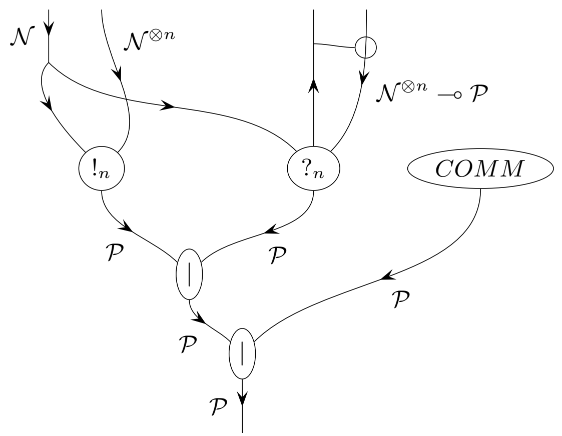
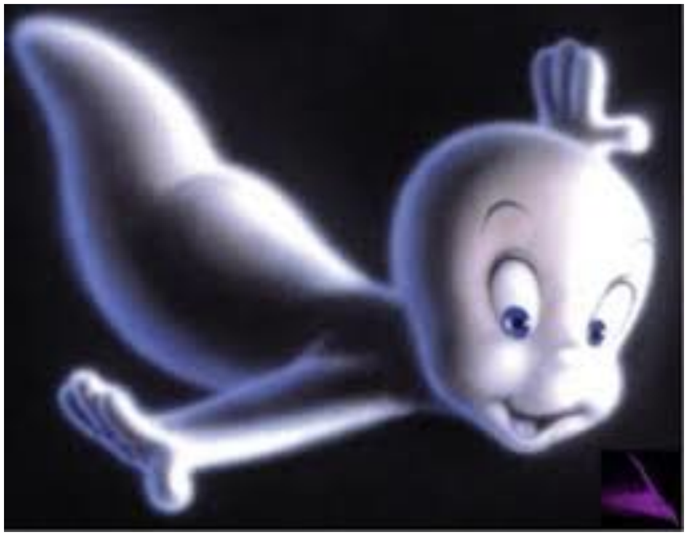
Casper Formalized Pt I

