Integration of Architecture Specification, Testing and Dependability Analysis

Swapna S. Gokhale
Joseph R. Horgan
Applied Research
Telcordia Technologies
Morristown, NJ 07960
{swapna,jrh}@research.telcordia.com

Kishor S. Trivedi.
Dept. of Electrical & Computer Engg.
Duke University
Durham, NC 27708
kst@ee.duke.edu

Outline

- ➢Introduction and motivation
- Discussion of the methodology
- Demonstration of methodology using a case study
- Conclusions and future research

Introduction and Motivation

- Software architecture is increasingly appreciated as a method of understanding and analysis as software systems continue to grow in size and complexity.
- Software architecture represents early design decisions:
  - Have a profound impact on the non-functional attributes of a system.
  - Difficult to change or reverse.
- Architecture analysis is one of the best vehicles to assess important quality attributes such as reliability, reusability, maintainability and performance.

Introduction and Motivation (contd..)

- Languages used to specify software architectures:
  - Focus on the high-level structure rather than the implementation details of a particular source module.
  - Play an important role in the development of software by composing source modules rather than individual statements.
- Development of tools to support understanding, testing, debugging, reengineering, and maintaining architecture specifications is gaining prominence.

Introduction and Motivation (contd..)

- Software architectures specified in architecture specification languages can be used for performance and dependability analysis:
  - Performance and dependability models can be constructed from such specifications to enable quantitative analysis.
- Lack of appropriate information to parameterize the quantitative models constructed from software specifications.
- Trace data generated during simulation/execution of architecture specifications can provide a rich source of information for model parameterization.
  - Collection and analysis of such trace data is likely to be supported by many tools.
- Similar approach has been demonstrated at the source code level.

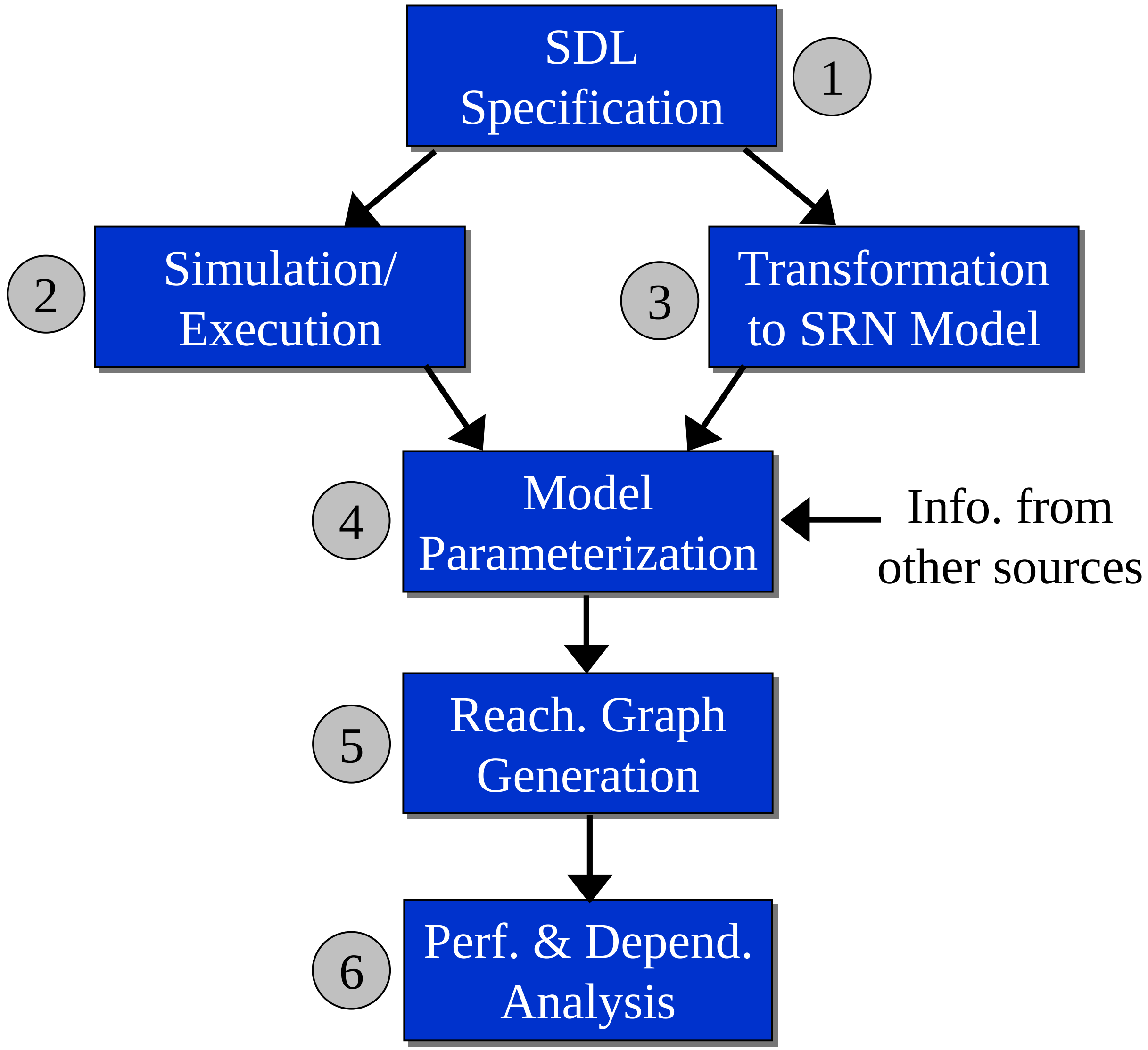
Introduction and Motivation (contd..)

