Modeling and Verification of MPI based distributed software (using ASMs)

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Presentation overview

- **Motivation**
- **Formal verification – three interesting properties**
- **Introduction to ASMs (really short one)**
- **Using ASMs to model basic MPI communication**
- **Mutual exclusion case study**
- **Conclusion & Future work**

Motivation

- **Complex distributed systems are hard for design and analysis**
- **Typical problems**

	Synchronous communication	Asynchronous communication
Parallelism (scalability)	HARD	EASY?
Deadlock	POSSIBLE	NOT POSSIBLE
System complexity	MODERATE	HUGE

Formal verification

- **Checks whether system conforms to specification**
- **Theorem proving & model checking**
- **Model checking with SPIN (Siegel 2005)**
  - theorems and manipulation to avoid state explosion
  - three interesting properties for model checking and distributed sytems
    - Safety (e.g. deadlock absence)
    - Liveness
    - Fairness

Introduction to ASM (abstract state machines)

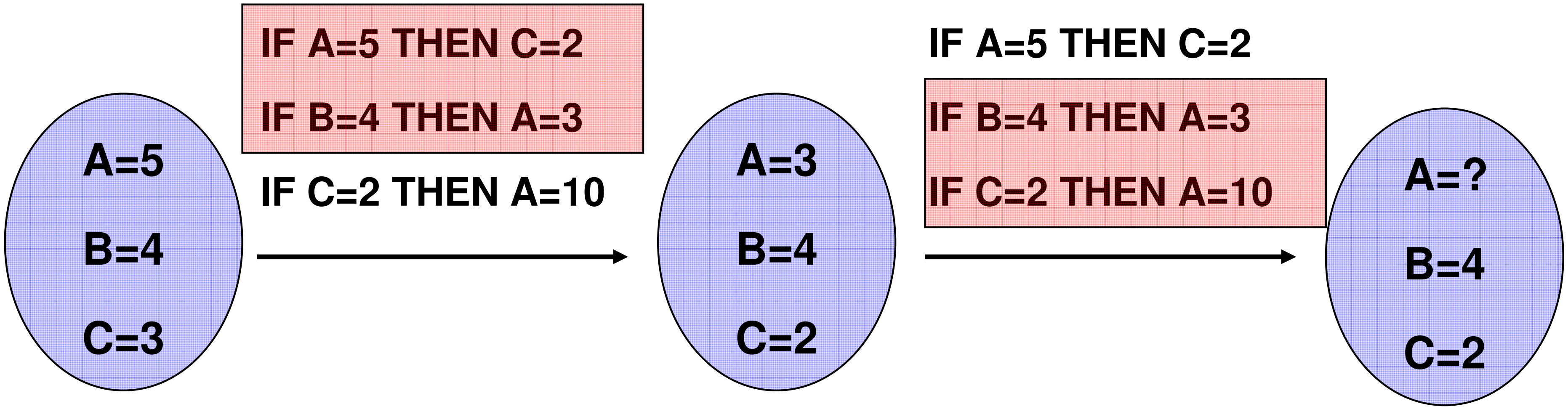
- **State machines – known concept**
- **Abstract state machines – similar to state machine but**
  - You need to define only the initial state and give the 'recipe' how to evolve (no enumeration)

  - Math:
    - Initial state (and every other state it evolved to) is a static algebra (set X, signature $\Sigma=\{f \mid X^r \rightarrow X\}$
    - State evolution:

```
If Condition then Update
```

