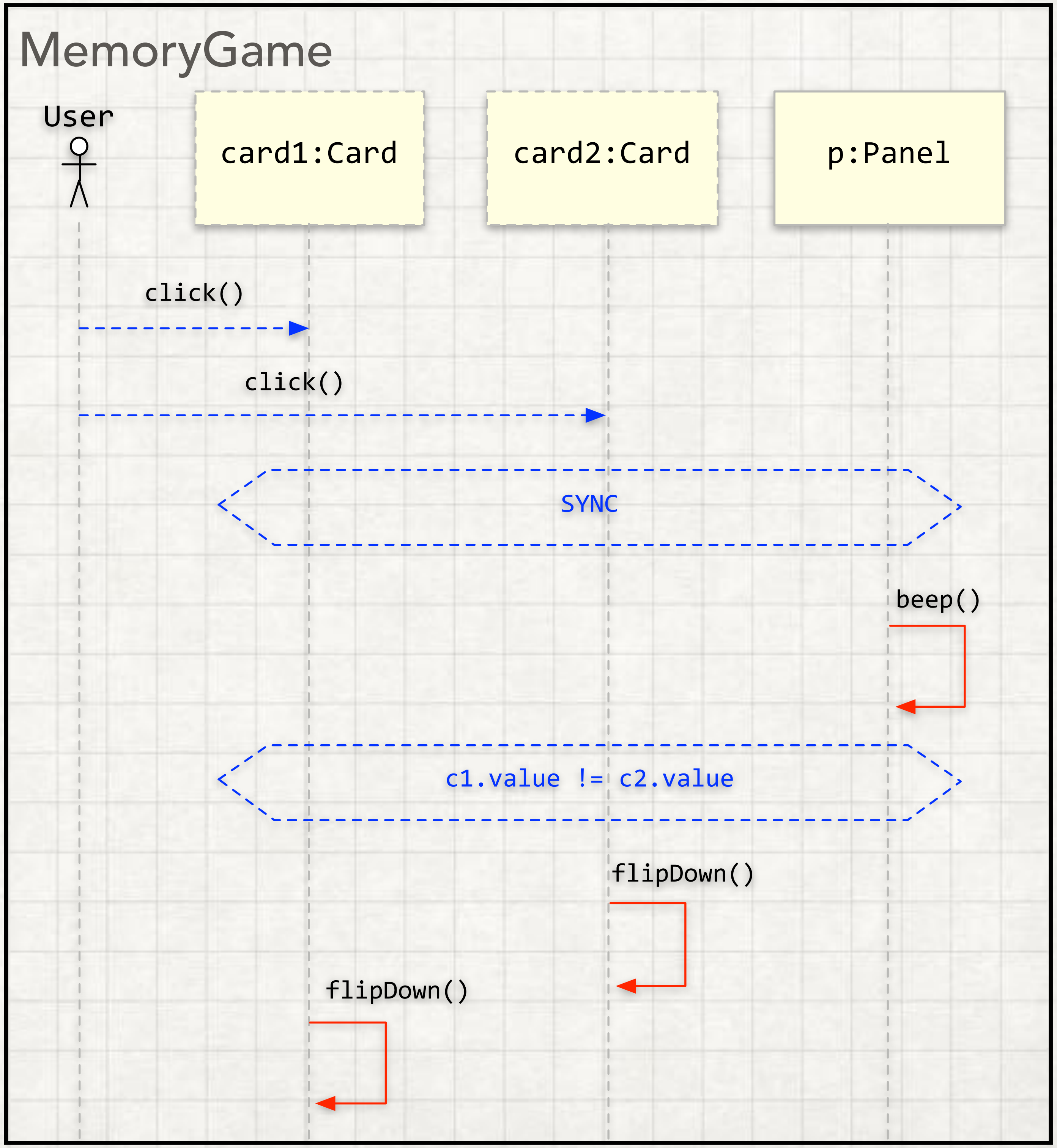
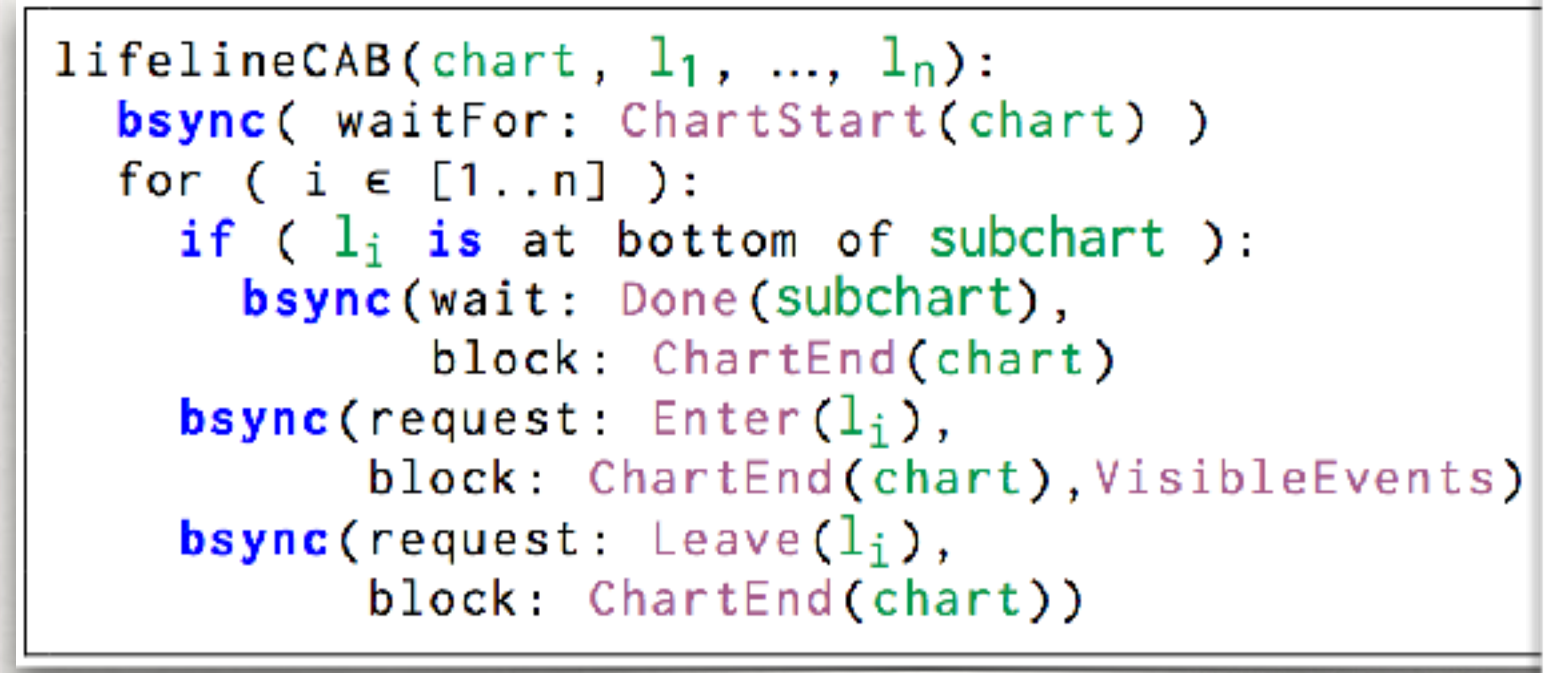
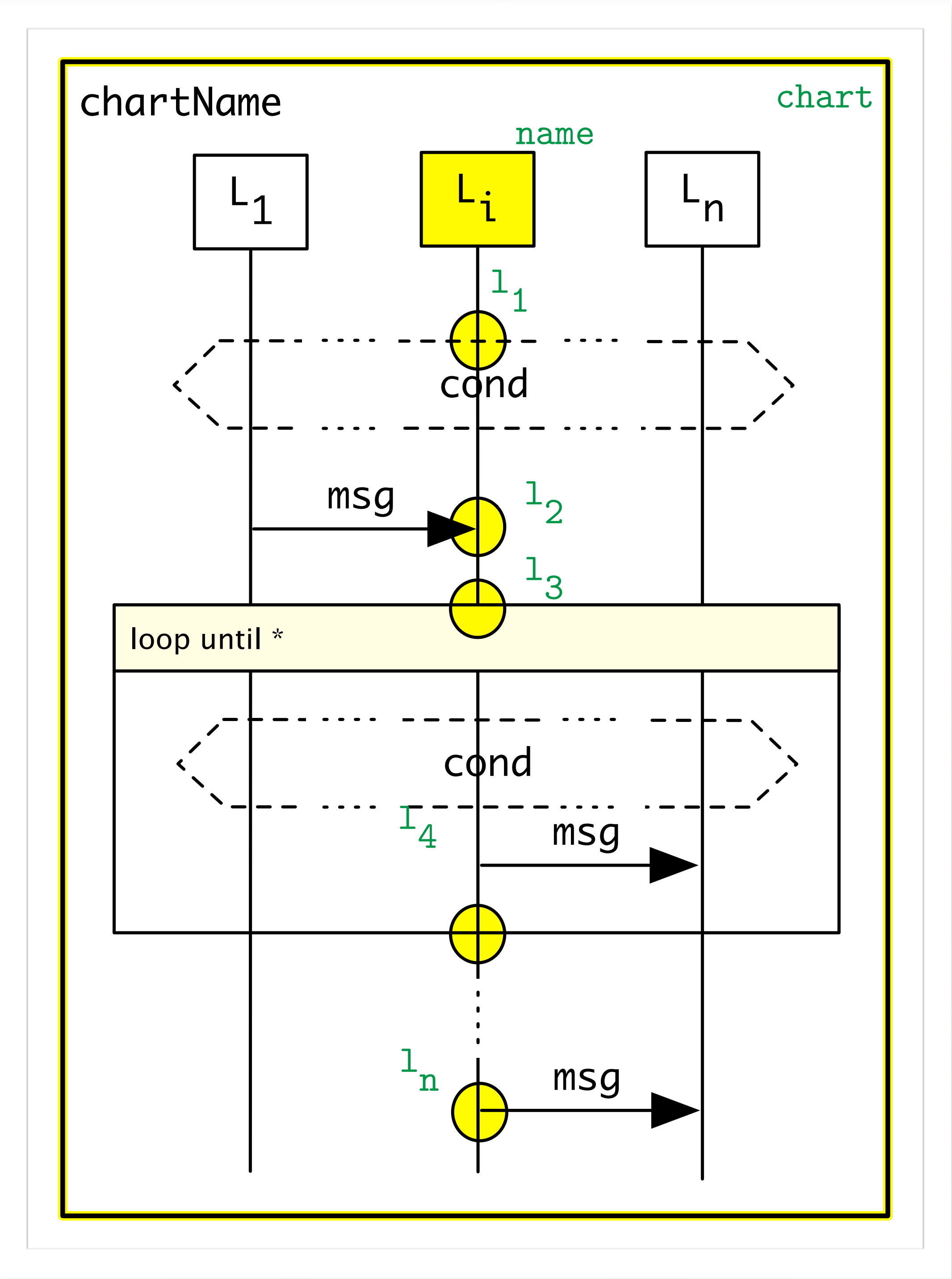