- Demonstrate a methodology to parameterize the performance and dependability models constructed from architecture specifications using trace data collected during simulation/execution of architectural specifications.
- Three-way integration between:
  - Architecture specification,
  - Specification simulation/execution and
  - Performance and dependability analysis.
- Methodology facilitated by Telcordia Software Visualization and Analysis Tool Suite (TSVAT) developed to support architectural specifications in SDL.

Outline

- Introduction and motivation
- ➢Discussion of the methodology
- Demonstration of methodology using a case study
- Conclusions and future research

Methodology



Step I: System Specification in SDL

- Specification and Description Language (SDL) chosen as a Communicating Extended Finite State Machine (CEFSM) specification language.
- Choice of SDL motivated by the following reasons:
  - ITU standard, many telecom systems are specified in SDL.
  - Well-defined semantics.
  - Many commercial tools available to investigate architectural specifications in SDL. .
  - Allows dynamic creation and termination of process instances and their corresponding communication paths during execution.
- First step is to specify the system in SDL.

Step I: System Specification in SDL (contd..)

- SDL provides a hierarchical abstraction of the system structure.
  - Top level is a system level specification.
  - System includes blocks.
  - Blocks include additional blocks or processes.
- Blocks communicate through channels.
  - Channels can be either delaying or non-delaying.
- Process in a block is defined by an extended finite state machine.
- Processes in a block communicate via signal routes.
  - Signal routes have no delay.
- SDL specification provides a process view of a software system.

