Safe Functional Mobile Code – CPPCC: Certified Proved-Property-Carrying Code

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Overview

- Mobile expressions (functional code) in Clean - dynamics
- Proving properties of functional programs - dedicated theorem prover: Sparkle
- Property carrying code architecture, type and semantical checks

Clean dynamics

- static type system extended with type `Dynamic`

- conversion to type `Dynamic` by function `dynamic`, example: `dynamic 3::Int`

- conversion from `Dynamic` to static type using pattern match, example: `unpackInt :: Dynamic -> Int;`
  `unpackInt (n::Int) = n; unpackInt _ = abort "not an integer"`

- mobile code, persistent data: SendDynamic, ReceiveDynamic, ReadDynamic, WriteDynamic

```
module f
import StdDynamic, StdEnv
:: Tree b = Node b (Tree b) (Tree b) | Leaf
Start world
 #! (ok,world) = writeDynamic (p +++ "function")
                    DynamicDefaultOptions dt world
 | not ok = abort "could not write dynamic"
 = (dt,world)
 where
  dt = dynamic count_leafs
  p  = "C:\\hz\\Clean 2.0\\Examples\\Dynamic\\"
count_leafs :: (Tree Int) -> Real
count_leafs tree = toReal (count tree 0)
 where  count :: (Tree Int) Int -> Int
  count Leaf                 n_leafs = inc n_leafs
  count (Node _ left right) n_leafs =
                 count left (count right n_leafs)
```

```
module v
import StdDynamic, StdEnv
:: Tree a = Node a (Tree a) (Tree a) | Leaf
Start world
 #! (ok,world)= writeDynamic (p +++ "value")
                    DynamicDefaultOptions dt world
 | not ok = abort "could not write dynamic"
 = (dt,world)
   where dt = dynamic (Node 99 tree2 tree2)
    tree2 = (Node 2 (Node 1 Leaf Leaf) Leaf)
    p  = "C:\\hz\\Clean 2.0\\Examples\\Dynamic\\"
```

```
module apply
import  StdDynamic, StdEnv
:: Tree a = Node a (Tree a) (Tree a)  |  Leaf
Start world
 # (ok,f,world)  = readDynamic (p +++ "function") world
 | not ok               = abort " could not read"
 # (ok,v,world) = readDynamic (p +++ "value") world
 | not ok               = abort " could not read"
 # result = apply f v;
 = (result, world);
where
 apply (f :: (Tree Int) -> Real) (v :: (Tree Int)) =  f v
 apply _ _                                         = abort "unmatched"
 p     = "C:\\hz\\Clean 2.0\\Examples\\Dynamic\\"
```

Verification of functional programs

- dedicated theorem prover of Clean : Sparkle - part of IDE
- referential trancparency, equational reasoning possible
- example: $\forall n \in Int, \forall \alpha, \forall xs \in [\alpha]$:
  $n \neq undef \rightarrow$ `take` $n\ xs ++$ `drop` $n\ xs = xs$

```
take :: Int ![a] -> [a]
tane n [x:xs]                             drop n [x:xs]
  | n > 0  = [x: take (n-1) xs]           | n>0       = drop (n-1) xs
  | otherwise = []                        | otherwise = [x:xs]
take n []  = []                           drop n []   = []
```

- Proof: using 8 tactics of 42: structural induction on xs, introduce (deduction rule for implication), reduce (substitution of definition), reflexivity, split cases, definedness (contradiction with definedness), rewrite goal (using hypothesis), contradiction

Property carrying code architecture

Requirements: mobile code does not use to much resources, read or modify data unauthorised, etc. Does do its task.

- Full dynamic-time code verification just before the application of the code
  (static, structural and type correctness verification: well-formedness, data-flow analysys for illegal memory access, type of instruction arguments, etc.) ,
- trusting the code producer unconditionally (with using a certificate mechanism, to check identity),
- trusting code integrity and performing run time pattern match for types.
- A hybrid model of safe mobile code exchange: Certified Proven Property Carrying Code. Minimal run-time overhead but proved correct code.