Lifeline

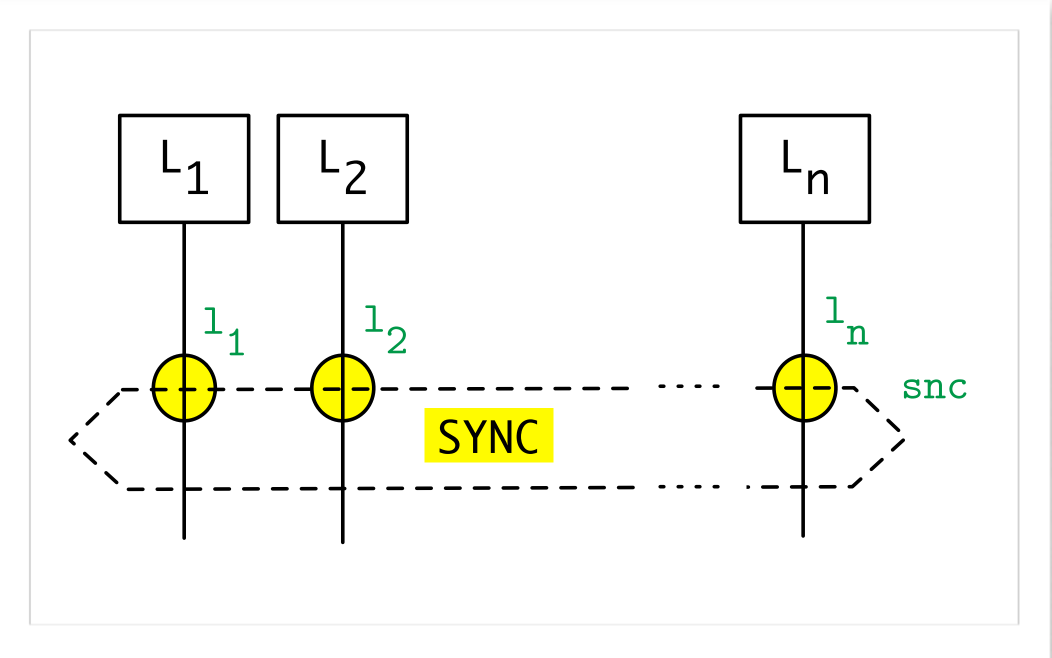


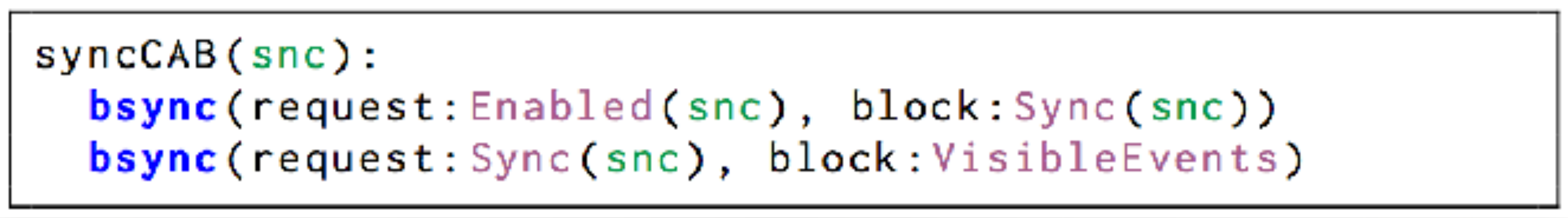
```
lifelineCAB(chart, l_1, …, l_n):
  bsync( waitFor: ChartStart(chart) )
  for ( i ∊ [1..n] ):
    if ( l_i is at bottom of subchart ):
      bsync(wait: Done(subchart),
            block: ChartEnd(chart)
    bsync(request: Enter(l_i),
          block: ChartEnd(chart),VisibleEvents)
    bsync(request: Leave(l_i),
          block: ChartEnd(chart))
```



Sync

- For each i in 1..n:
  - blockUntilCAB(Enabled(**snc**), Enter(**l_i**))
- For each i in 1..n:
  - blockUntilCAB(Leave(**l_i**), Sync(**snc**))