Applying π-calculus

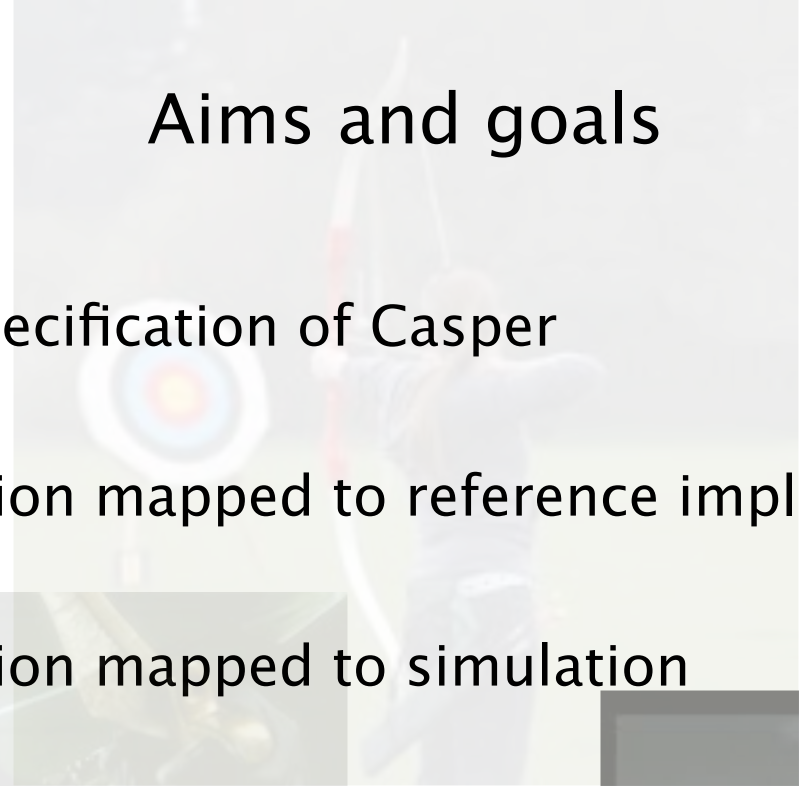
to modeling the Casper protocol





Vlad Zamfir, L.G. Meredith

Aims and goals

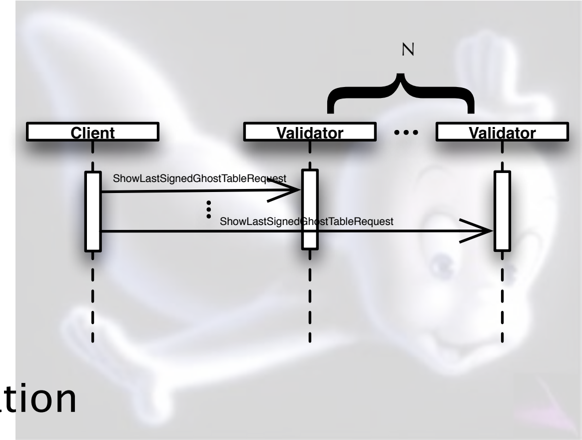


Formal specification of Casper

Specification mapped to reference implementation

Specification mapped to simulation

Methodology



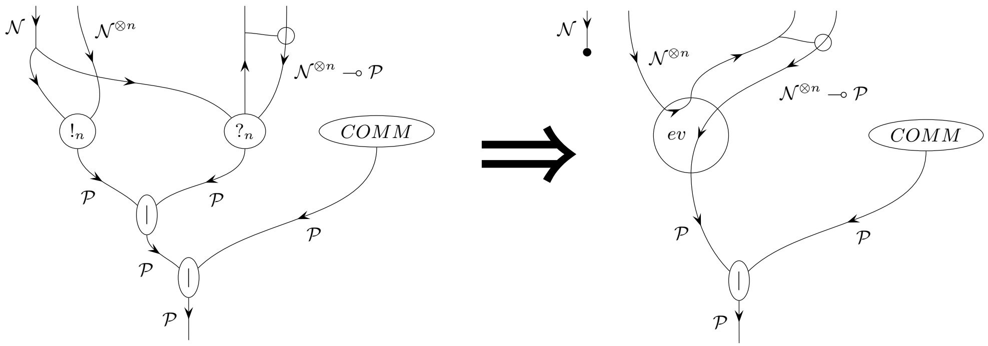
Bootstrap Casper spec using interaction diagrams