Further semantic requirements, examples

Insertion into a sorted list (safety-critical, time-critical):

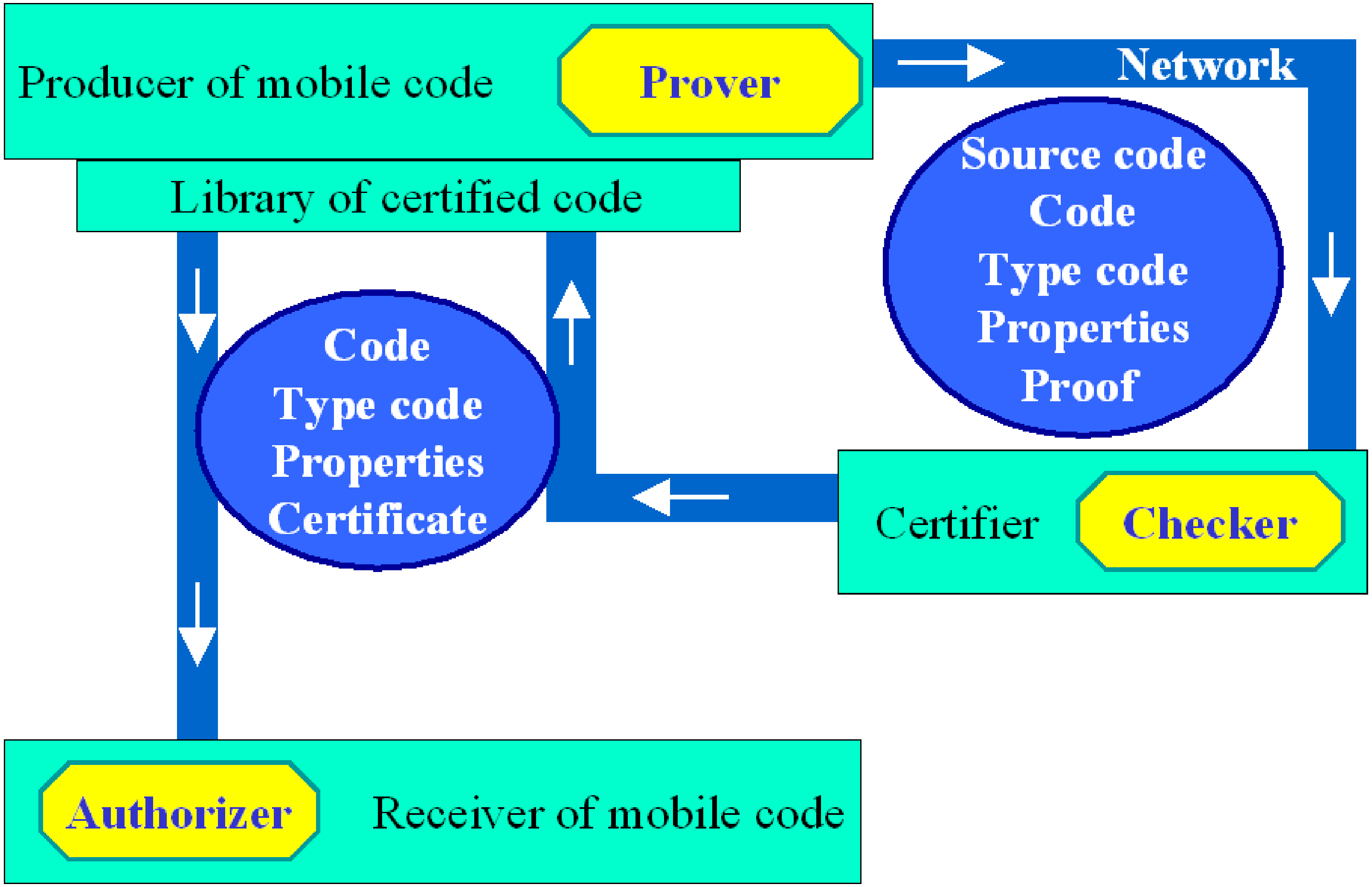
- the result of the operation is such that every element of the list is either the first element or an element that is greater than or equal to the previous element,
- termination
- upper bound for memory usage
- upper bound for execution time