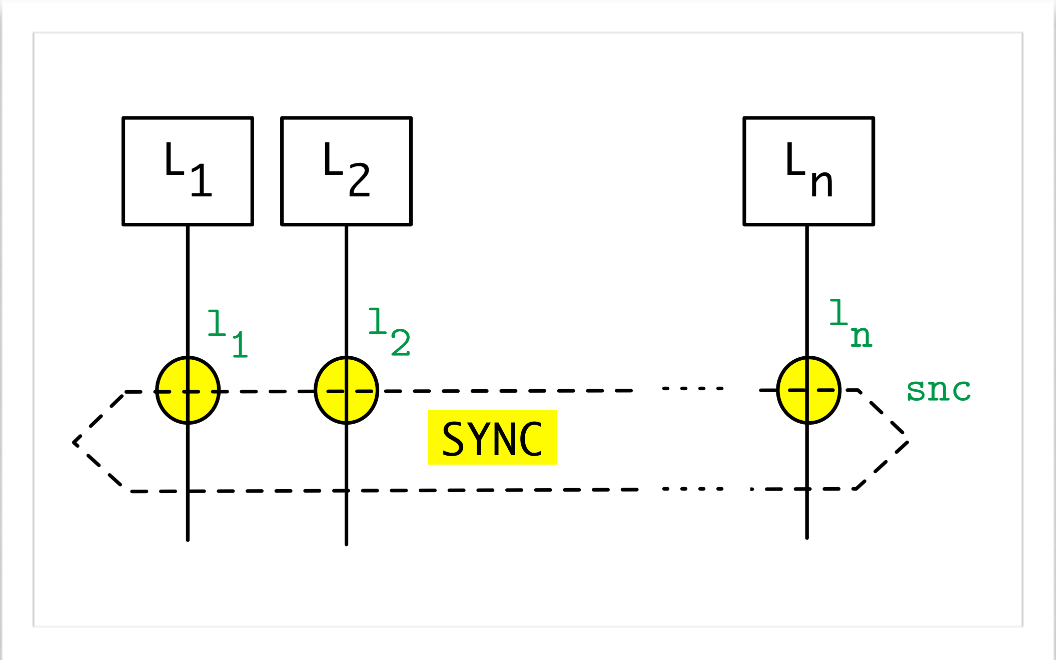


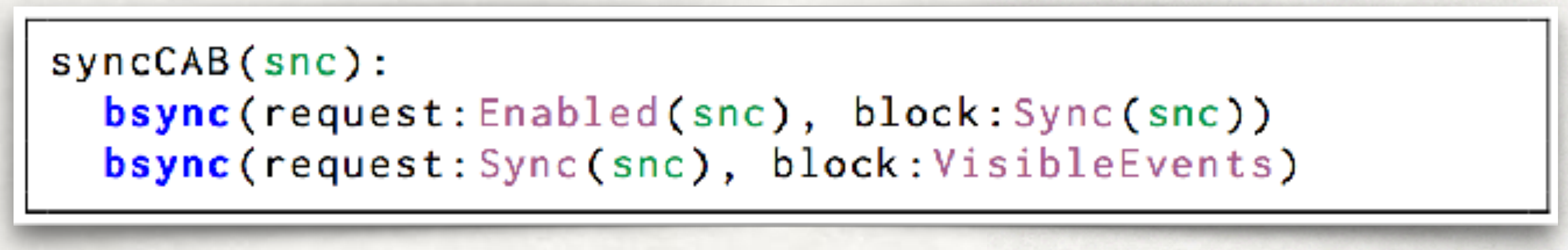


```
syncCAB(snc):
  bsync(request:Enabled(snc), block:Sync(snc))
  bsync(request:Sync(snc), block:VisibleEvents)
```

Sync

- For each i in 1..n:
  - blockUntilCAB(Enabled(**snc**),
    Enter($\mathbf{l_i}$))
- For each i in 1..n:
  - blockUntilCAB(Leave($\mathbf{l_i}$),
    Sync(**snc**))





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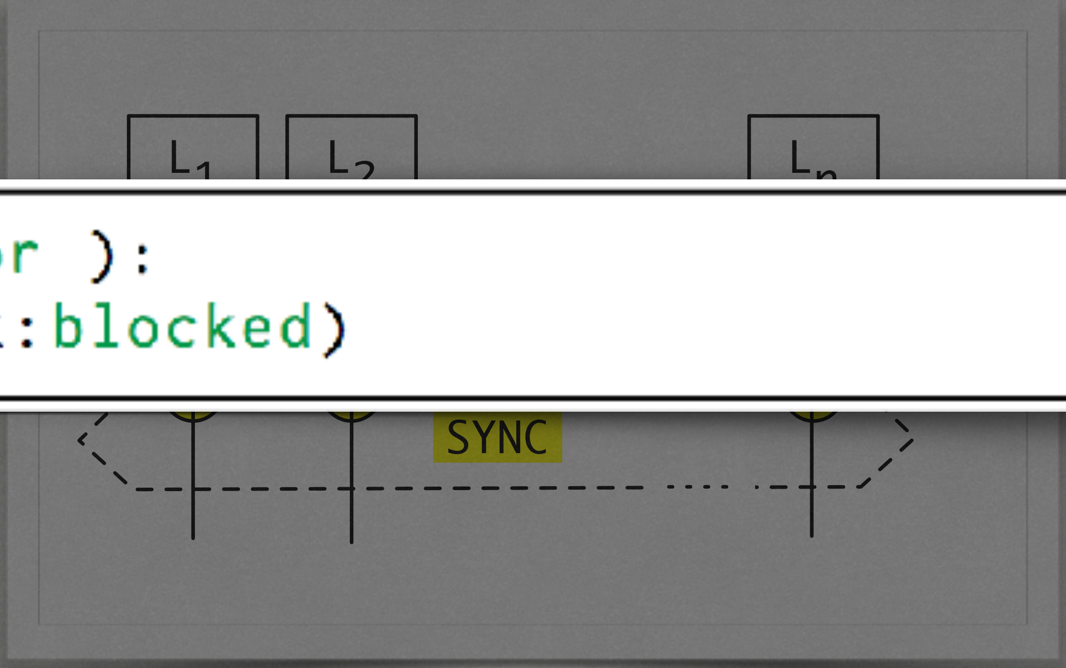
  bsync(request:Enabled(snc), block:Sync(snc))
  bsync(request:Sync(snc), block:VisibleEvents)
```

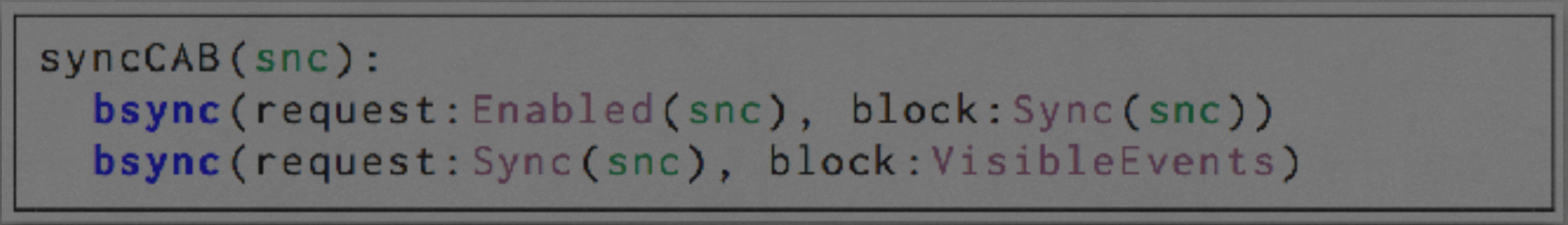
Sync

- For each i in 1..n:
  - blockUntilCAB(Enabled(snc),
    Enter(l_i))

```
blockUntilCAB( blocked, waitedFor ):
  bsync(waitFor:waitedFor, block:blocked)
```

- Sync(snc)





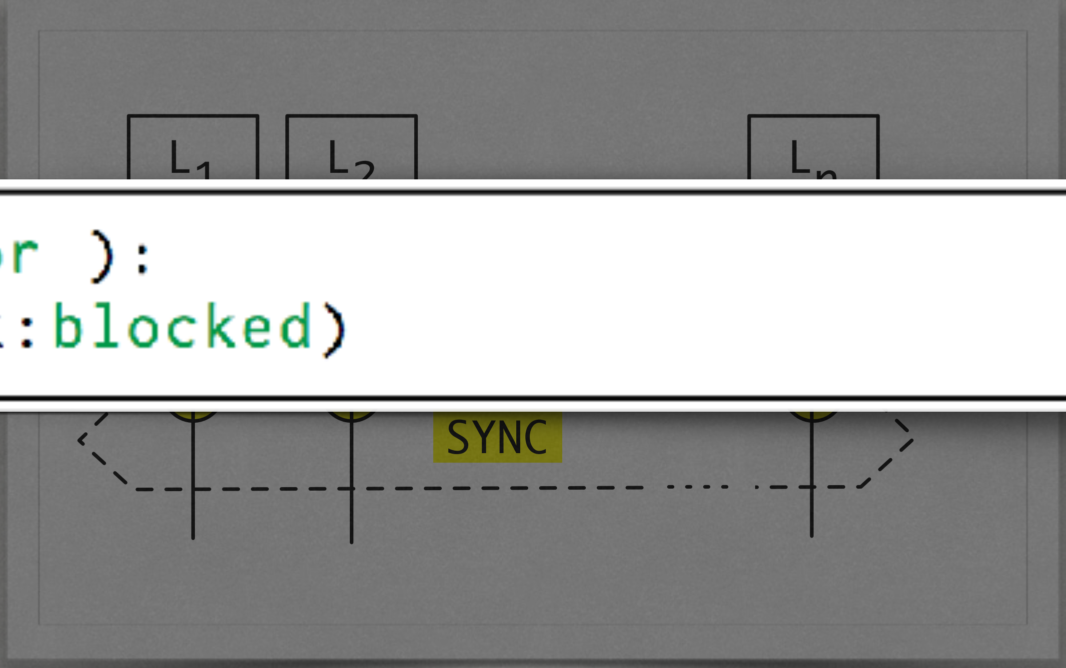
```
syncCAB(snc):
  bsync(request:Enabled(snc), block:Sync(snc))
  bsync(request:Sync(snc), block:VisibleEvents)
```

Sync

“Block `blocked` until `waitedFor` is selected”

- For each i in 1..n:
  - blockUntilCAB(Enabled(**snc**), Enter(l_i))
-
  Sync(**snc**)