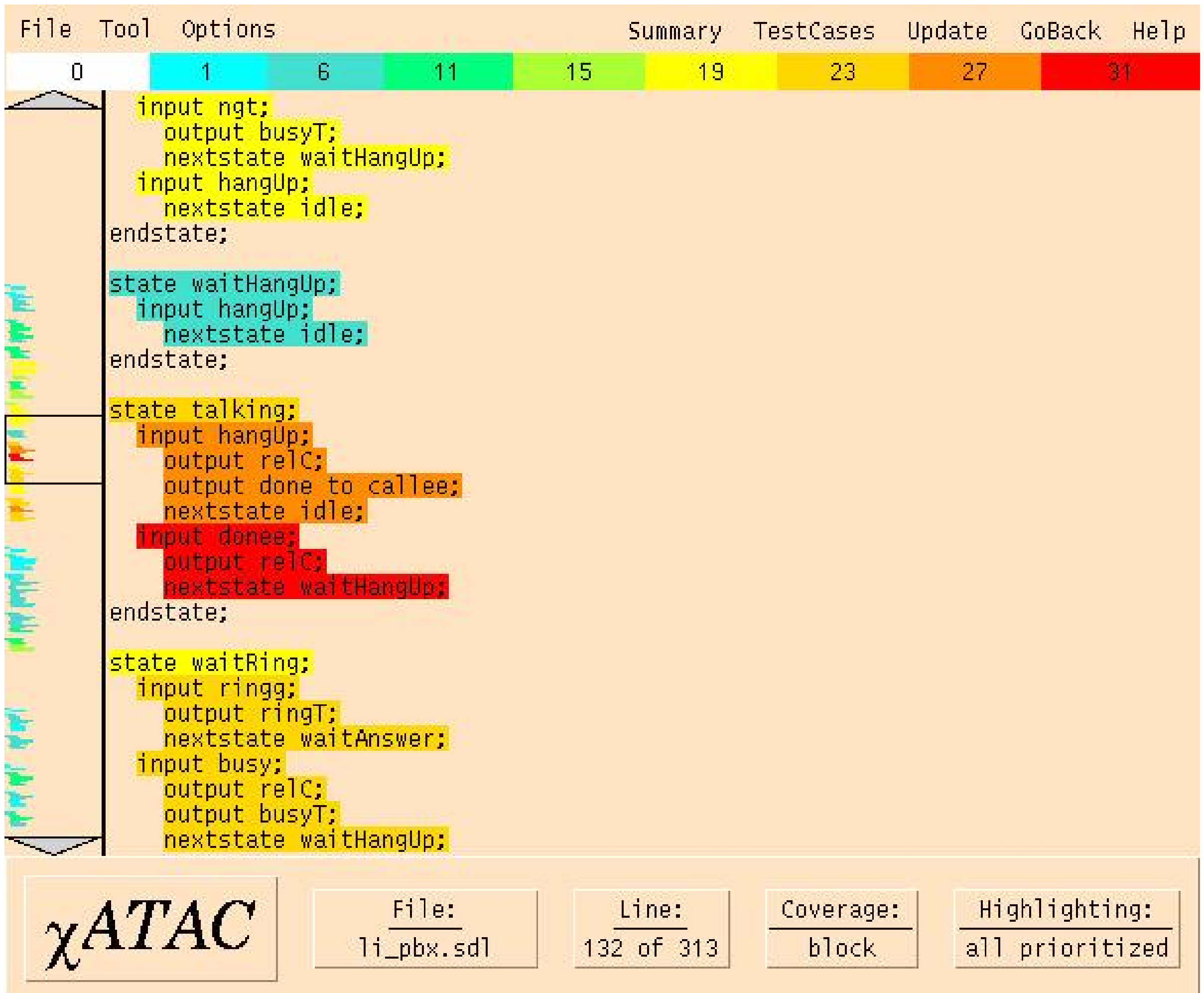
Step II: Specification Simulation/Execution

- Simulate/execute the system specified in SDL.
- Simulator from Telelogic to simulate the SDL specification.
- Simulator instrumented with TSVAT used to collect trace data during simulation.
- Telcordia Software Visualization and Analysis Tool Suite developed to support architecture specification, debugging and testing and to collect trace data.

Step II: Specification Simulation/Execution (contd..)

- TSVAT based on the creation of a flow graph of the specification, laying out its execution structure.
- Trace files indicate the number of times a given part of the specification, such as a process, a transition, a decision, a state input, or a data flow has been exercised in a single simulation run or at the end of testing.
- Reports coverage with respect to the following criteria:
  - Functions (Processes in SDL).
  - Basic transitions (Statement sequence in SDL that is always executed sequentially, no internal branching constructs).
  - Decisions (Conditional branches from one transition to the other.)
- Execution traces can be used to extract branching probabilities of the various decisions in the specification.
- Simulation guided by an operational profile, then branching probabilities would be a characteristic of field usage.

Step II: Specification Simulation/Execution (contd..)



Step III: Translation from SDL Specification to SRN Model

- SDL specification of a system translated to a Stochastic Reward Net (SRN) model.
  - SRN model facilitates quantitative performance and dependability analysis.
- SRNs are a generalization of Generalized Stochastic Petri Nets (GSPNs), which in turn are a generalization of stochastic Petri Nets (SPNs).
- Stochastic Petri Net (SPN):
  - Allows exponential firing times with the transitions.
- Generalized Stochastic Petri Net (GSPN):
  - Exponential as well as zero firing times with transitions.
  - Allows the definition of conditions to inhibit the firing of a transition.