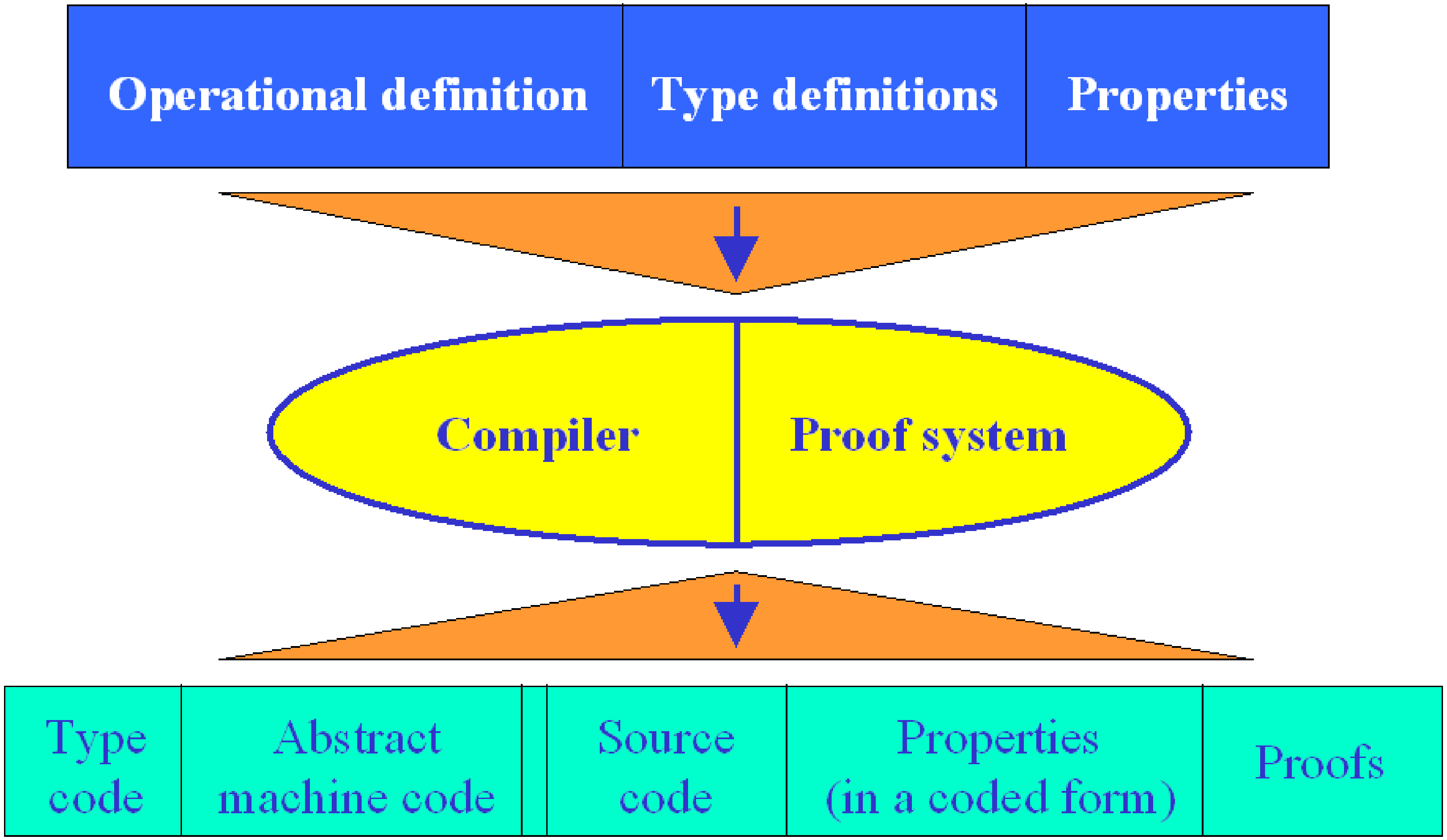
The Certified Proved-Property-Carrying Code architecture (CPPCC) Three main parties involved in the scenario:

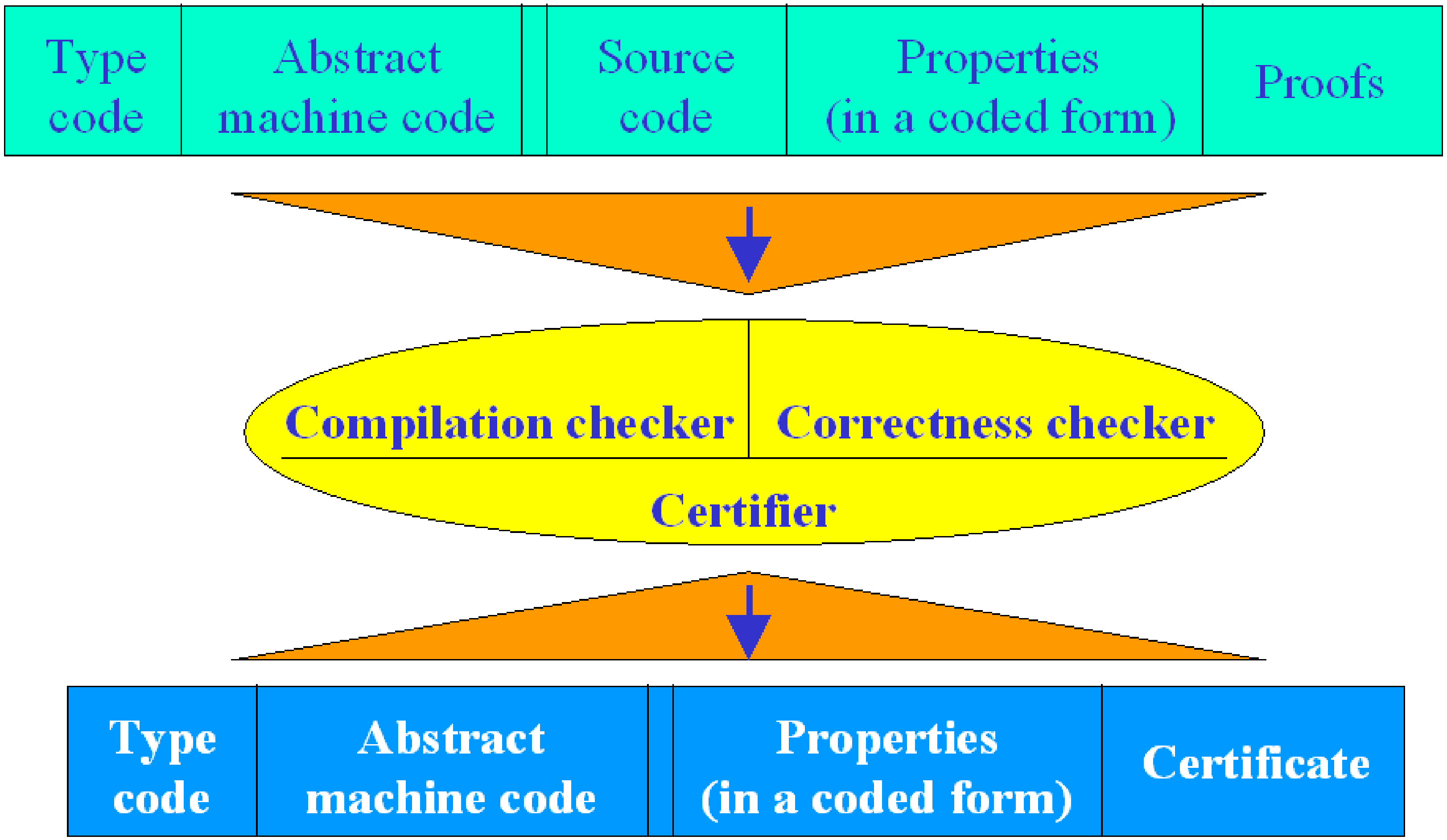
1. producer of the mobile code, adds proofs of properties

