Data Types and Behavioral Types

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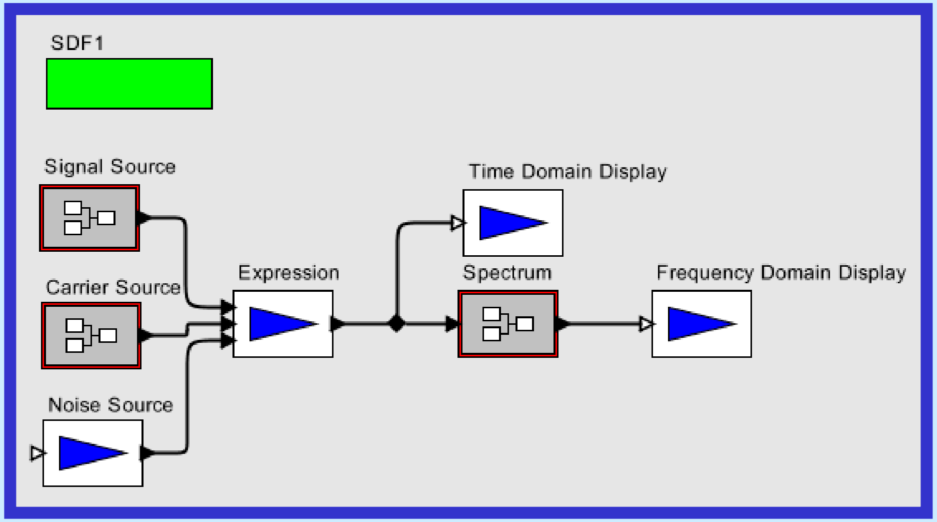
Component Interfacing

- Two levels of interface:
  - data types and
  - dynamic interaction: communication & execution
- Dynamic behavior defined by models of computation (MoC)

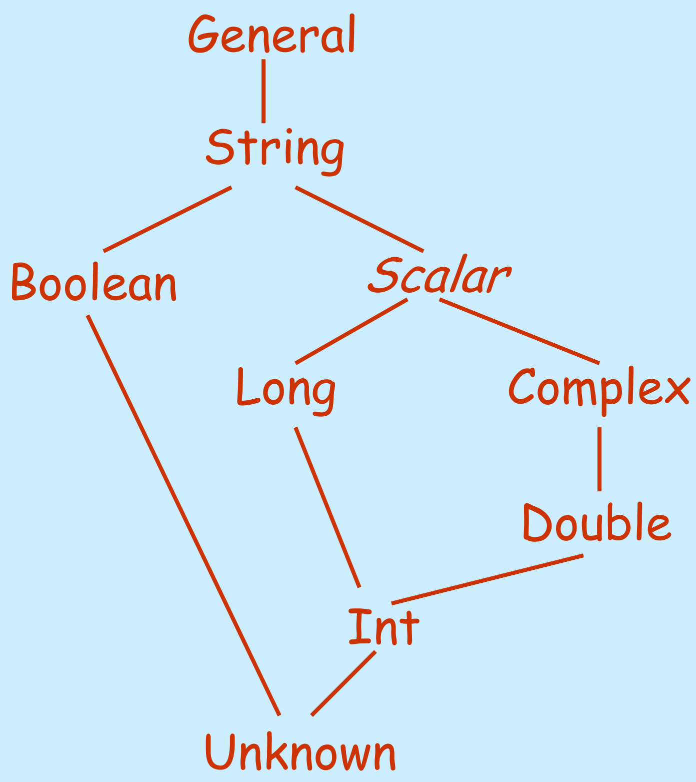


Capturing Dynamic Behavior

- Dynamic behavior in each MoC can be described formally, using type systems
- Success of type systems:
  - Safety through type checking
  - Polymorphism supports reuse (flexible components)
  - Type conversion
  - Program optimization
  - Interface documentation, clarification
  - Run-time reflection of component interfaces

Data Types in Ptolemy II

- Lattice-based infrastructure
- Support polymorphism, type conversion, and structured types

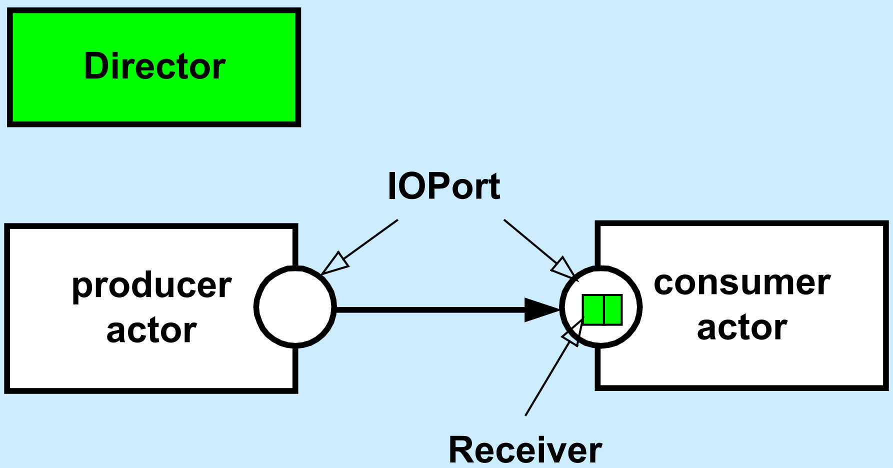


Behavioral Type

- Data types only specify static aspects of interface
- Proposal:
  - Capture the dynamic interaction of components in types
  - Obtain benefits analogous to data typing
  - Call the result *behavioral types*