Step III: Translation from SDL Specification to SRN Model

- Stochastic Reward Net (SRNs):
  - Substantially increase the modeling power of GSPNs by adding guard functions, marking dependent arc multiplicities, general transition priorities, and reward rates at the net level.
- SRNs provide the same capabilities as Markov Reward Models:
  - Markov Reward Model is a Markov chain with a reward rate (real number) assigned to each state.
  - Compute measures such as expected reward rate both in the steady state and at a given time, the expected accumulated reward until absorption or a given time, and the distribution of accumulated reward until absorption or until a given time
- Define rules to translate a process-level SDL specification to a SRN model.

Step IV: SRN Model Parameterization

- Parameters of the SRN model obtained by translation from a SDL specification can be categorized into five classes depending on the sources of information used for parameterization:
  - Execution time parameters.
  - User inputs.
  - Branching probabilities.
  - Inputs from other components/processes.
  - Failure and repair parameters.
- Execution time parameters:
  - Parameters associated with the execution of tasks and decisions.
  - Heavily dependent on implementation specifics.
  - Generate code semi-automatically from SDL specifications and use measurements obtained from the execution of this partial code.

Step IV: SRN Model Parameterization (contd..)

- User inputs:
  - Model the inputs representing the actions of a user.
  - Expected by the system at various stages of execution.
  - Distributions and the actual values may be derived from historical data or expert opinion.
- Branching probabilities:
  - Reflect the probabilities of occurrence of the various outcomes of a decision.
  - Extracted from the trace data collected during the simulation/execution of SDL specification.

Step IV: SRN Model Parameterization (contd..)

- Inputs from other processes:
  - Each process in an application may expect certain inputs from other processes in the application.
  - Some parameters may be obtained by considering the execution of other processes in the system.
- Failure and repair parameters:
  - Characterize the failure and repair behavior of the processes.
  - Characterize the failure and repair behavior of each task/decision within a process.
  - Necessary to compute measures such as the reliability and availability.
  - Obtained from historical data or based on expert opinion.

Step V: Reachability Graph Generation

- Reachability graph of a SRN is the set of states that are reachable from other states.
- Generated using SPNP (Stochastic Petri Net Package) developed at Duke University.
- SPNP is a versatile modeling tools for the solution of Stochastic Petri Net (SPN) models.
  - SPN models are described in an input language called CSPL (C-based SPN language).
  - CSPL is an extension of C programming language with additional constructs to facilitate the description of SPN models.

Step VI: Performance and Dependability Analysis

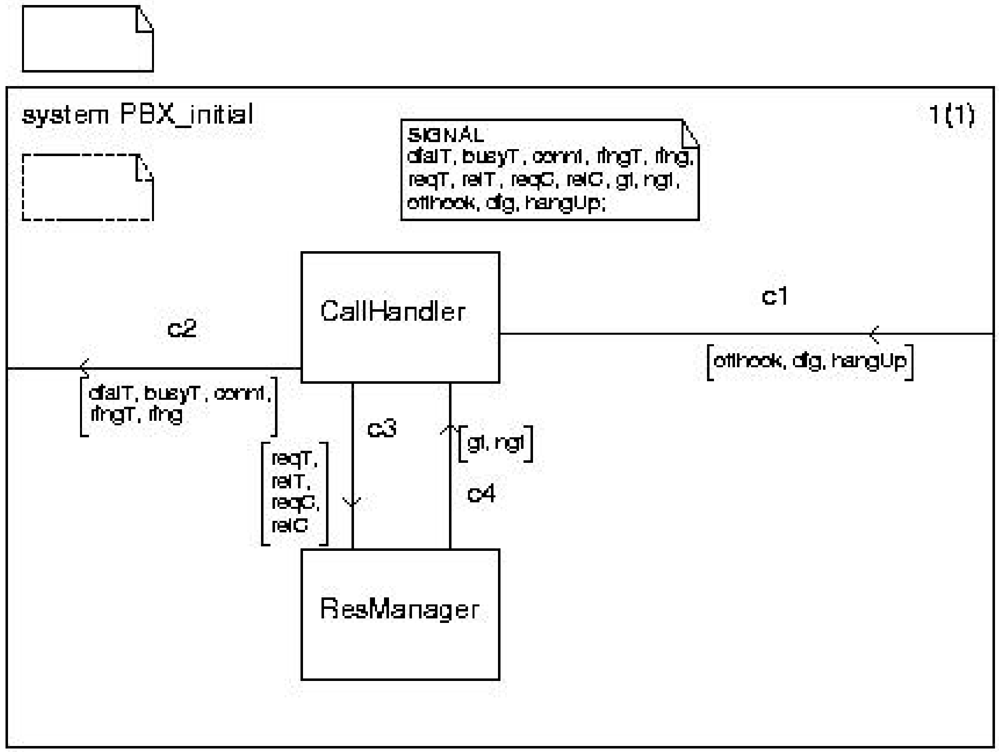
- Parameterized Stochastic Reward Net (SRN) model of the application may be used for performance and dependability analysis.
- SPNP used to compute various measures of interest such as performance, reliability and availability.
- Quantitative analysis based on Markov Reward Model paradigm.