Map interaction diagrams to initial π-calculus specification

Refine specification

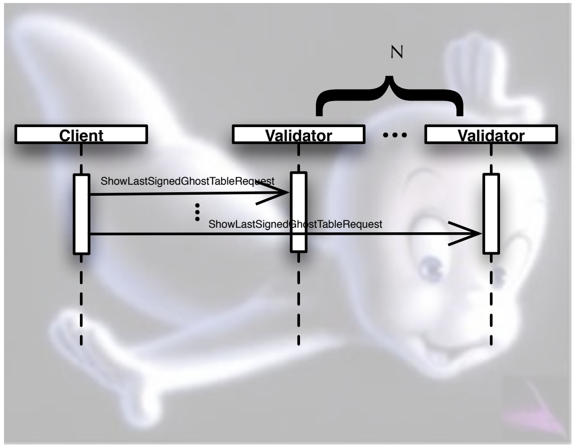
Map refined specification to SpecialK

Map refined specification to Stochastic π-machine

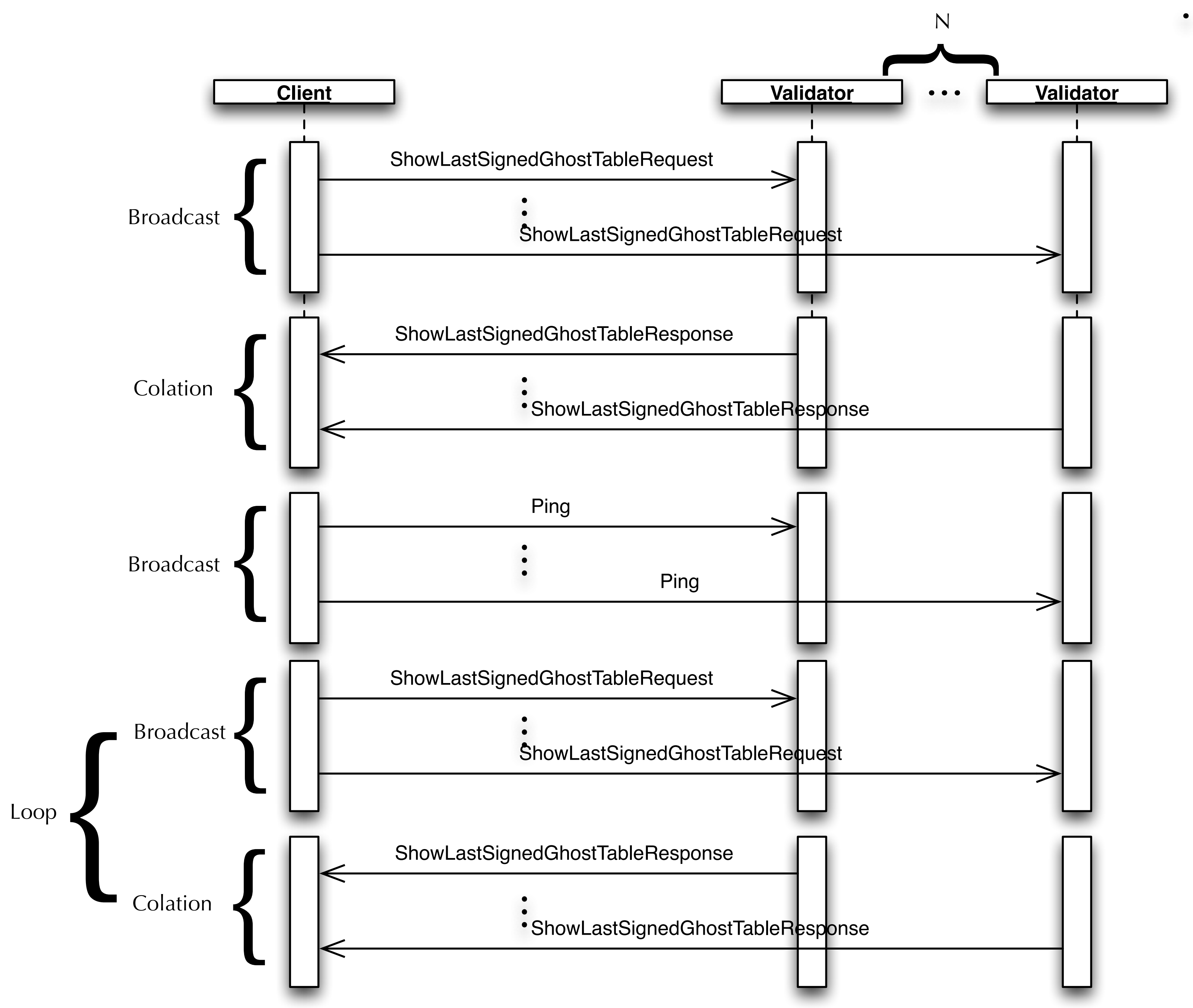


Casper in π-calculus

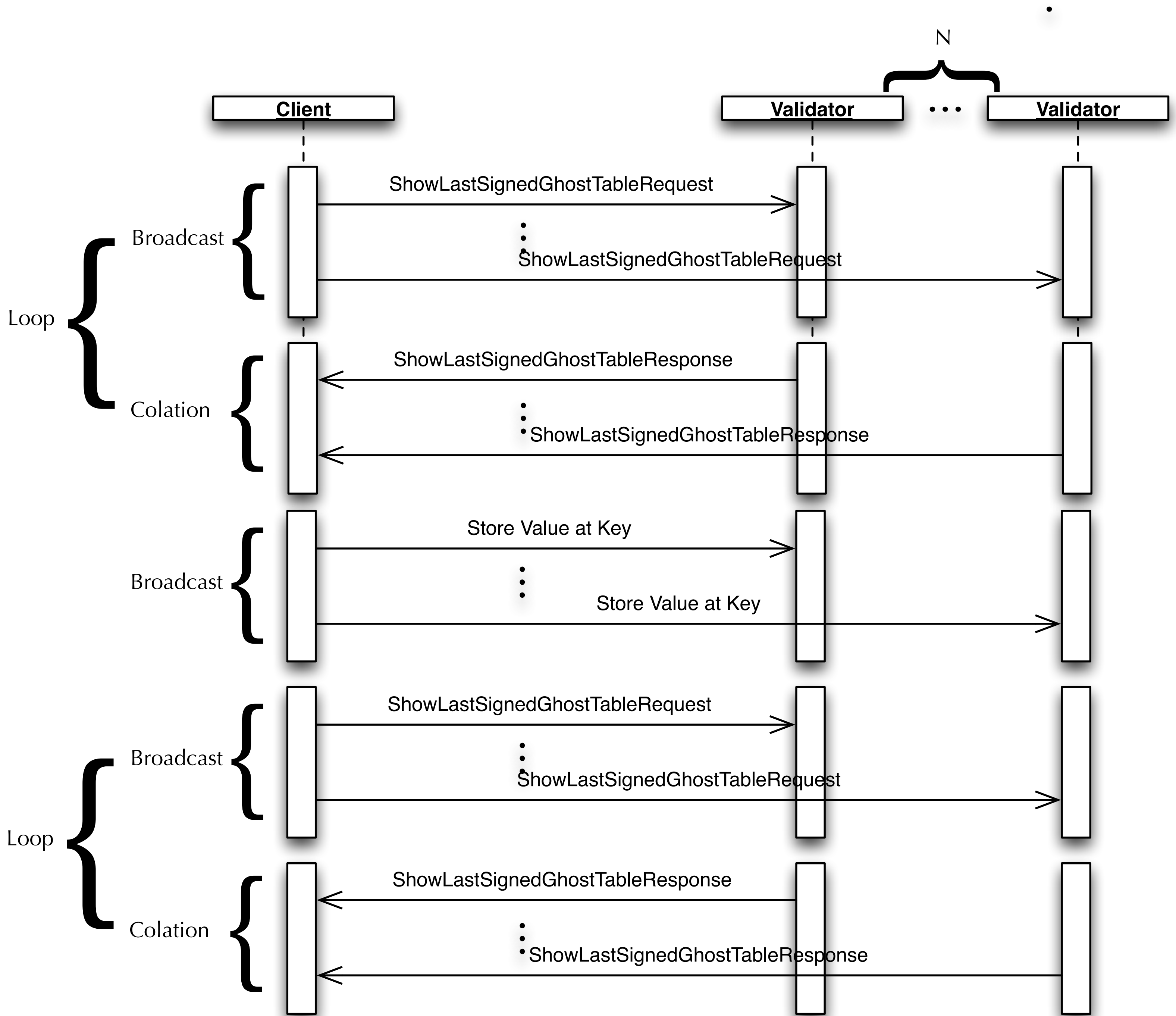
Casper in interaction diagrams



Client <-> Validator interactions