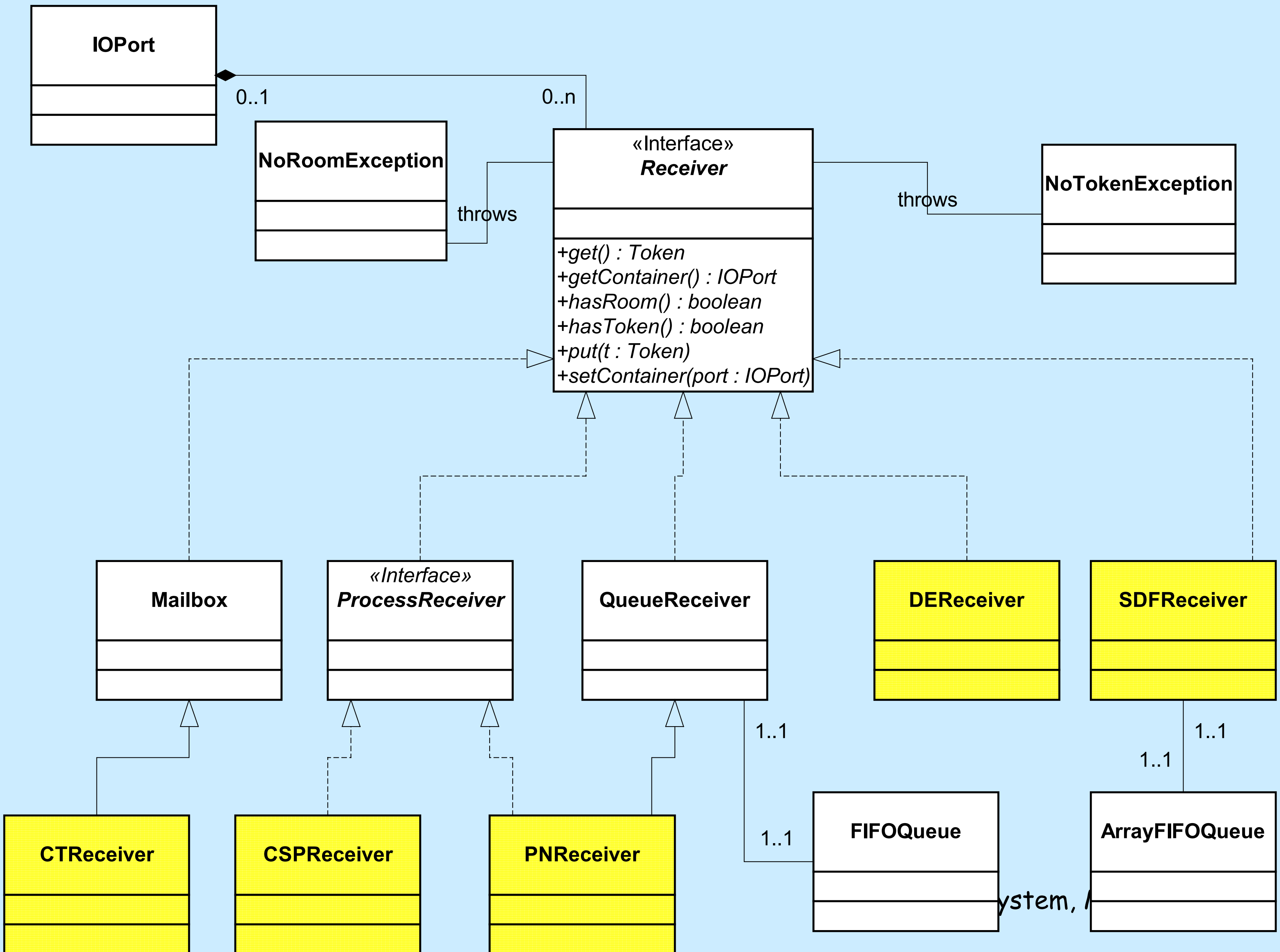
Interaction Semantics

- Flow of control issues
  - in Ptolemy II, these are defined by a *Director* class
- Communication between components
  - in Ptolemy II, this is defined by a *Receiver* class



Actor interface for execution: fire
Receiver interface for communication: put, get, hasToken

Receiver Object Model



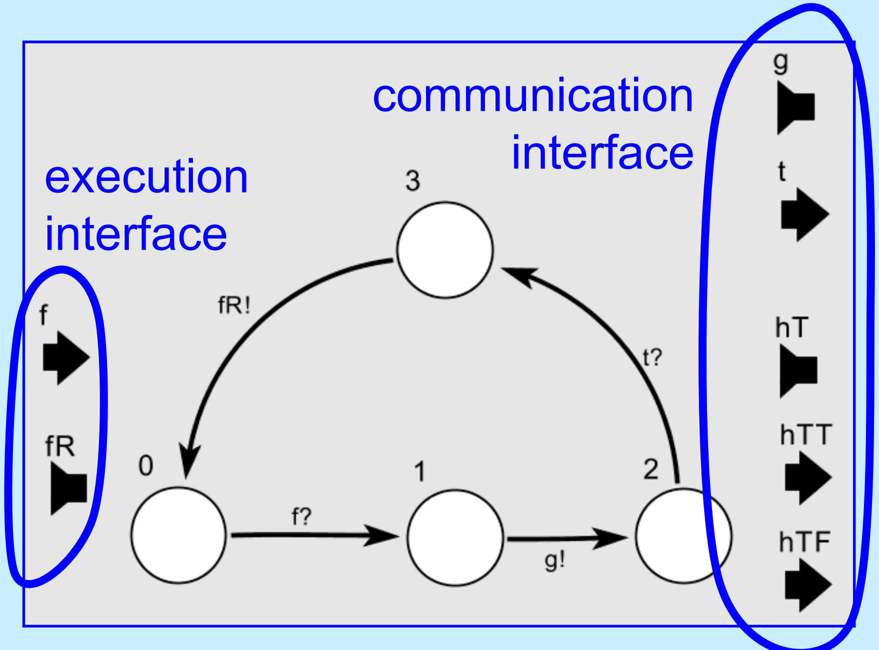
Models of Computation

- Define the interaction semantics
- Implemented in Ptolemy II by a *domain*
  - Receiver + Director
- Examples:
  - Communicating Sequential Processes (CSP): rendezvous-style communication
  - Process Networks (PN): asynchronous communication
  - Synchronous Data Flow (SDF): stream-based communication, statically scheduled
  - Discrete Event (DE): event-based communication
  - Synchronous/Reactive (SR): synchronous, fixed point semantics

Formal Interaction Semantics: Use *Interface Automata*

- Based on interface automata
  - Proposed by de Alfaro and Henzinger
  - Concise composition (vs. standard automata)
  - *Alternating simulation* provides contravariance
- Compatibility checking
  - Done by automata composition
  - Captures the notion "components can work together"
- Alternating simulation (from Q to P)
  - All input steps of P can be simulated by Q, and
  - All output steps of Q can be simulated by P.
  - Provides the ordering we need for subtyping & polymorphism
- Key theorem about compatibility and alternating simulation

Example: Synchronous Dataflow (SDF) Consumer Actor Type Definition



Such actors are passive, and assume that input is available when they fire.