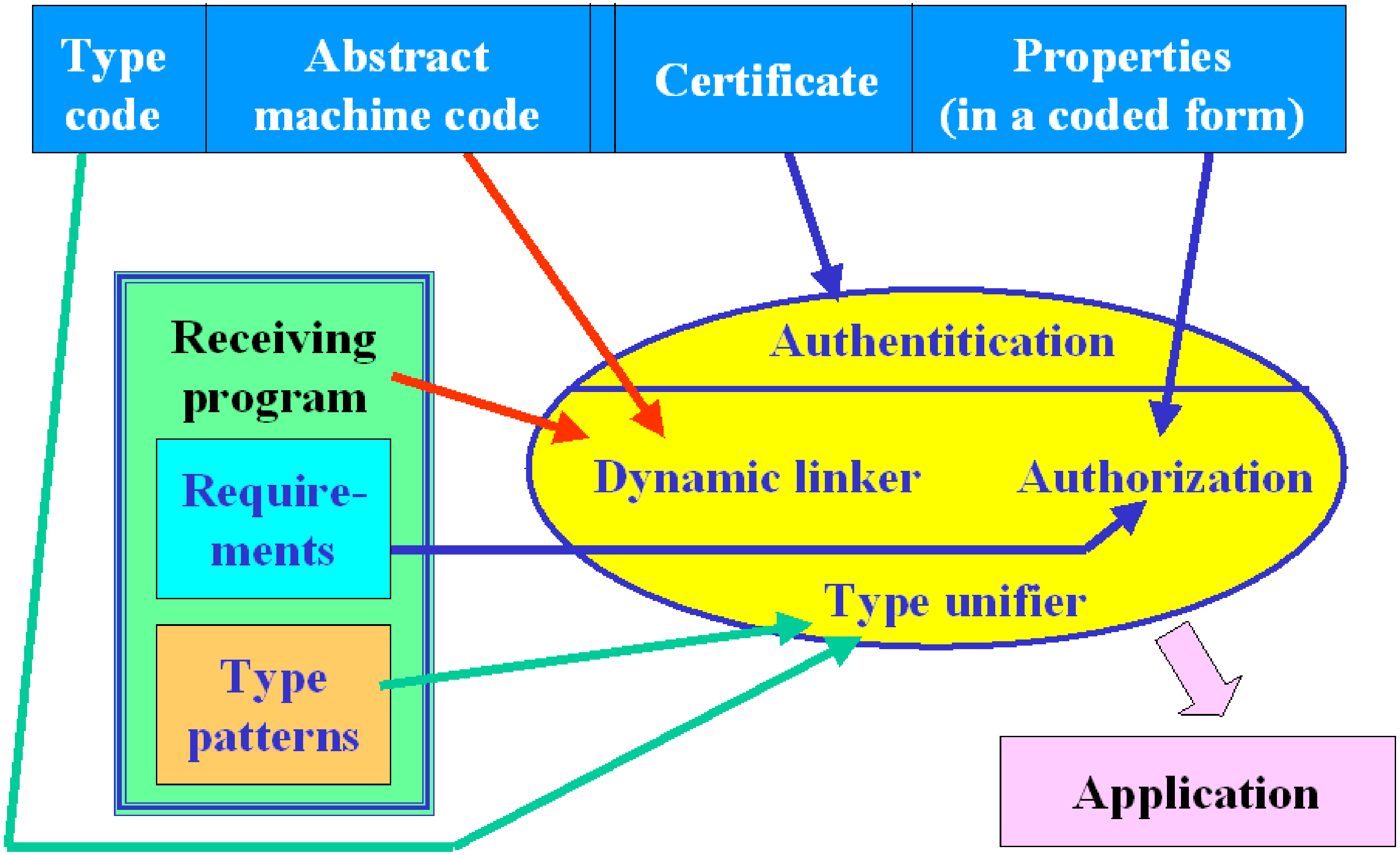
2. receiver, executes code only after safety checks which ensure that the code satisfies the requirements specified in the receiver's code,

3. certifying authority, reduce the work-load of the receiver, does static-time.


Producer of mobile code
Prover
Network
Library of certified code
Source code
Code
Type code
Properties
Proof
Code
Type code
Properties
Certificate
Certifier
Checker
Authorizer
Receiver of mobile code


Operational definition
Type definitions
Properties
Compiler
Proof system
Type code
Abstract machine code
Source code
Properties (in a coded form)
Proofs


Type code
Abstract machine code
Source code
Properties (in a coded form)
Proofs
Compilation checker
Correctness checker
Certifier
Type code
Abstract machine code
Properties (in a coded form)
Certificate



Type code
Abstract machine code
Certificate
Properties (in a coded form)
Receiving program
Require-ments
Type patterns
Authentitication
Dynamic linker
Authorization
Type unifier
Application