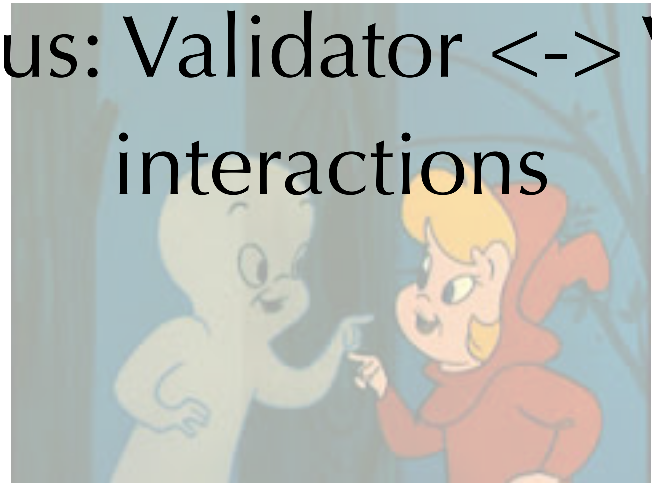


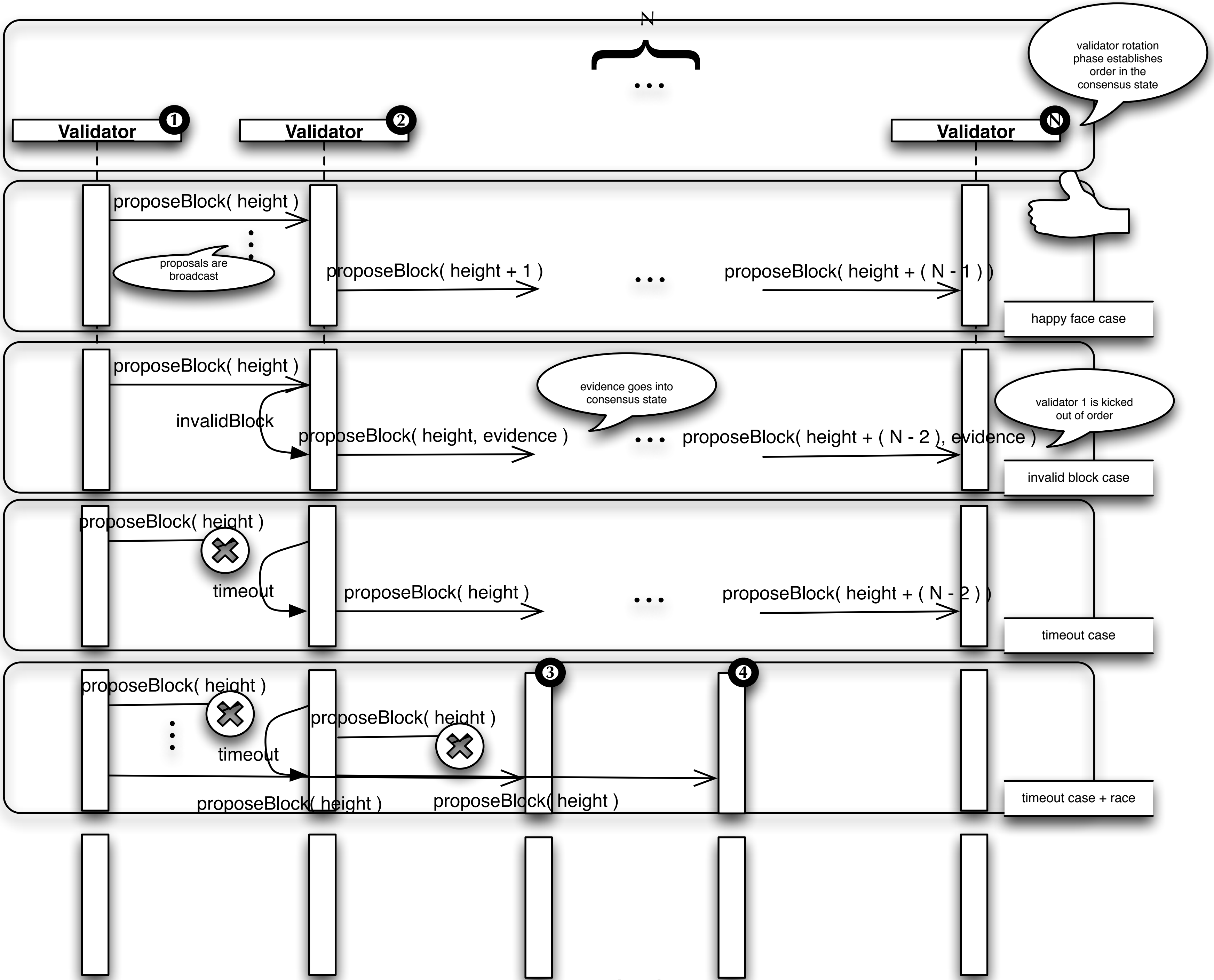
Casper in π-calculus



Casper in π-calculus

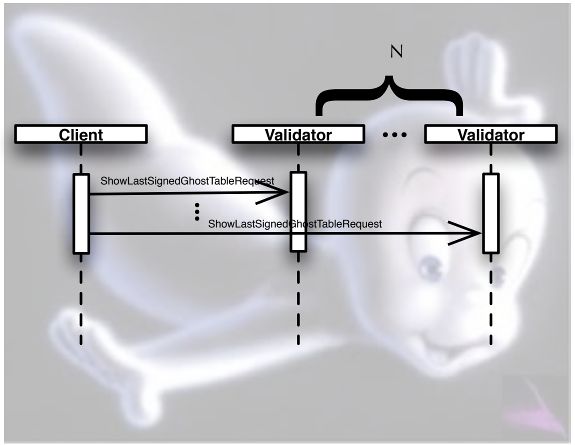
Consensus: Validator <-> Validator interactions