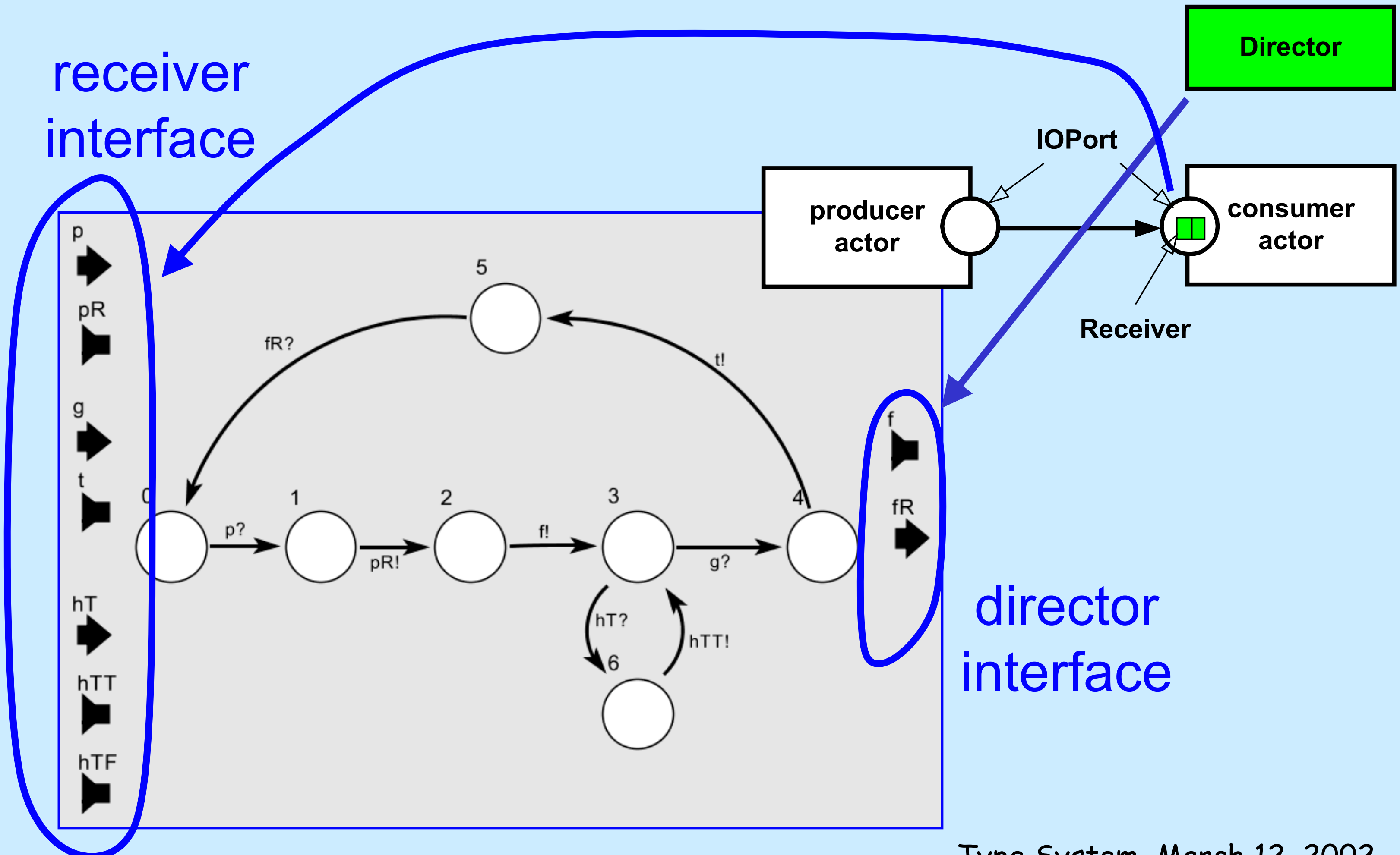
Inputs:

f	fire
t	Token
hTT	Return True from hasToken
hTF	Return False from hasToken

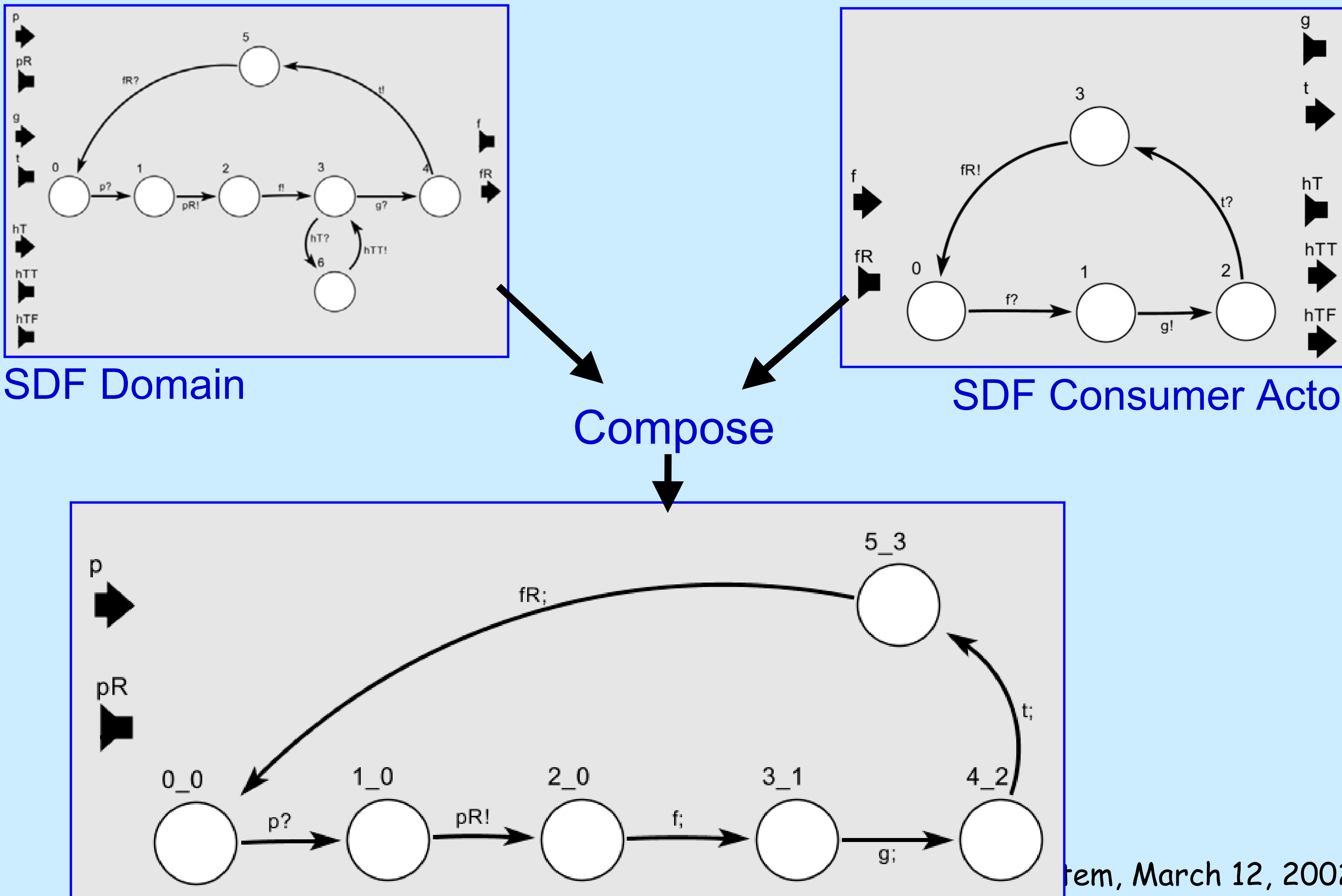
Outputs:

fR	Return from fire
g	get
hT	hasToken

Type Definition – Synchronous Dataflow (SDF) Domain

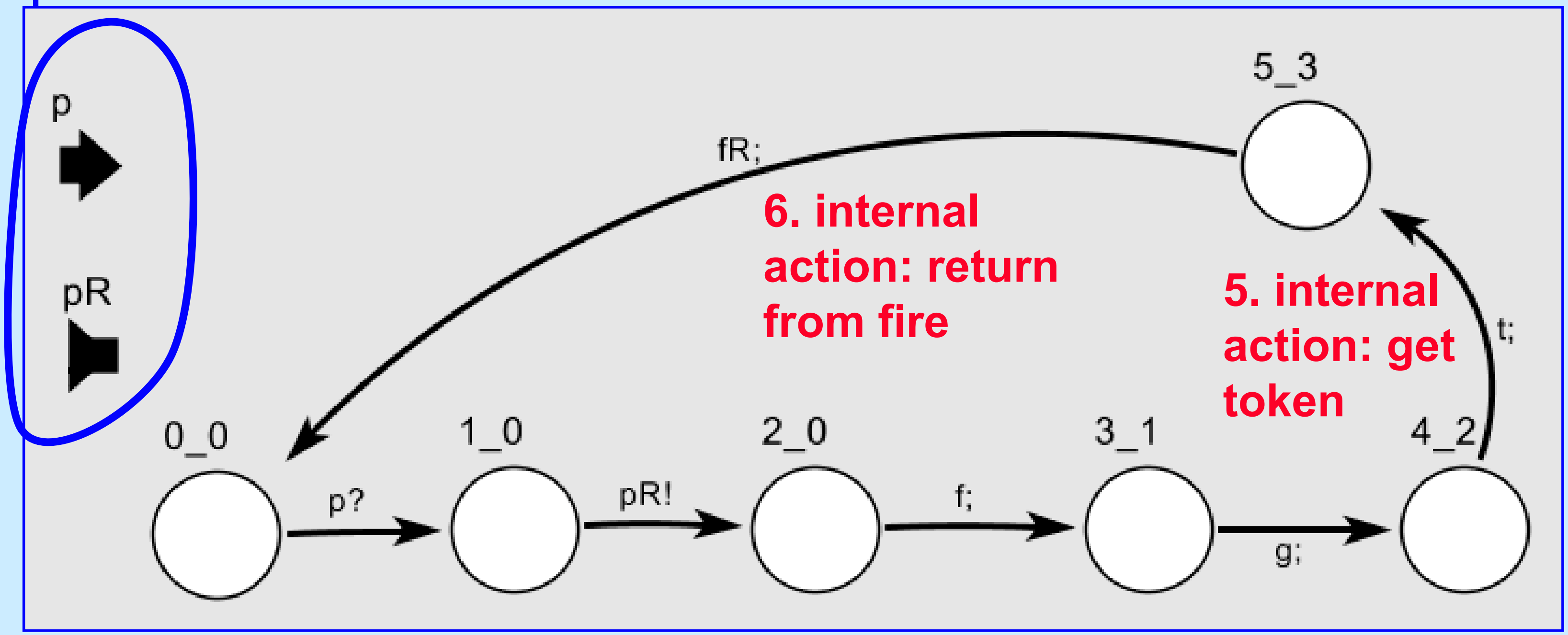


Type Checking - Compose SDF Consumer Actor with SDF Domain



Type Definition - SDF
Consumer Actor in SDF Domain

interface to