```
blockUntilCAB( blocked, waitedFor ):
  bsync(waitFor:waitedFor, block:blocked)
```



```
syncCAB(snc):
  bsync(request:Enabled(snc), block:Sync(snc))
  bsync(request:Sync(snc), block:VisibleEvents)
```

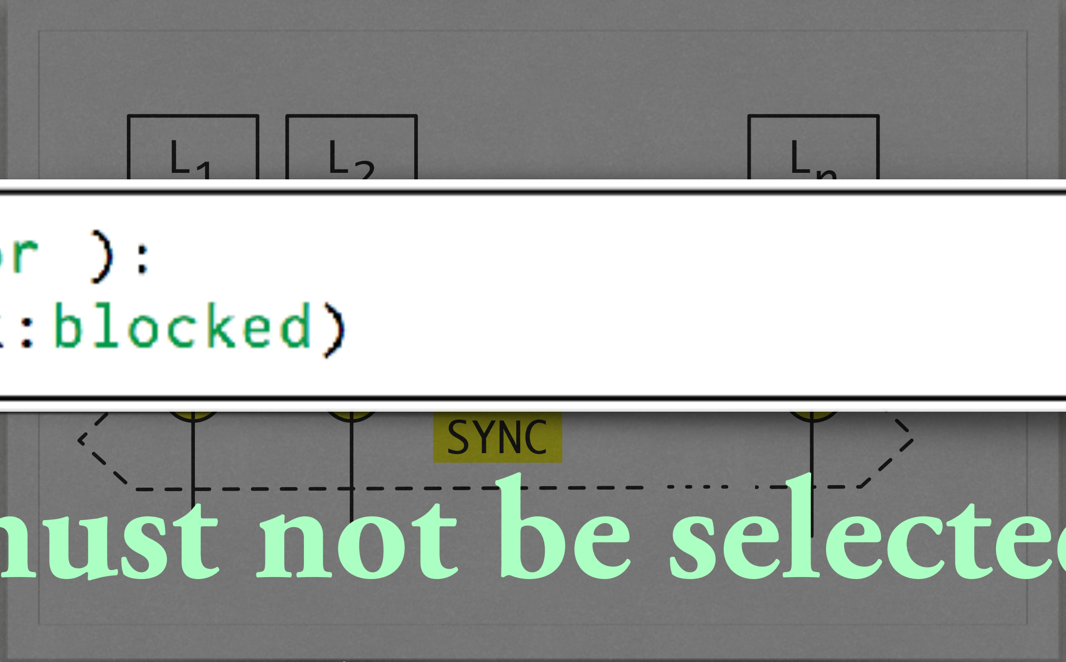
Sync

VISUAL DICTIONARY: LSC

“Block `blocked` until `waitedFor` is selected”

- For each i in 1..n:
  - `blockUntilCAB(Enabled(snc), Enter(l_i))`
- `blockUntilCAB(Leave(l_i)), Sync(snc))`

```
blockUntilCAB( blocked, waitedFor ):
  bsync(waitFor:waitedFor, block:blocked)
```

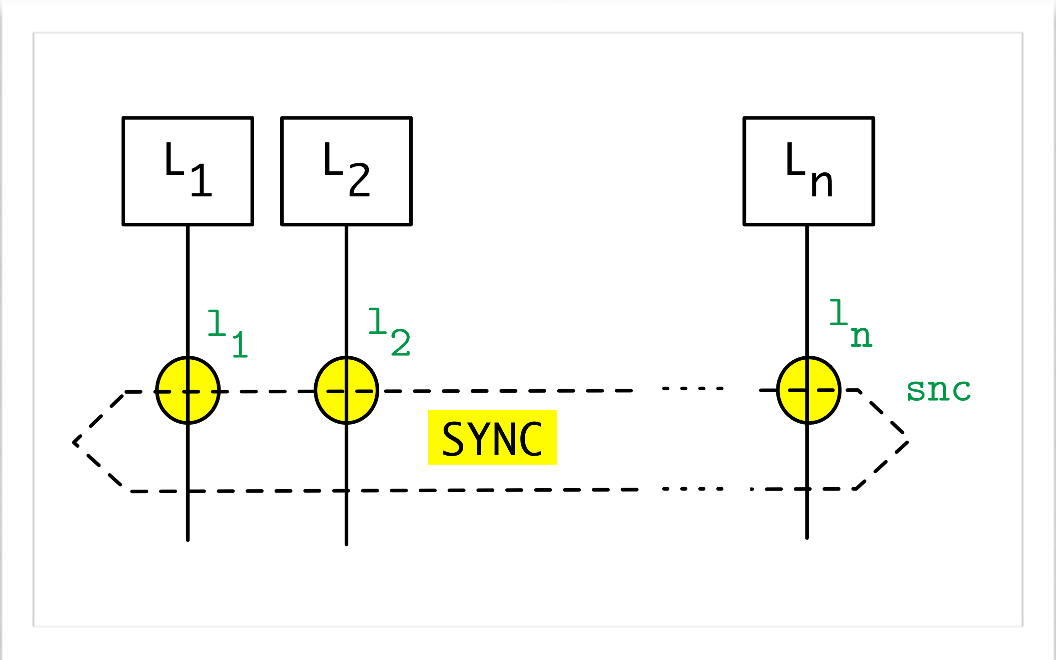


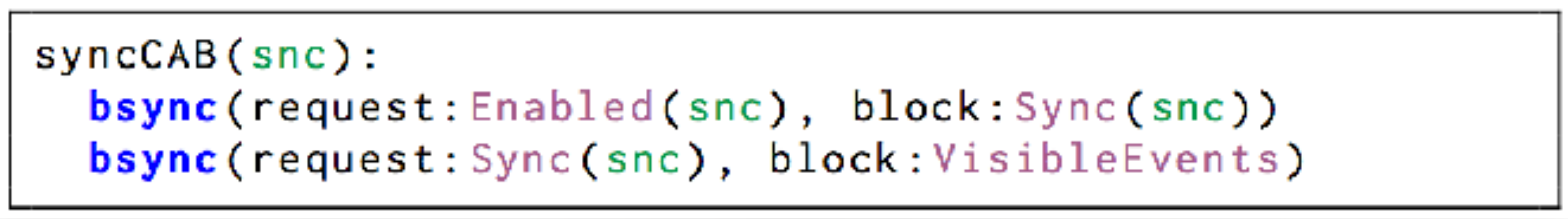
“`blocked` must not be selected until `waitedFor` is”

```
syncCAB(snc):
  bsync(request:Enabled(snc), block:Sync(snc))
  bsync(request:Sync(snc), block:VisibleEvents)
```

Sync

- For each i in 1..n:
  - blockUntilCAB(Enabled(**snc**), Enter(**l_i**))
- For each i in 1..n:
  - blockUntilCAB(Leave(**l_i**), Sync(**snc**))





