A Framework for Systems of Asynchronous Concurrent Processes

Marek Rychlý

Outline

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- Distributed information systems
- Asynchronous network model
- Process algebras (CCS, π-calculus, …)
- Modified asynchronous network model
- Framework for modified network model
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Introduction

- Globalization
  - International companies
  - The European Union
  - Evaluating global changes in natural environment
  - E-business
- Information systems
  - Decentralization (VPN, PDA)
  - Service oriented (SOA, MAS)
  - Dynamic relations (the importance of middleware)

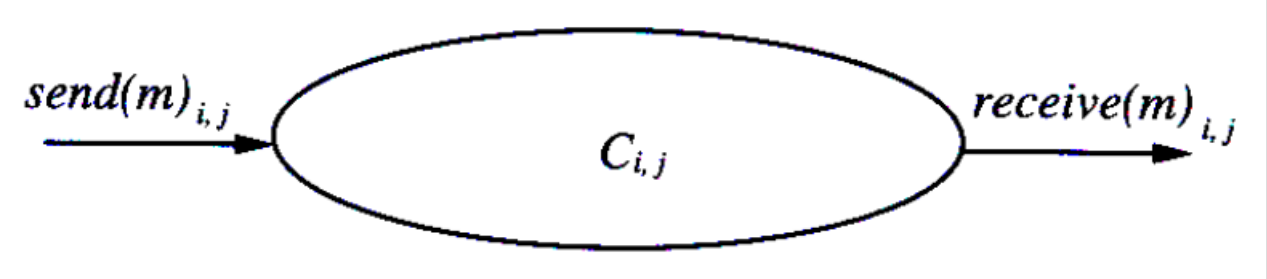
Distributed ISs

- Modern ISs are built as SW confederations
  (Peer to Peer networks)
- Many autonomous components
- Gateways (interfaces) to the middleware
- Middleware provides dynamic connections
  - according to functionality (available services)
  - according to free resources
  - according to policies of components
- Examples:
  - E-business systems
  - Distributed file sharing systems
  - GRID systems

Asynchronous network model

- directed graph of communicating processes
- edges are communicating channels
- two operations:
  - asynchronous $send(m)_{i,j}$
  - synchronous $receive(m)_{i,j}$
- many types of channels:
  - „universal reliable FIFO channel“
  - „reliable reordering channel“
  - „channel with failures“ (losses, duplications, …)

Asynchronous network model



- can be modelled as an I/O automaton
  - a labelled transition system model with output, internal and always enabled input actions and „a fair execution“
  - developed by Lynch and Tuttle, 1987

Process algebras
(„process calculus“, „process theory“)

- an algebraic approach to the system of concurrent processes (at a high level of abstraction)
- tools for the formal verification
  - synchronization (critical sections)
  - liveliness, fair execution (deadlocks)
  - temporal logics (to describe properties of executions)
- *Calculus of Communicating Systems* (CCS) Milner, 80th and 90th years
- *Communicating Sequential Processes* (CSP) Hoare, 1984-85
- …

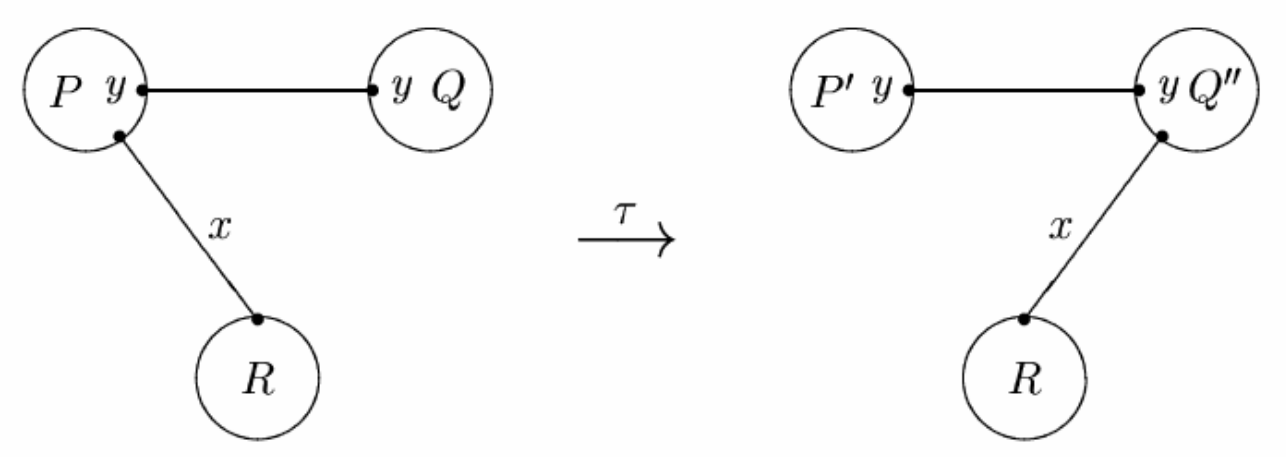
π-calculus
(calculus of mobile processes)