producer actor



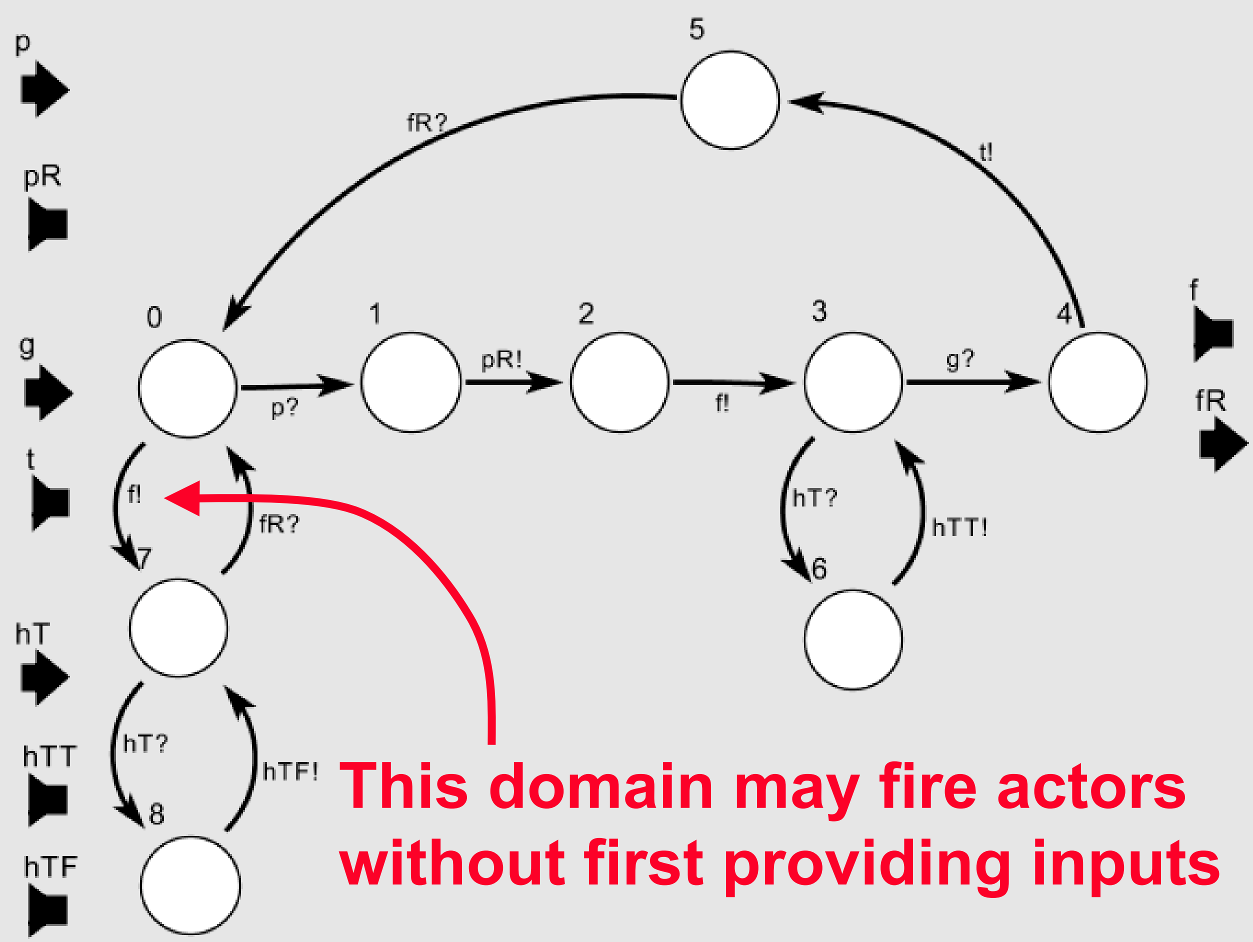
1. receives token from producer

2. accept token

3. internal action: fire consumer

4. internal action: call get()

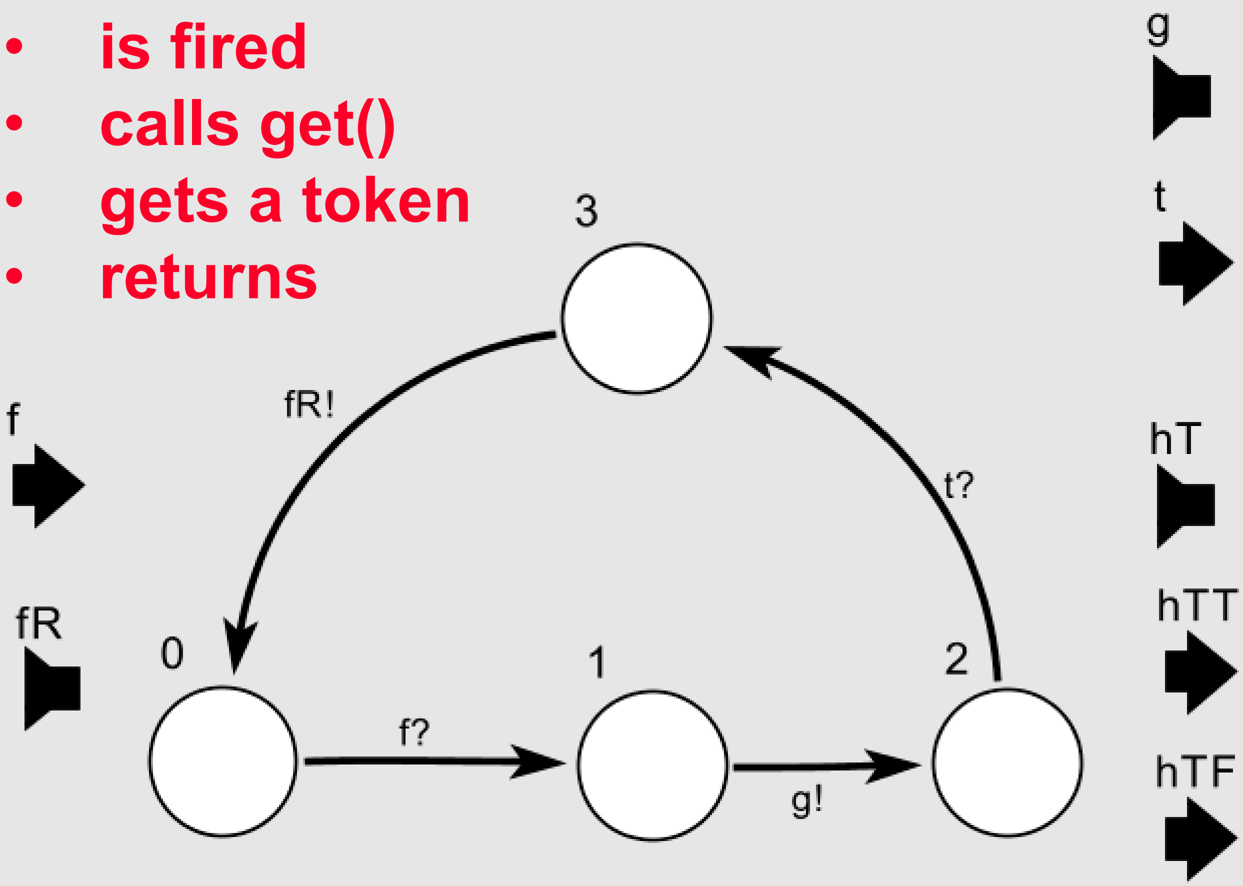
Type Definition - Discrete Event (DE) Domain