`Update:` $f(t_1,\ldots,t_2)=t$, $(f\in\Sigma \quad t_x,t\in X)$

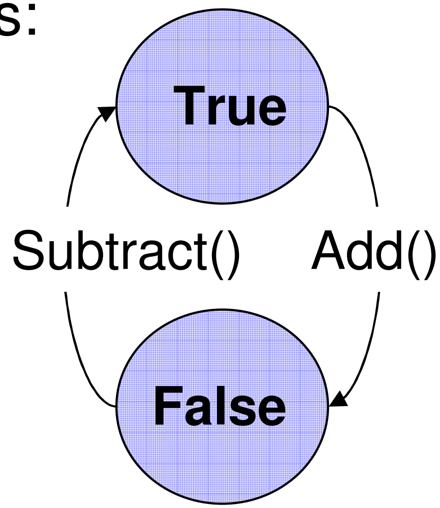
Introduction to ASM (example)



Using ASMs to model basic MPI communication

- **ASML (abstract state machine language) – object oriented**
- **Model exploration – Spec Explorer**
- **How to define MPI processes ?**
  - every process is instance of the special *process class*
  - Every method in the process class is considered as atomic action
  - Example: process that executes sequence of actions: Add(),Subtract(),Add(),...

```
class process()
      var state as Boolean=true

Add()
  require state=true
  state:=false

Subtract()
  require state=false
  state:=true
```



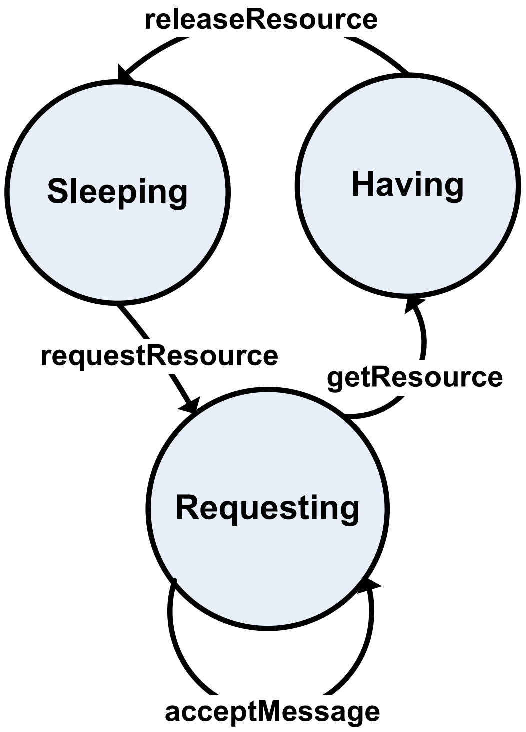
Using ASMs to model basic MPI communication

- **Encoding MPI communication**

<table>
<tr><th></th><th>BLOCKING</th><th>NON BLOCKING</th></tr>
<tr><td>SEND</td><td>Blocking Send()
  require state=DESIRED STATE
  receiver.messageQueue+=[Message]
  state=MESSAGE SENT</td><td>Make the same transfer as blocking but only when MPI_WAIT is posted?</td></tr>
<tr><td>RECEIVE</td><td colspan="2">AnnounceMessageReceive()
   require state=DESIRED STATE
   me.announces+={Announce()}
   state:=DESIRED STATE + RECEIVE ANNOUNCED
ReceiveMessage()
   require messageQueue contains message
   (BL)require DESIRED STATE + RECEIVE ANNOUNCED
   applicationBuffer=getMessage(messageQueue)
   state:=MESSAGE RECEIVED</td></tr>
</table>