```
syncCAB(snc):
  bsync(request:Enabled(snc), block:Sync(snc))
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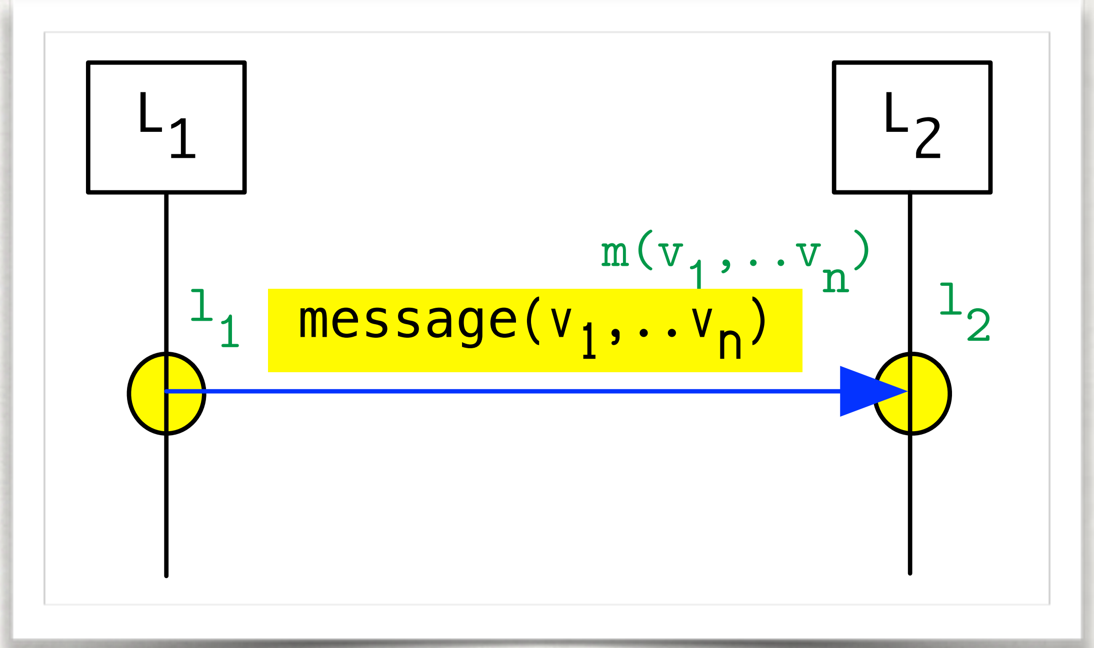
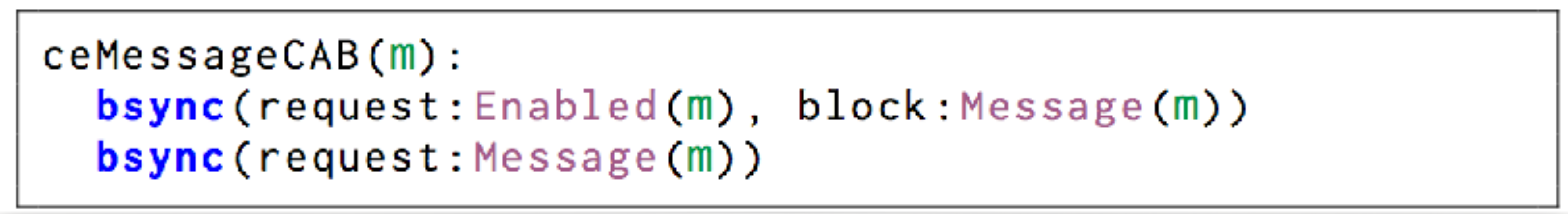
```

Cold, Executed Message

- BlockUntilCAB(Enabled(**m**), Enter(**l_1**))
- BlockUntilCAB(Enabled(**m**), Enter(**l_2**))
- BlockUntilCAB(Leave(**l_1**), Message(**m**))
- BlockUntilCAB(Leave(**l_2**), Message(**m**))
- For each non-affected variable **a**:
  - BlockUntil(Bound(**a**), Message(**m**))
- For each affected variable **a**:
  - BindFromCAB(**a**, Message(**m**))

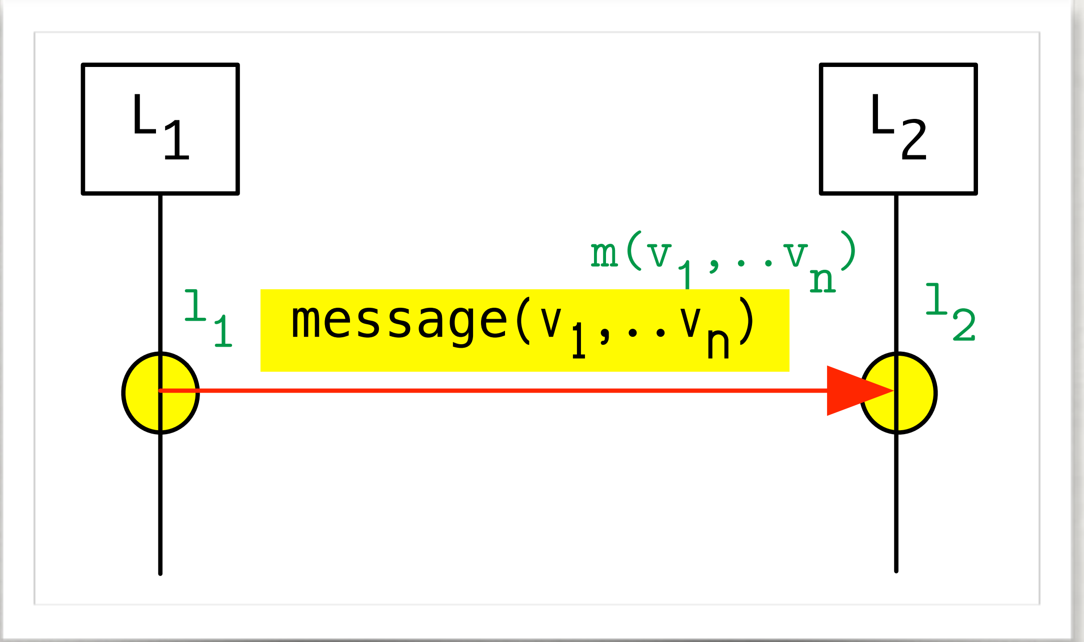


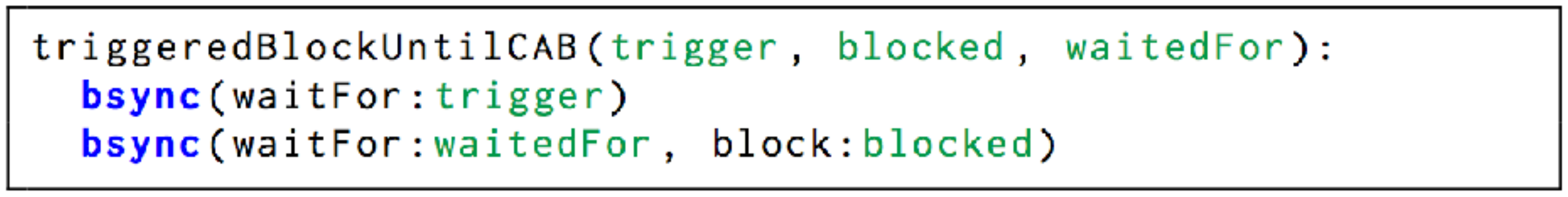