- R. Milner, J. Parrow a D. Walker (1992): *A Calculus of Mobile Processes*
- CCS with dynamic comm. structures
- only two concepts:
  - agent: communicating process,
  - name: comm. channel, variable, data, …
- key properties:
  - name passing
  - replication
- modifications:
  - polyadic, with replication, non-recursive, high-order, with name equality, …

π-calculus: operations

- $x\langle y\rangle.P$ – operation „send“
- $x(y).P$ – operation „receive“
- $\tau.P$ – internal (hidden) action
- $(x)P$ – new name
- $P|Q$ – parallel composition
- $P+Q$ – non-deterministic choice
- $A(x_1,\ldots,x_n)$ – agent execution
- $[x=y]P$ – name equality (extension)
- $!P$ – replication (extension)

Example



$$(y)(\overline{y}x.P' \mid y(z).Q') \mid R \xrightarrow{\tau} (y)(P' \mid Q'\{x/z\}) \mid R$$

π-calculus: proofs

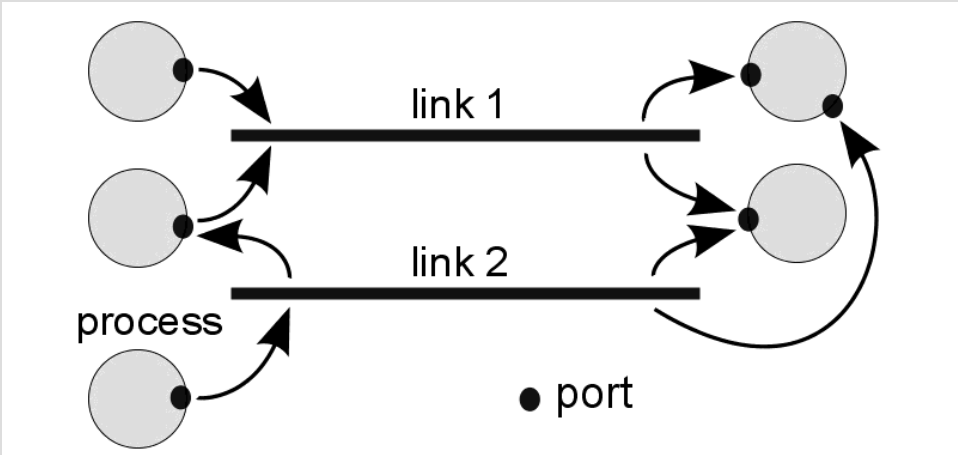
- Implementation of λ-calculus (Robin Milner, 1992)
- Bisimulation equivalence:
  - early and late: input action after/before substitution (isn't congruent, Milner 1992)
  - open bisimulation: all actions (is congruent, Sangiorgy 1996)
- Proof of bisimulation equivalence in finite recursive π-calculus (Mads Dam, 1997)
  - auto-prover (Björn a Moller, 1994)
    The Mobility Workbench - A Tool for the π-Calculus

Motivation

- Is it possible to catch a process in IS?
  - Business Process Modelling Language (?)
- Can we focus on the communication?
- Can be a distributed IS modelled in ANM?
- Is ANM compatible with ISO/OSI Network Model?
- Is it possible to specify a communication structure of IS (middleware) in π-calculus?
- Relationship of π-calculus and ANM?