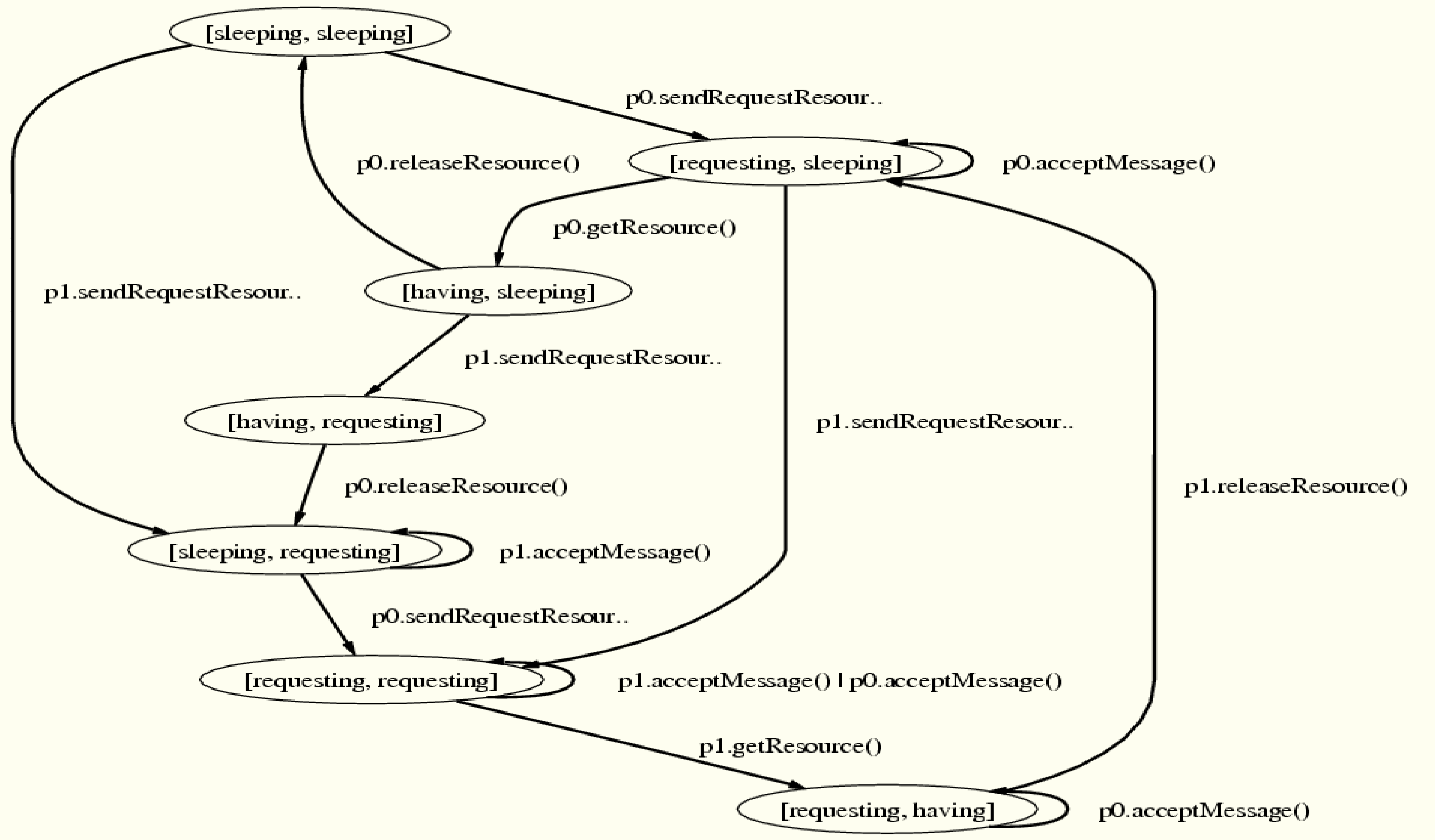
Mutual exclusion – case study

- **Lamport 1978, only non-blocking communication**
- **Three properties (safety, liveness, fairness)**