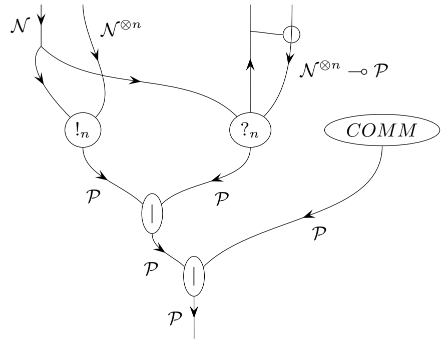


Casper in π–calculus

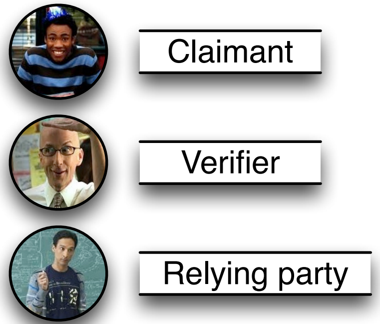
How to turn interaction diagrams into π-calculus specs

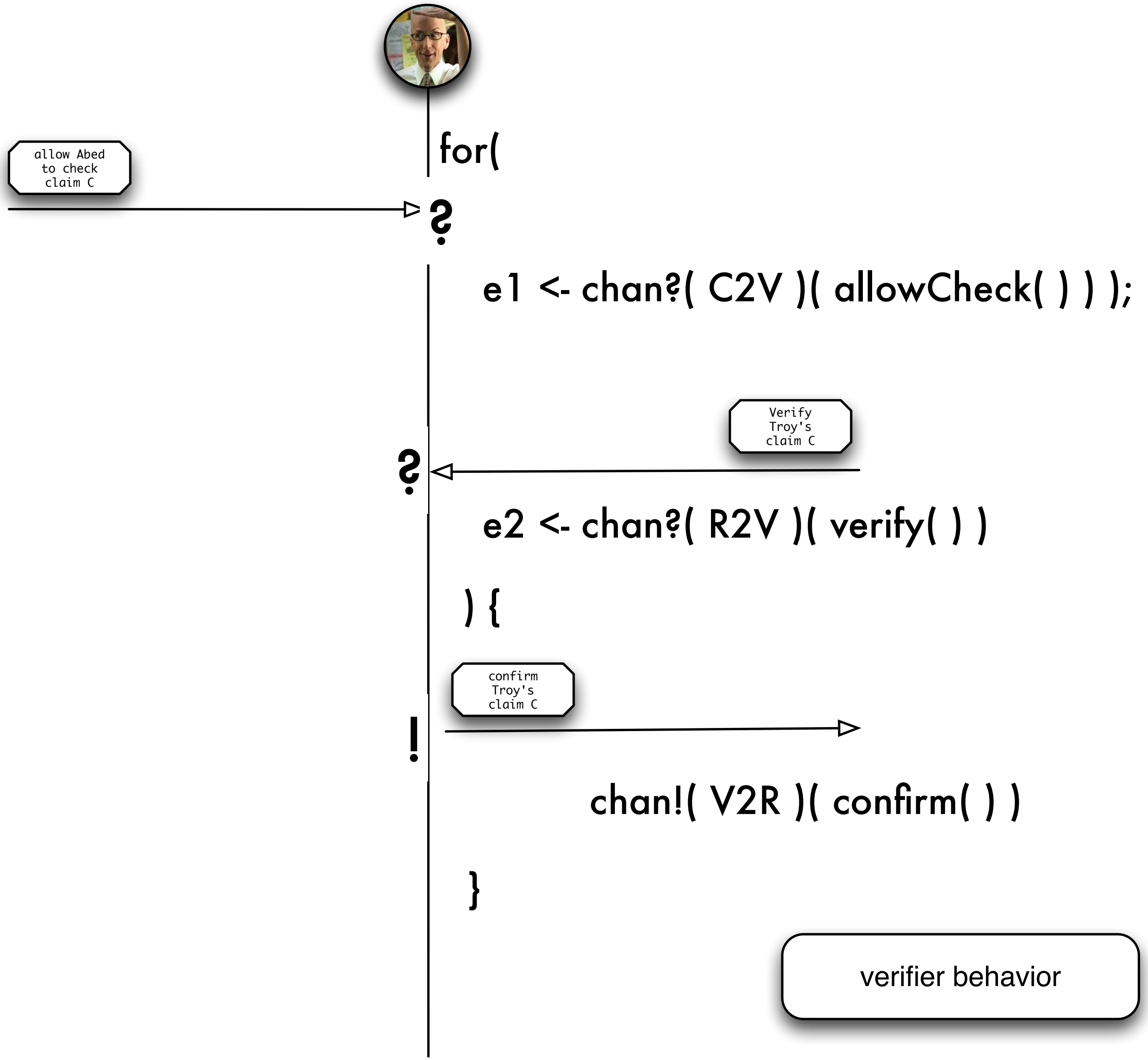