Outline

- Introduction and motivation
- Discussion of the methodology
- ➢ Demonstration of methodology using a case study
- Conclusions and future research

Case Study: Telecom Application

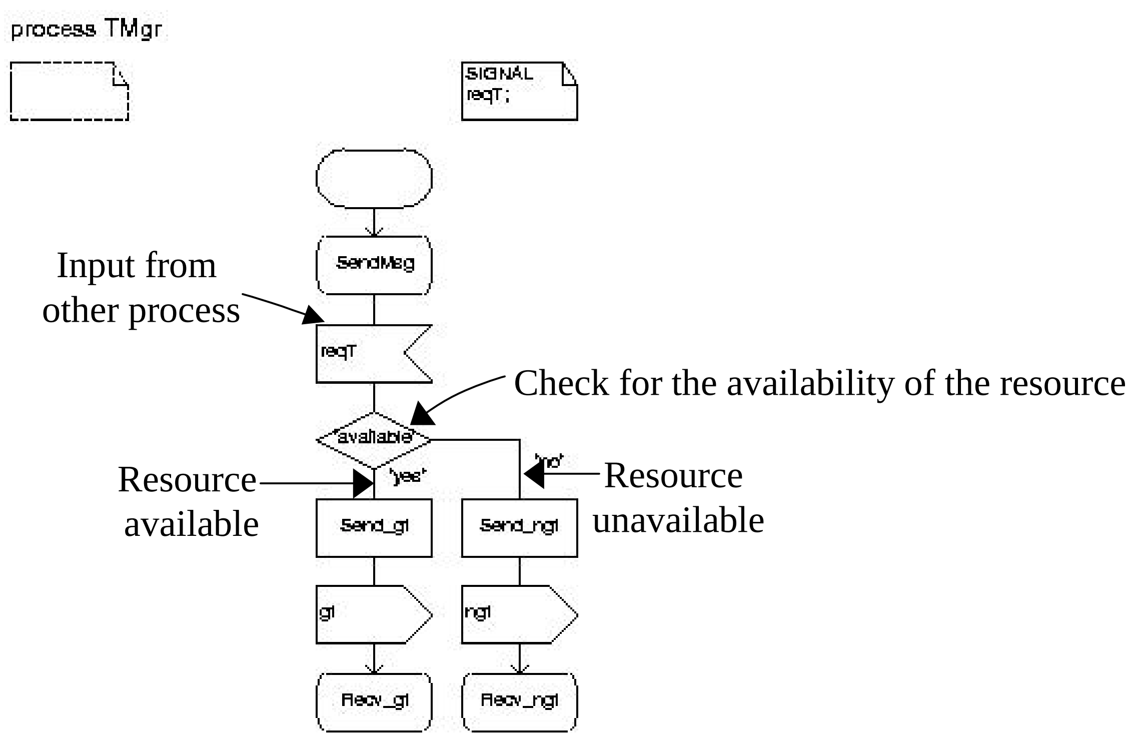
Block-level SDL Specification of Telecom Application



- Two distributed blocks, CallHandler and ResManager.
- CallHandler controls the call processing functions.
- CallHandler has two processes: Caller and Callee
- ResManager involves inventory control and remote database access.
- ResManager has two processes: RMgr and TMgr.
- Communication between CallHandler and ResManager occurs over delaying channels c3 and c4, indicating that the two blocks can be implemented in a distributed fashion.