```
ceMessageCAB(m):
  bsync(request:Enabled(m), block:Message(m))
  bsync(request:Message(m))
```

Hot, Executed Message

- Same CABs as Cold, Executed Message
- triggeredBlockUntilCAB(Enabled(**m**), ExitEvents(**m**.parent), Message(**m**))

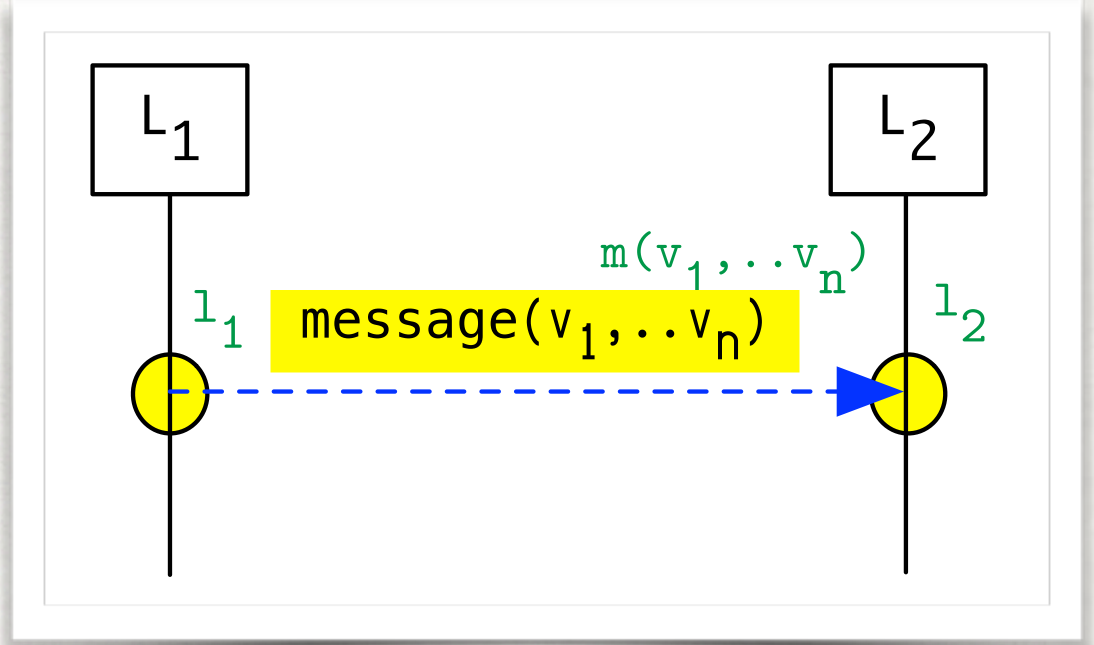


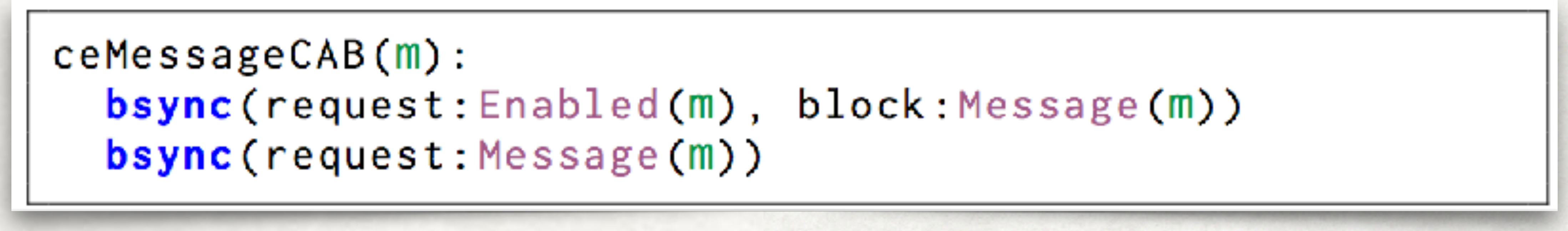


```
triggeredBlockUntilCAB(trigger, blocked, waitedFor):
  bsync(waitFor:trigger)
  bsync(waitFor:waitedFor, block:blocked)
```

Cold, Monitored Message

- `Same CABs as Cold, Executed message`
- `Small change to ceMessageCAB:`

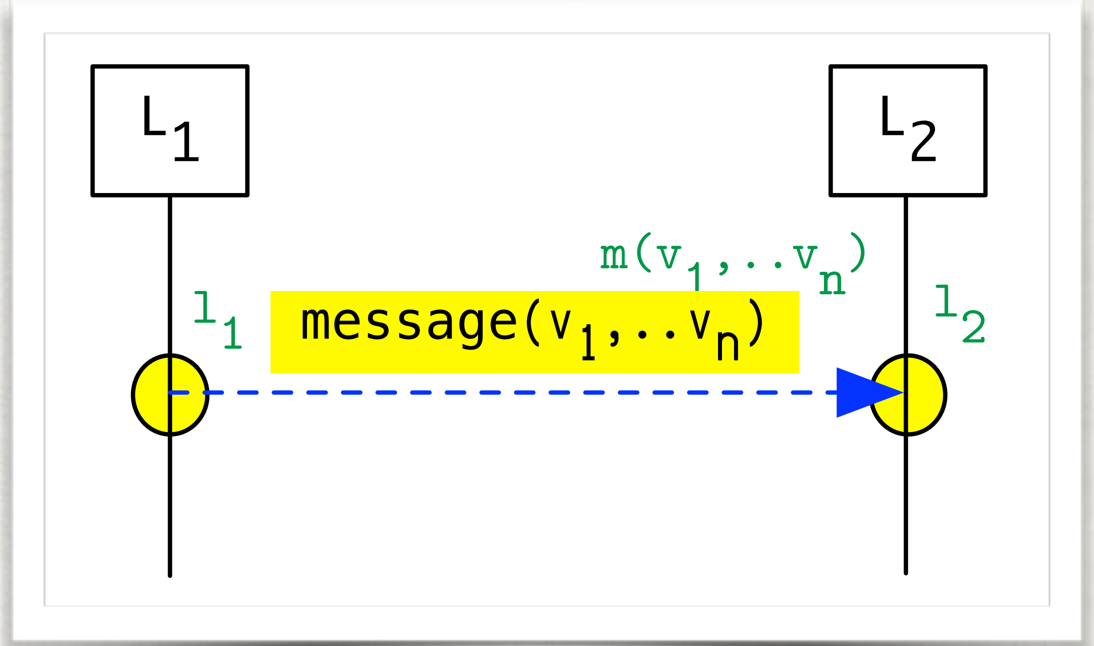


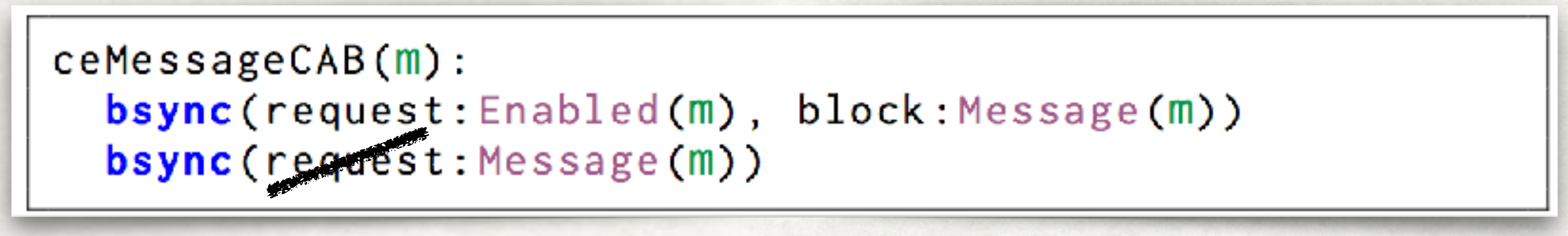


```
ceMessageCAB(m):
  bsync(request:Enabled(m), block:Message(m))
  bsync(request:Message(m))
```

Cold, Monitored Message

- Same CABs as Cold, Executed message
- Small change to ceMessageCAB:



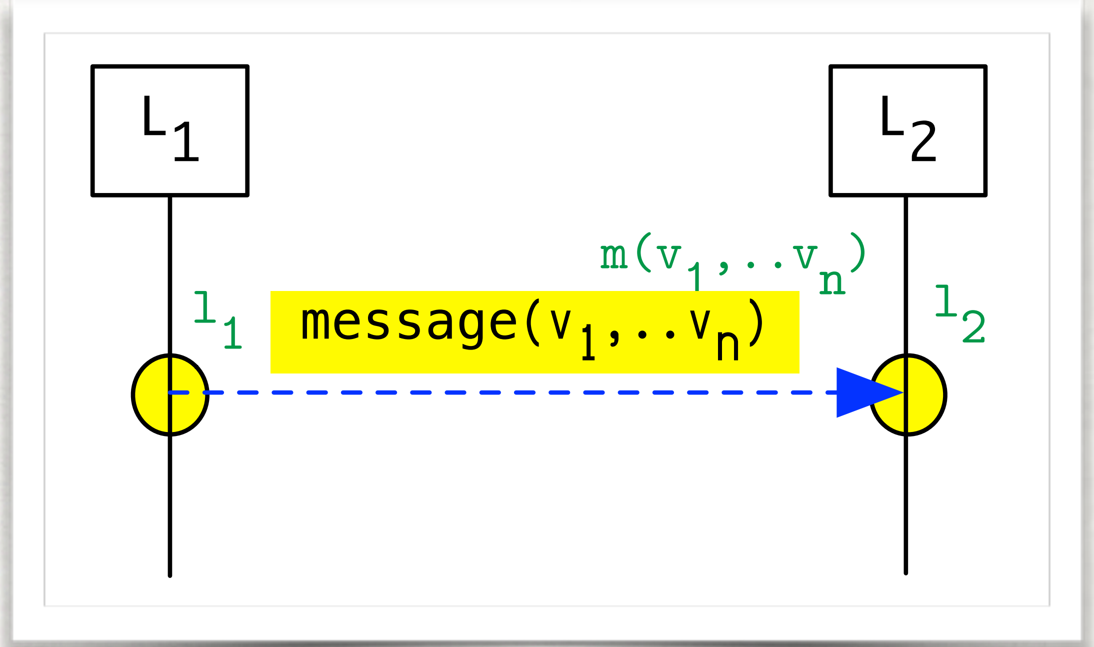