$\Rightarrow$



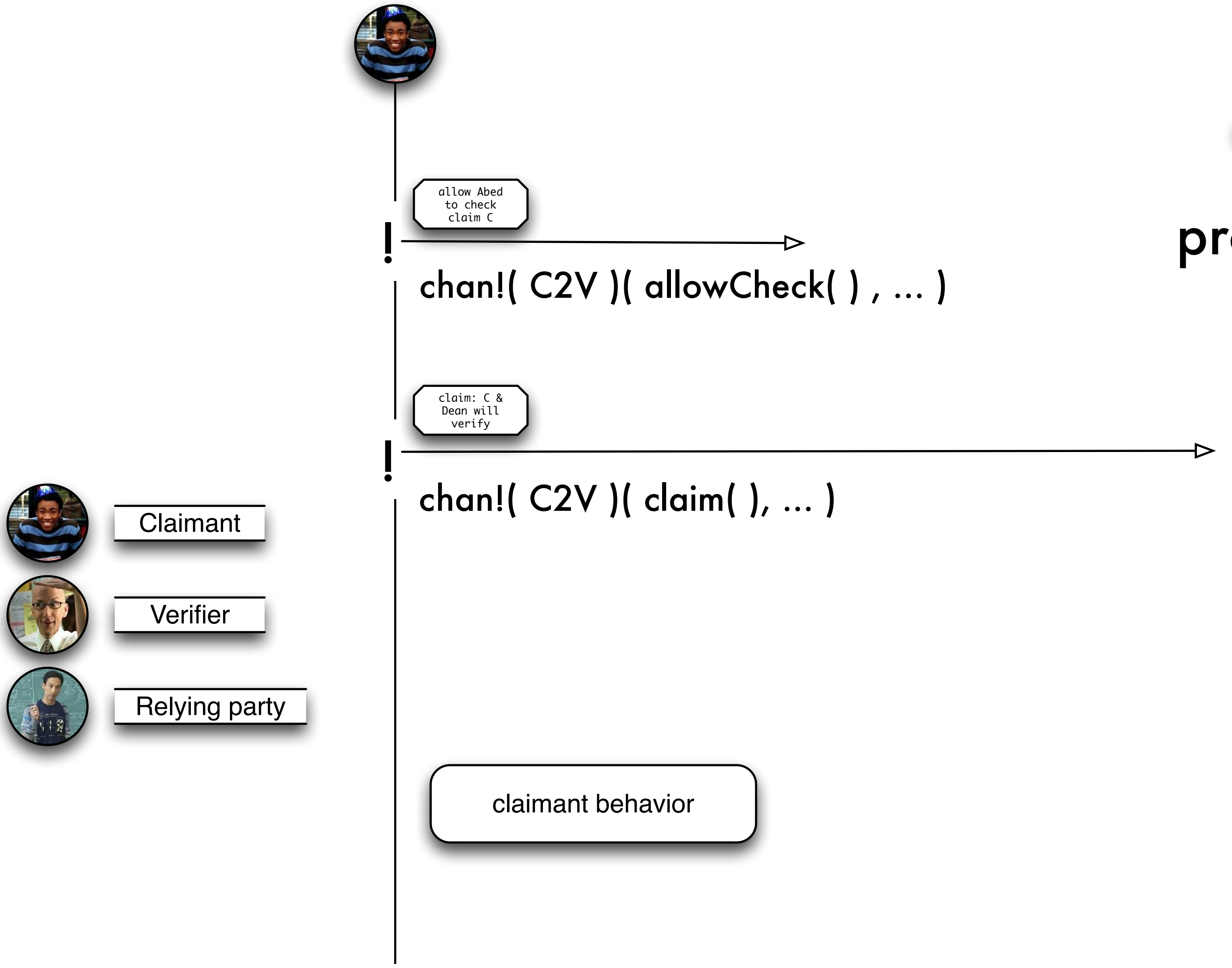
programming model






```
for(
  e1 <- chan?( C2V )( allowCheck( ) ) );
  e2 <- chan?( R2V )( verify( ) )
) {
    chan!( V2R )( confirm( ) )
}
```