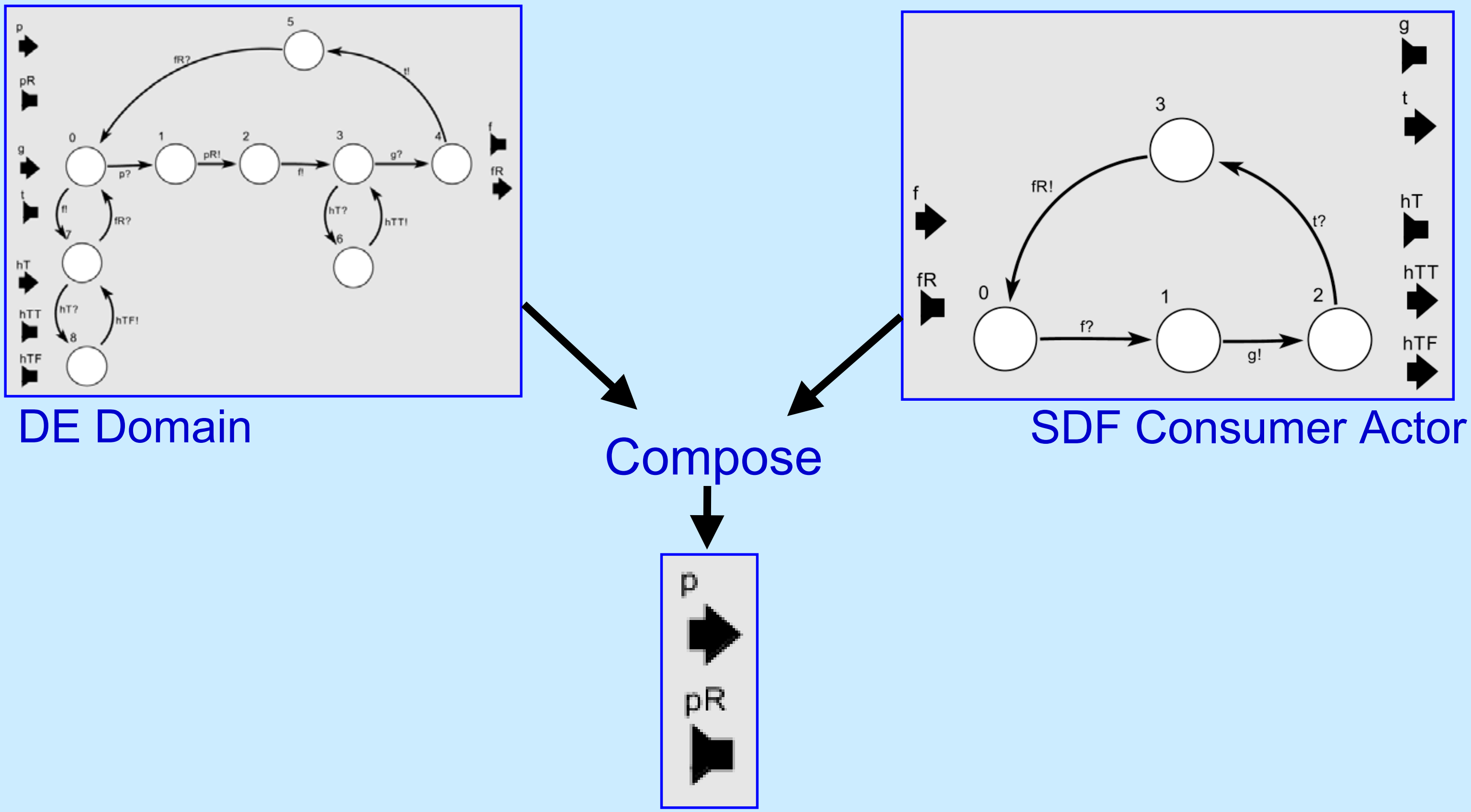
This domain may fire actors without first providing inputs

Recall Component Behavior
SDF Consumer Actor

- is fired
- calls get()
- gets a token
- returns



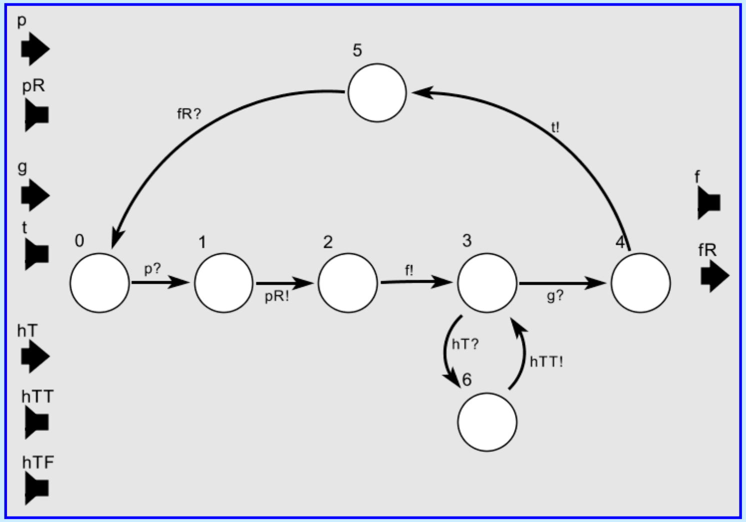
Type Checking - Compose SDF Consumer Actor with DE Domain



- Empty automaton indicates incompatibility
- Composition type has no behaviors

Subtyping Relation
Alternating Simulation: SDF ≤ DE

SDF Domain



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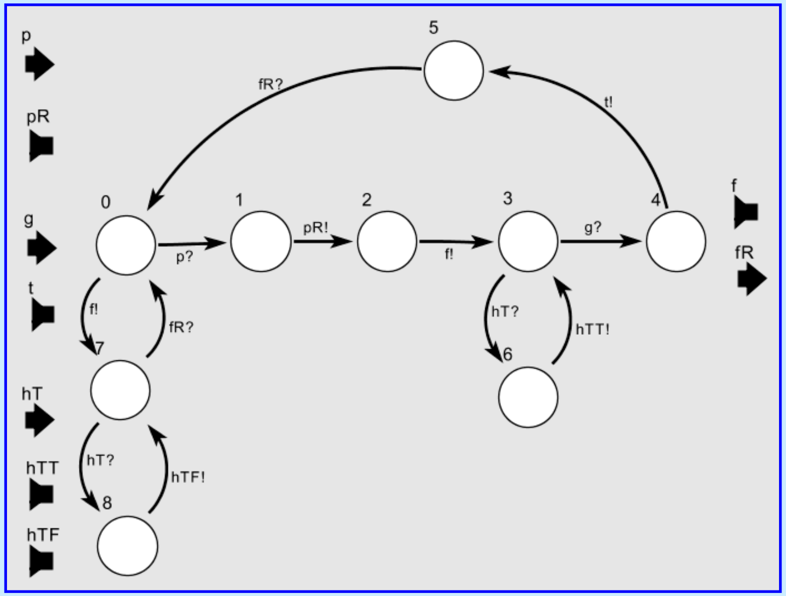
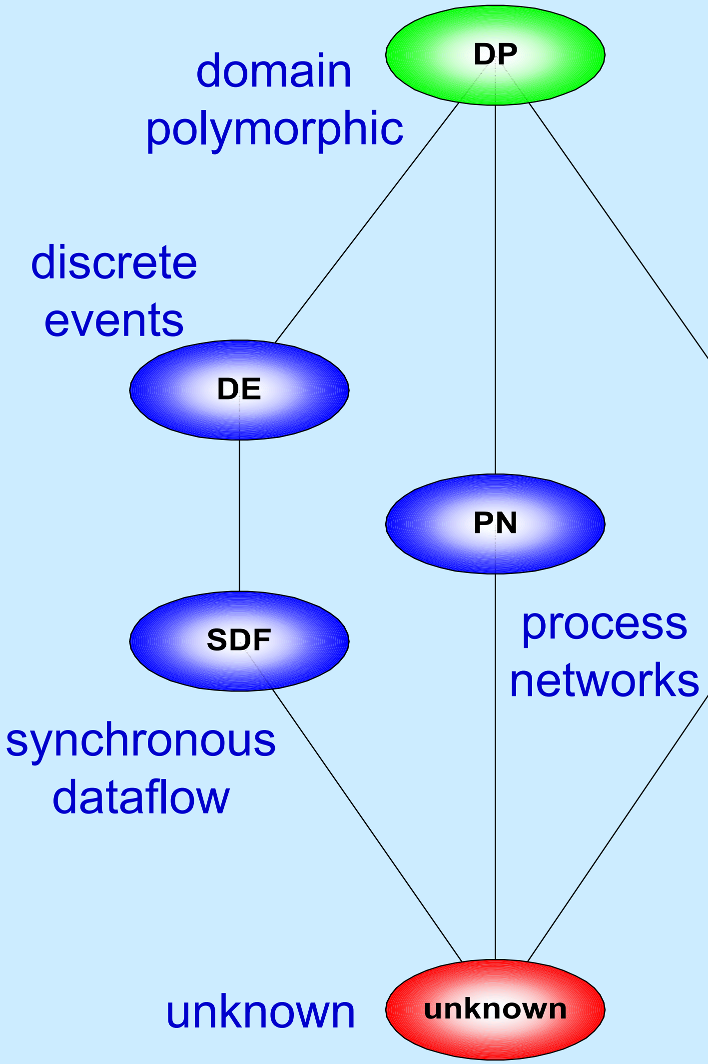
DE Domain