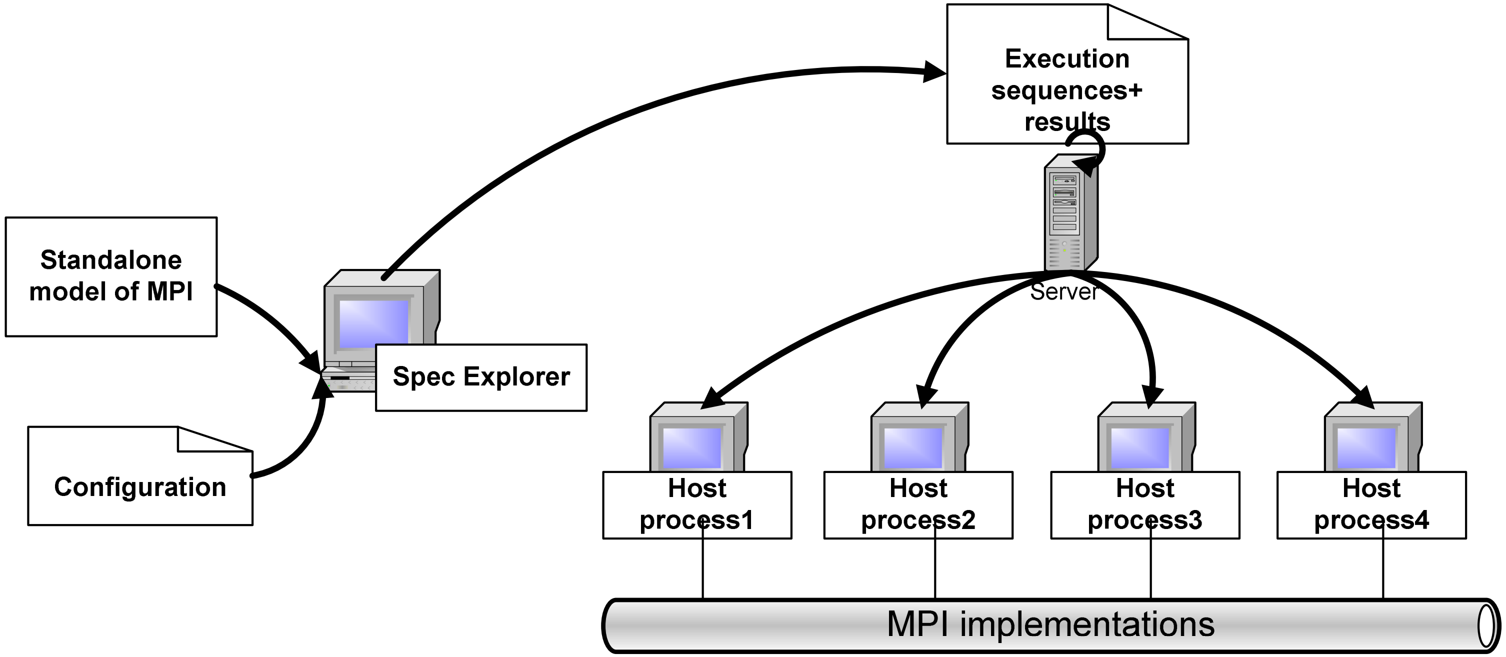

```
requestResource()
 require state=tState.sleeping
 state:=tState.requesting
 foreach iProcess in processes
                  where iProcess<>me
  iProcess.messageQueue+=[NewRequest]
  requestQueue+=[NewRequest]
  clock+=1,nOfReceivedAck:=0

acceptMessage()
 require Size(messageQueue)>0
 require state=tState.requesting
 messageQueue:=Tail(messageQueue)
 clock:=max(messageQueue(0).clock+1,clock+1)
 match messageQueue(0).messageType
  REQ: requestQueue+={messageQueue(0)}
       sender.messageQueue+=[NewAcknowledge]
  REL: requestQueue-=request(sender)
  ACK: nOfReceivedAck+=1
```

Mutual exclusion – exploration & verification



Future Work

- Standalone model of MPI (only basic communication)
- Configurations (made several by hand now)
- Host processes (support execution of MPI functions supported by the model)



Conclusion

- **ASMs are powerfull for capturing requirements**
- **ASMs can give an insight to a distributed system**
- **Some basic (but important) properties can be verified using available tools**
- **Questions?**