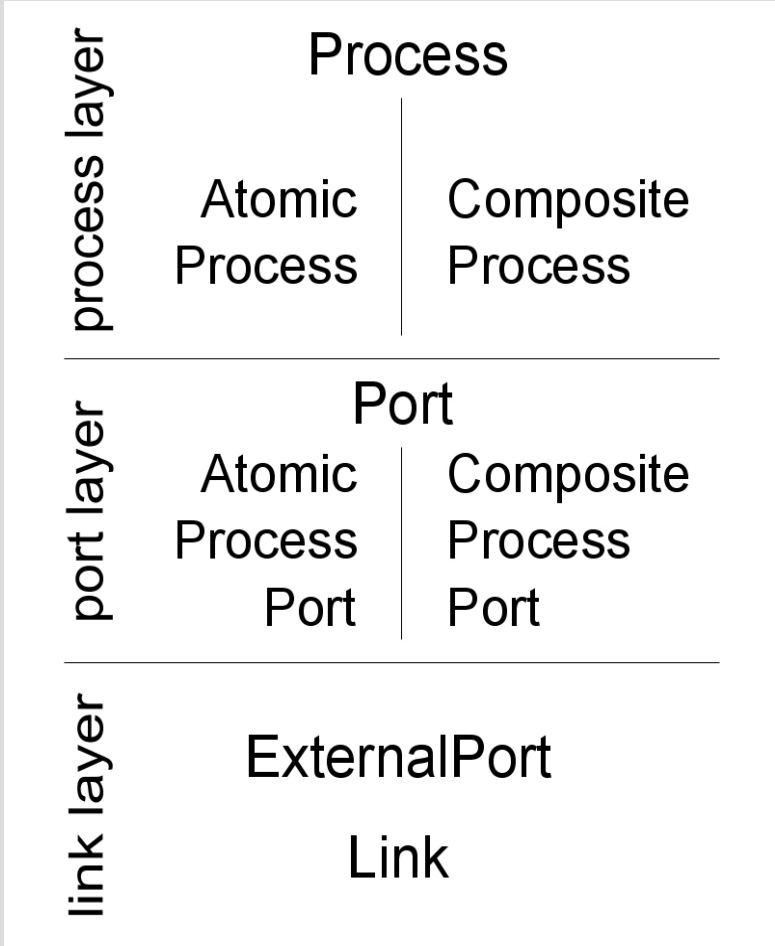
Modified asynchronous network model

- Original ANM: process and channel
- Interface between process and channel:
  - application layer: processes
  - presentation layer: interfaces
  - transport layer: channels
- Modified network model:
  - „process“
  - „port“
  - „link“
- Translatable into original ANM



Framework for modified asynchronous network model

- Tool for modelling in modified network model
- *white-box* framework (and implementation library of components for *black-box* frame.)
- Hierarchy and encapsulation of processes



Framework… – implementation

- Ports are registered as observers of links
- All observers receive an event from the link, but only one of them can handle the event (without an interaction with the link)
- Ports of composite processes only resend events towards inner processes, the reverse direction is realized directly (on demand)

(UML Class diagram in the papers)

Formal specification

- High level of abstraction in the model
  - focused on the communication
  - unknown semantics of atomics processes
- Systems implemented using the framework are compatible with modified network model
- Systems implemented using the framework can be translated into π-calculus
- We suppose „universal reliable FIFO channel“ in formal specification (ideal)