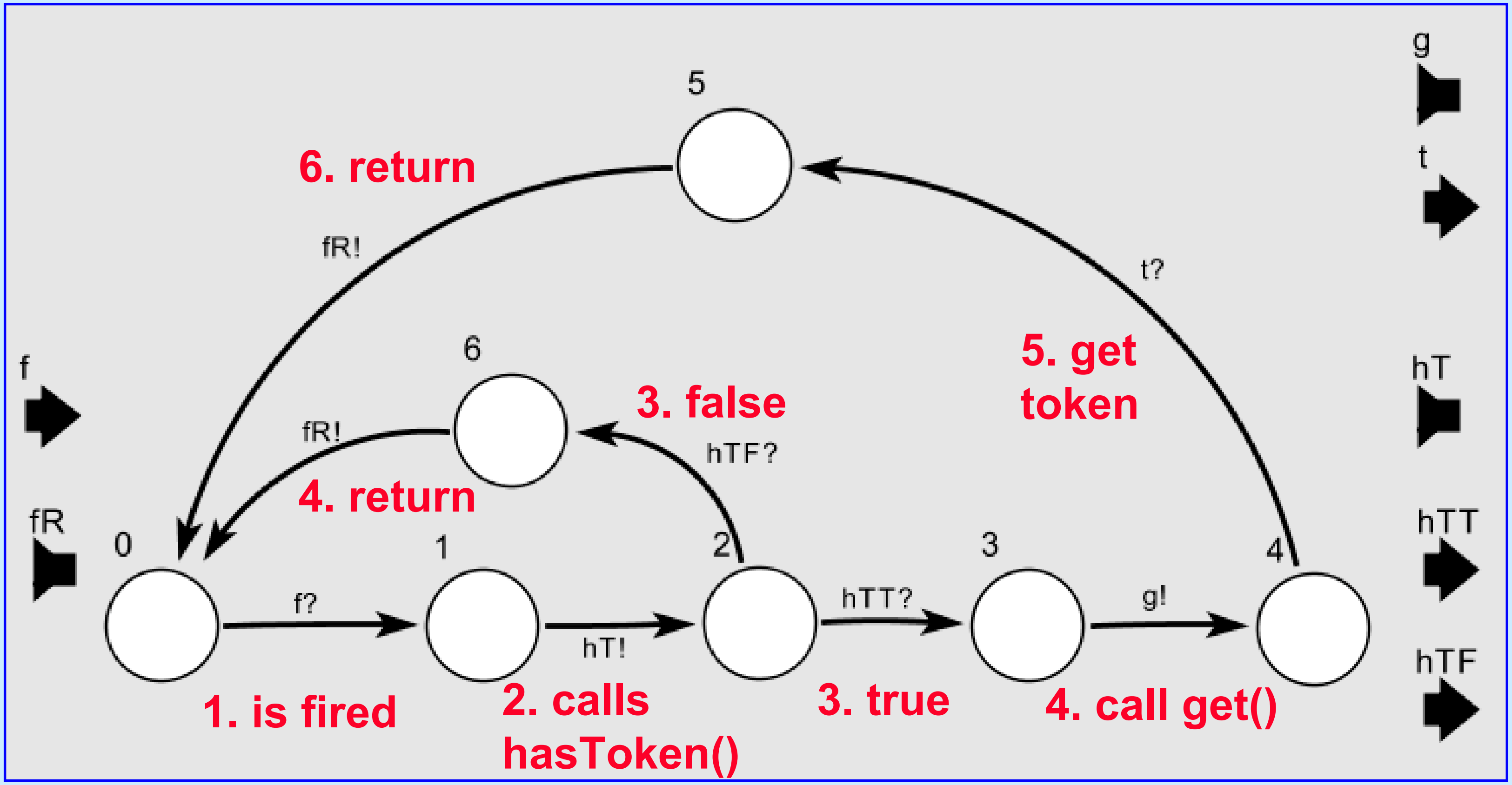
System-Level Type Lattice – Defined by Alternating Simulation



- Subtyping relation
- Shown here for a few Ptolemy II domains

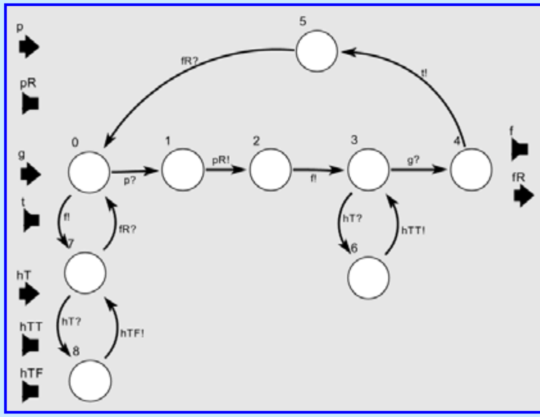
If an actor is compatible with a certain type, it is also compatible with the subtypes