```
ceMessageCAB(m):
  bsync(request:Enabled(m), block:Message(m))
  bsync(request:Message(m))
```

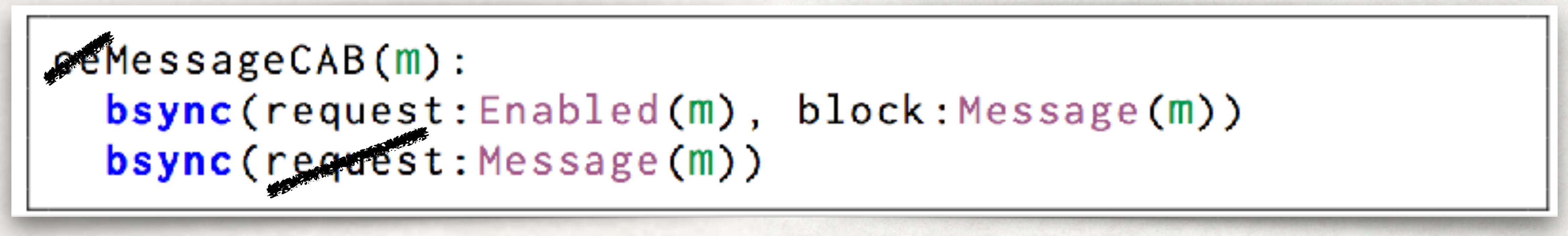
waitFor

Cold, Monitored Message

- Same CABs as Cold, Executed message
- Small change to ceMessageCAB:



cm

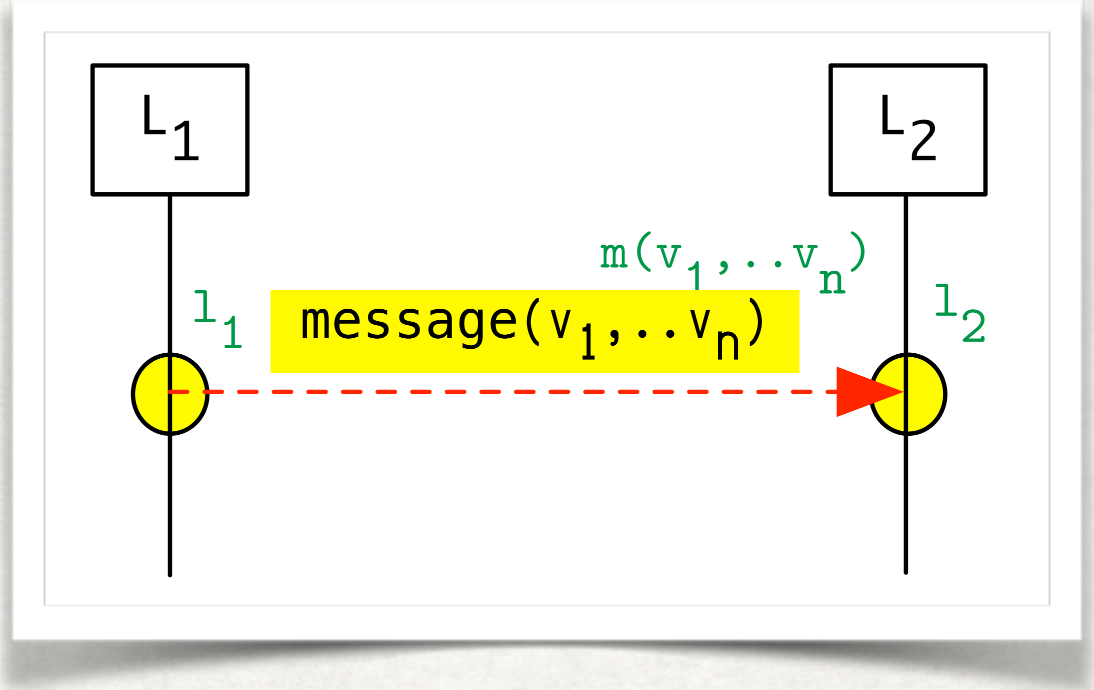


```
~~ce~~MessageCAB(m):
   bsync(request:Enabled(m), block:Message(m))
   bsync(~~request~~:Message(m))
```

waitFor

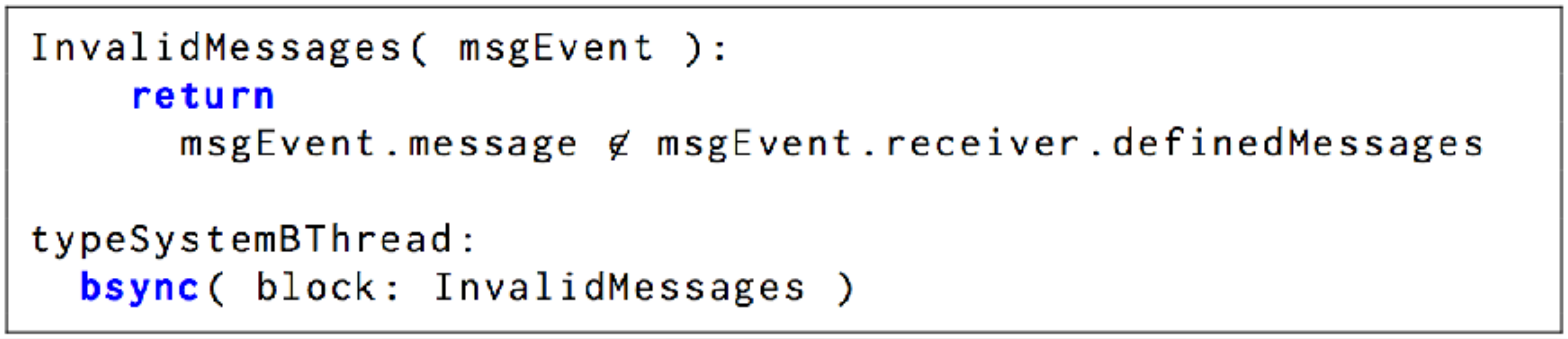
Hot, Monitored Message

- Same CABs as Cold, Monitored Message
- triggeredBlockUntilCab(Enabled(**m**), ExitEvents(**m**.parent), Message(**m**))



System-Wide Alteration: Type Safety

Prevent all messages that are not defined by the receiver from being sent.

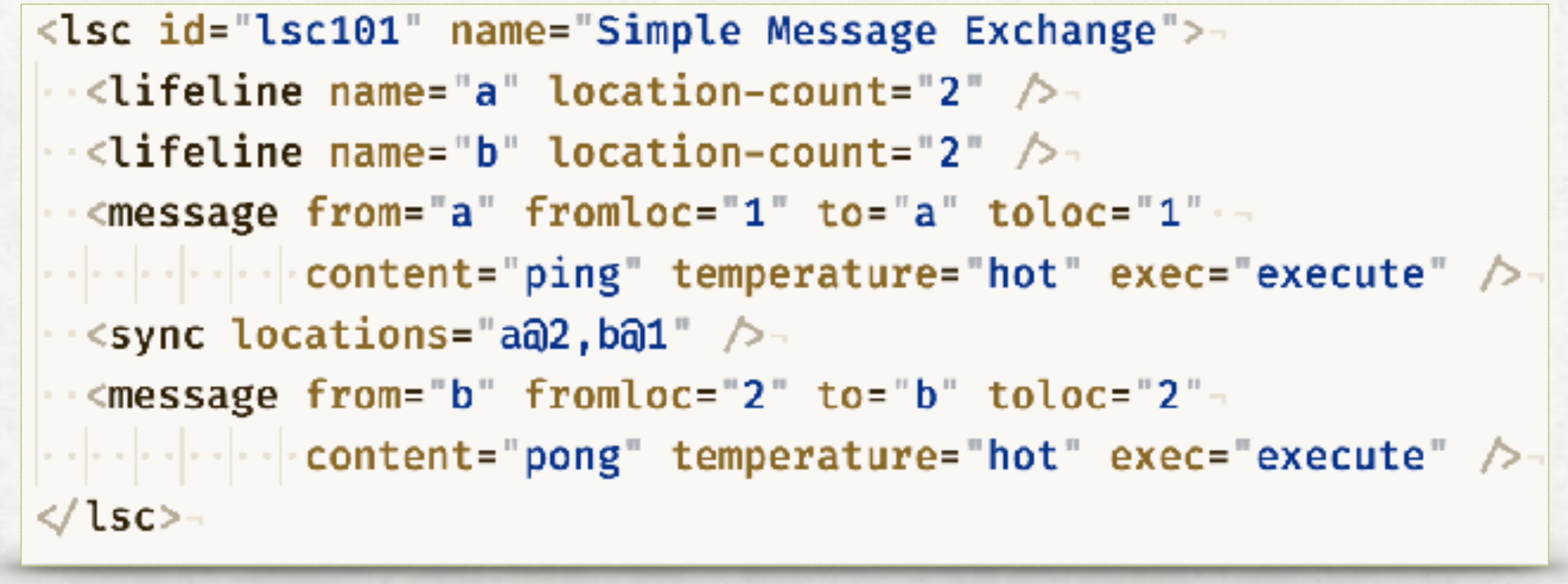