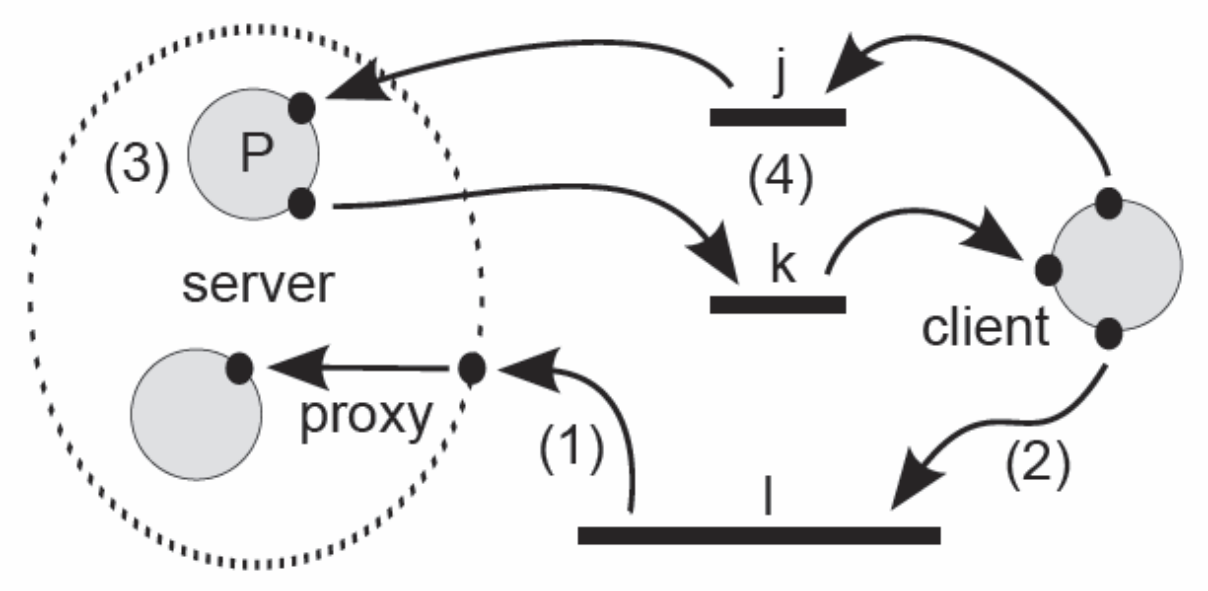
Specification in π-calculus

- The atomics process is process of π-calculus
- The port is two channels (input and output)
- The link is expressed as π-calculus process, which connects input and output channels:

$$\text{link}(p1_{in}, \ldots, pn_{in}, q1_{out}, \ldots, qm_{out}) = \sum_{i=1}^{n} \sum_{j=1}^{m} qj_{out}(x).\overline{pi_{in}}\, x \,.\text{link}(p1_{in}, \ldots, pn_{in}, q1_{out}, \ldots, qm_{out})$$

- The composite process is a parametric process (a parallel composition of its internal processes) with the ports of a composite process as its parameters

Specification of sample system



$$\text{Client}(l_{out}) = (k_{in}).\overline{l_{out}}\ k_{in}\ .k_{in}(j_{out}).\text{Client}_{\text{connected}}(k_{in},\ j_{out})$$

$$\text{Server}(l_{in}) = \text{Server}(l_{in}) \mid l_{in}(k_{out}).\text{P}(k_{out})$$

$$\text{P}(k_{out}) = (j_{in}).\overline{k_{out}}\ j_{in}\ .\text{Server}_{\text{connected}}(j_{in},\ k_{out})$$

Formal verification

- After translation into π-calculus in MWB
- Problem with infinite recursion (replication)
  - Can be replaced with a finite number of concurrent processes?
  - Is it possible to use some recycling mechanism?
- We can:
  - prove weak and strong open bisimulation equiv.
  - find deadlocks
  - simulate and test system (as „a black-box“ and „a white-box“)
- Can be connected with a formal specification of processes in ISs?

Verification of sample system

```
agent Client(lout) = (^kin)'lout<kin>.kin(jout).ClientConn<kin,jout>
agent Server(lin) = lin(kout).P<kout> (*reduced*)
agent P(kout) = (^jin)'kout<jin>.ServerConn<jin,kout>
agent System = (^lin,lout)(Server<lin> | Client<lout> | Link<lin,lout>)
agent Link(in,out) = out(x).'in<x>.Link<in,out>
agent ClientConn(kin,jout) = 0
agent ServerConn(jin,kout) = 0
```

- The recursion is reduced to one instance
- „Connected“ versions of processes are specified as null processes (for demonstrating purpose)
- MWB finds in System a deadlock reachable by three commitments (a connection is established and both the server and client finished, but the link process is ready to another communication)

Future research

- Model:
  - Comparison with other formalisms (Petri-nets)
  - Elimination of an infinite recursion
  - Influence of a network layer QoS on the model
  - Relation with UML2 (design pattern Port)
- Framework:
  - Lesser dependence on the network model
  - Framework implementation and case-studies
  - Specification of SOA, CORBA Event Service, …

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