Type Definition – Domain Polymorphic Consumer Actor

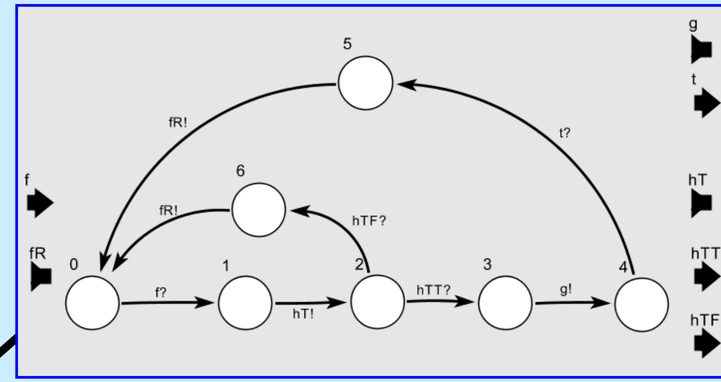


This actor checks for token availability before attempting to get the token.

Domain Polymorphic Actor Composes with the DE Domain

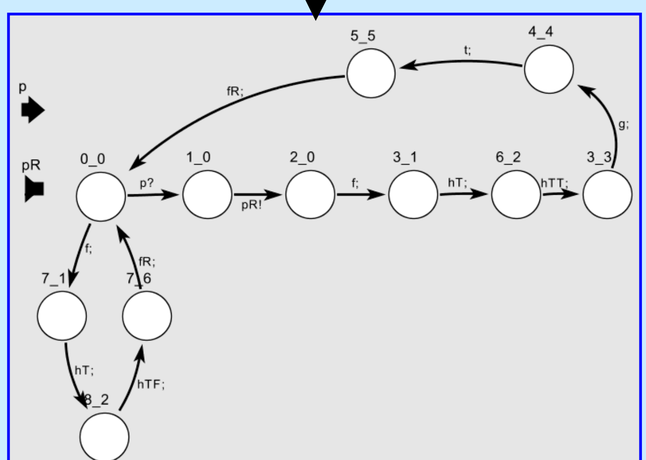


DE Domain

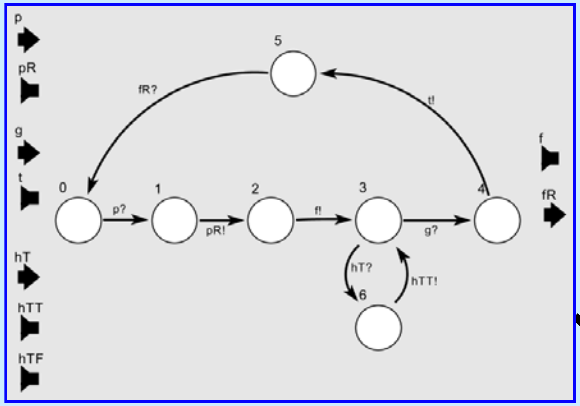


Poly Actor

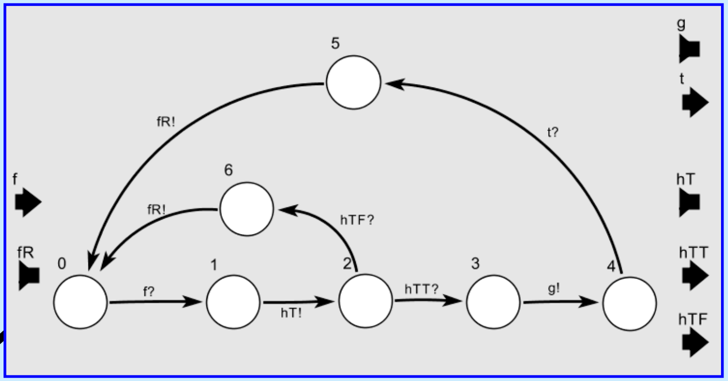
Compose



Domain Polymorphic Actor Also Composes with the SDF Domain

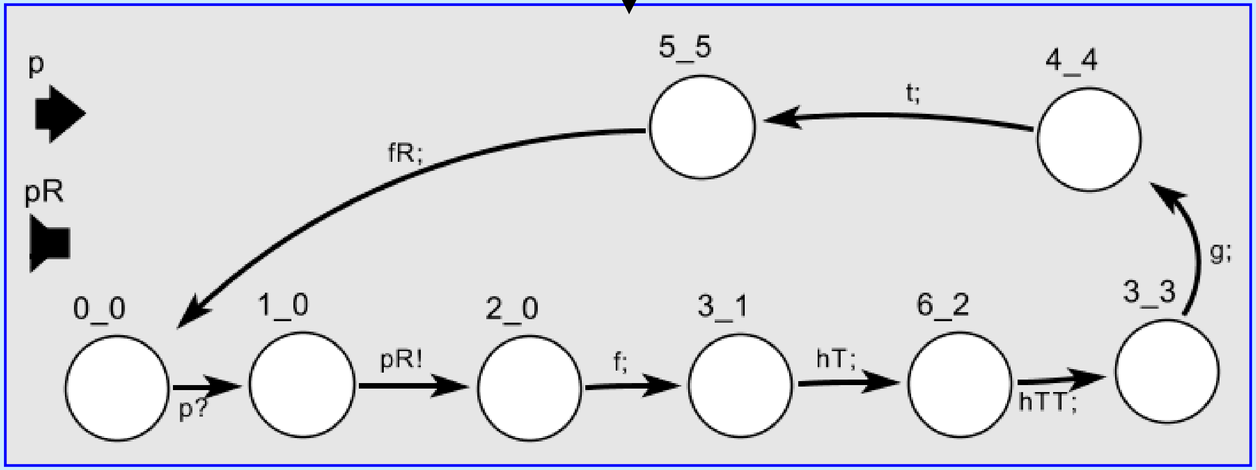


SDF Domain



Poly Actor

Compose



Conclusion

- Data types
  - Lattice-based infrastructure
  - Support polymorphism, type conversion, and structured types
- Behavioral types
  - Formally captures the structure of MoCs
  - Describe interaction types and component behavior using *interface automata*
  - Perform type checking through *automata composition*
  - Subtyping order is given by the alternating simulation relation, supporting *polymorphism*