Just walk this line to calculate the specification of the verifier's behavior and derive code

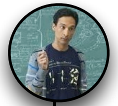


programming model

and this line to calculate the specification of the claimant's behavior and derive code

Casper in π-calculus

programming model



```
for(
    e1 <- chan?( C2R )( claim( ) ) )
) {
    chan!( C2R )( verify( ), ... )
    for(
        e1 <- chan?( C2R )( trudat( ) ) )
    ) {
        ...
    }
}
```

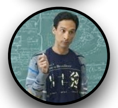
claim: C & Dean will verify

Verify Troy's claim C

confirm Troy's claim C

 Claimant

 Verifier

 Relying party

relying party behavior

and this line to calculate the specification of the relying party's behavior and derive code

How to turn π-calculus specs into scala code

P,Q ::= 0

```
{ }
```

a![v1, …, vn]

```
[| a |]( m ) ![ [| v1 |]( m ), …, [| vn |]( m ) ]
```

a?(x1, …, xn)P

```
for( [ x1, …, xn ] <- [| a |]( m ) ){
    [| P |]( m )( x1, …, xn )
}
```

P | Q

```
spawn{ [| P |]( m ) };spawn{ [| Q |]( m ) }
```

(new a)P

```
{ val q = new Queue(); [| P |]( m[ a <- q ] ) }
```

(def X(x1, …, xn) = P)[v1, …, vn]

```
object X {
   def apply( x1, …, xn ) = {
      [| P |]( m ) ( x1, …, xn )
   }
}
```

X[v1, …, vn]

```
X( [| v1 |]( m ), …, [| vn |]( m ) )
```

```
[| - |]( - ) : ( π-calculus, Map[Symbol,Queue] ) -> Scala
```

Casper in π-calculus

applied π-calculus

Syntax

P,Q ::= 0

a![t]Q

a?(t)P

P | Q

(new a)P

(def X(t) = P)[u]

X[t]

t,u ::= val | var | fn(t1, ..., tN)

val ::= bool | int | string | double | ...

var ::= _ | X | Y | Z | ...

fn ::= x | y | z | ...

Structural congruence

The *structural congruence* of processes, noted $\equiv$, is the least congruence containing α-equivalence, $\equiv_\alpha$, making $(P, |, 0)$ into commutative monoids and satisfying

$$(\mathsf{new}\ x)(\mathsf{new}\ x)P \equiv (\mathsf{new}\ x)P$$

$$(\mathsf{new}\ x)(\mathsf{new}\ y)P \equiv (\mathsf{new}\ y)(\mathsf{new}\ x)P$$

$$((\mathsf{new}\ x)P) \mid Q \equiv (\mathsf{new}\ x)(P \mid Q)$$

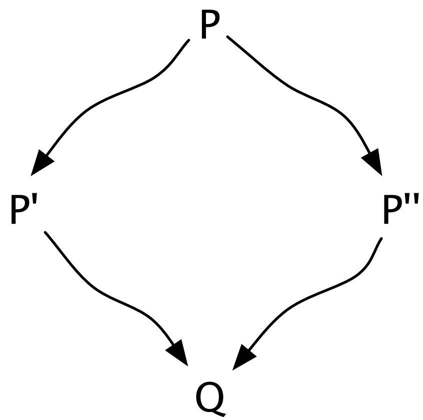
$$\frac{\text{unify}(t, u, s)}{a?(t)P \mid a![u]Q \to Ps \mid Qs}$$

$$\frac{P \to P'}{P \mid Q \to P' \mid Q}$$

$$\frac{P \to P'}{(\text{new } a)P \to (\text{new } a)P'}$$

$$\frac{P \equiv P' \quad P' \to Q' \quad Q' \equiv Q}{P \to Q}$$

Casper in π-calculus



Confluence

lambda calculus is confluent

π–calculus is **not** confluent

a![u1]Q1 | a?(t)P | a![u2]Q2

typical race condition

Casper in π–calculus