```
InvalidMessages( msgEvent ):
    return
      msgEvent.message ∉ msgEvent.receiver.definedMessages

typeSystemBThread:
  bsync( block: InvalidMessages )
```

Implementation

- LSCs represented in XML
- Queries and mapping done in XQuery
- Target language is Javascript, execution using BPjs
    - BP engine on top of Mozilla Rhino
    - Fork us on GitHub: github.com/michbarsinai/BP-javascript-search

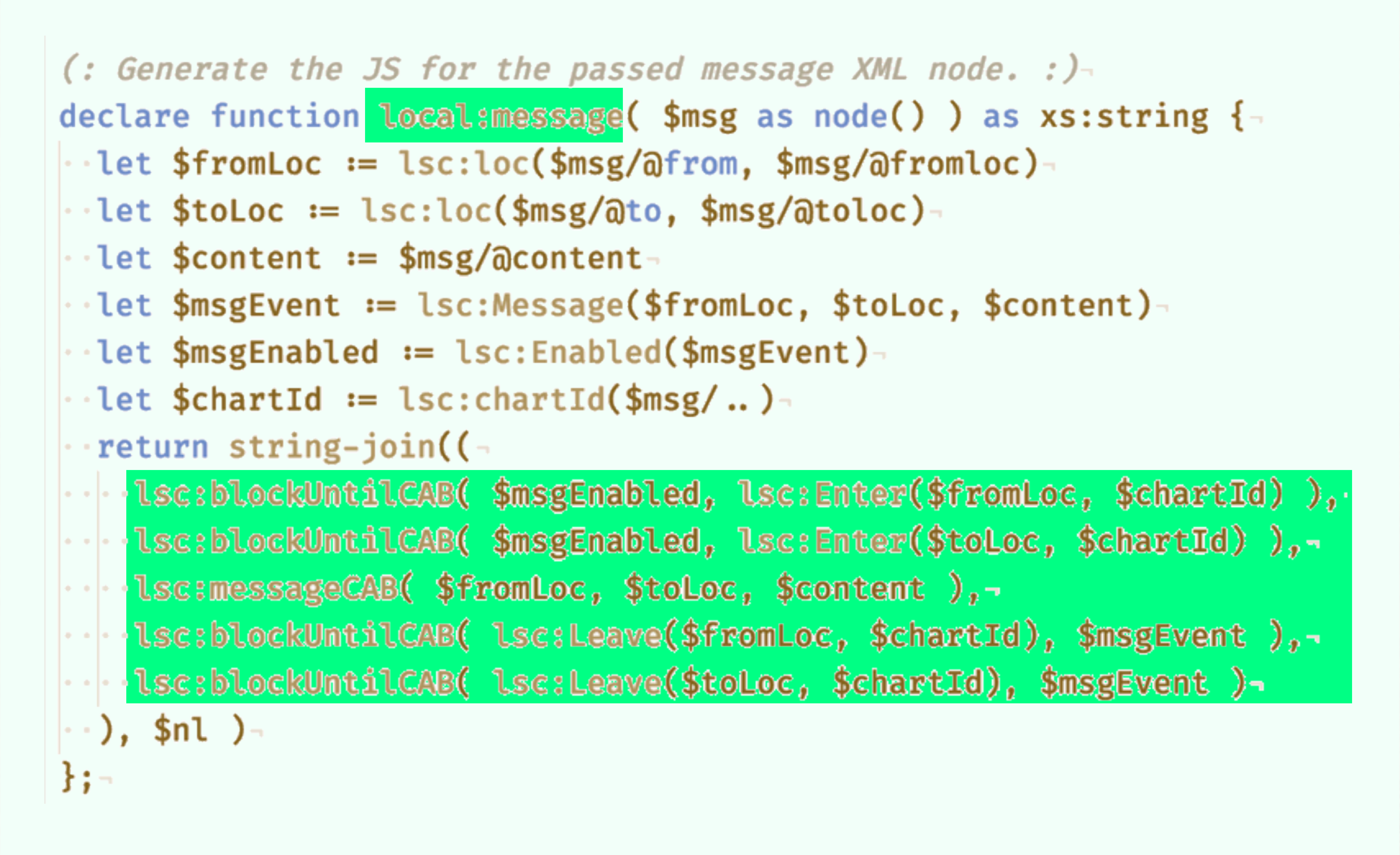


```
<lsc id="lsc101" name="Simple Message Exchange">
  <lifeline name="a" location-count="2" />
  <lifeline name="b" location-count="2" />
  <message from="a" fromloc="1" to="a" toloc="1"
           content="ping" temperature="hot" exec="execute" />
  <sync locations="a@2,b@1" />
  <message from="b" fromloc="2" to="b" toloc="2"
           content="pong" temperature="hot" exec="execute" />
</lsc>
```

Implementation

```
(: Generate the JS for the passed message XML node. :)
declare function local:message( $msg as node() ) as xs:string {
  let $fromLoc := lsc:loc($msg/@from, $msg/@fromloc)
  let $toLoc := lsc:loc($msg/@to, $msg/@toloc)
  let $content := $msg/@content
  let $msgEvent := lsc:Message($fromLoc, $toLoc, $content)
  let $msgEnabled := lsc:Enabled($msgEvent)
  let $chartId := lsc:chartId($msg/..)
  return string-join((
    lsc:blockUntilCAB( $msgEnabled, lsc:Enter($fromLoc, $chartId) ),
    lsc:blockUntilCAB( $msgEnabled, lsc:Enter($toLoc, $chartId) ),
    lsc:messageCAB( $fromLoc, $toLoc, $content ),
    lsc:blockUntilCAB( lsc:Leave($fromLoc, $chartId), $msgEvent ),
    lsc:blockUntilCAB( lsc:Leave($toLoc, $chartId), $msgEvent )
  ), $nl )
};
```

Implementation



```
(: Generate the JS for the passed message XML node. :)
declare function local:message( $msg as node() ) as xs:string {
  let $fromLoc := lsc:loc($msg/@from, $msg/@fromloc)
  let $toLoc := lsc:loc($msg/@to, $msg/@toloc)
  let $content := $msg/@content
  let $msgEvent := lsc:Message($fromLoc, $toLoc, $content)
  let $msgEnabled := lsc:Enabled($msgEvent)
  let $chartId := lsc:chartId($msg/..)
  return string-join((
      lsc:blockUntilCAB( $msgEnabled, lsc:Enter($fromLoc, $chartId) ),
      lsc:blockUntilCAB( $msgEnabled, lsc:Enter($toLoc, $chartId) ),
      lsc:messageCAB( $fromLoc, $toLoc, $content ),
      lsc:blockUntilCAB( lsc:Leave($fromLoc, $chartId), $msgEvent ),
      lsc:blockUntilCAB( lsc:Leave($toLoc, $chartId), $msgEvent )
  ), $nl )
};
```

Related Work

- Semantic Mapping: Done before. E.g:
  - **AToM3** [deLara, Vangheluwe, 2002]
  - **UML, fUML** [OMG]
  - Both use metamodels
- **“Coping with Semantic Variation Points in Domain-Specific Modeling Languages”** Latombe, Crégut, Deantoni, Pantel, B. Combemale *(EXE’15)*
  - Two-tier structure, top tier lists available options, lower tier selects options based on semantic variant

Thanks.

Questions?

Defining Semantic Variations of Diagrammatic Languages using Behavioral Programming and Queries