Case Study: Telecom Application

Process-level specification of the Process TMgr

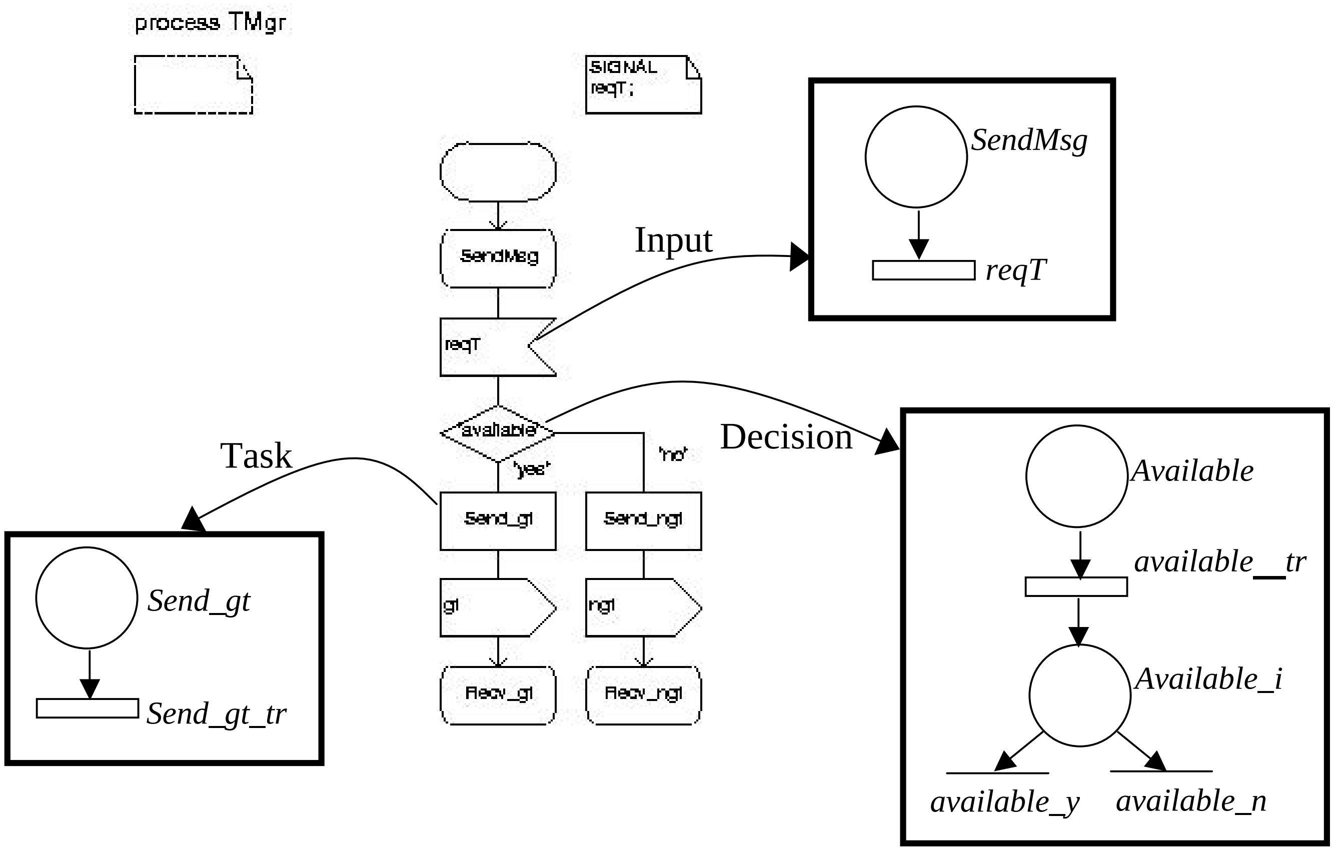


Case Study: Telecom Application

- Graphical SDL representation of the Telecom Application was transformed to a textual SDL representation.
  - Textual representation was approximately 300 lines of SDL code.
- Textual SDL representation was instrumented with TSVAT.
- SDL specification of the Telecom Application was simulated using the simulator from Telelogic.
- 13 simulations runs were conducted.
  - Trace data was collected during the simulation runs.

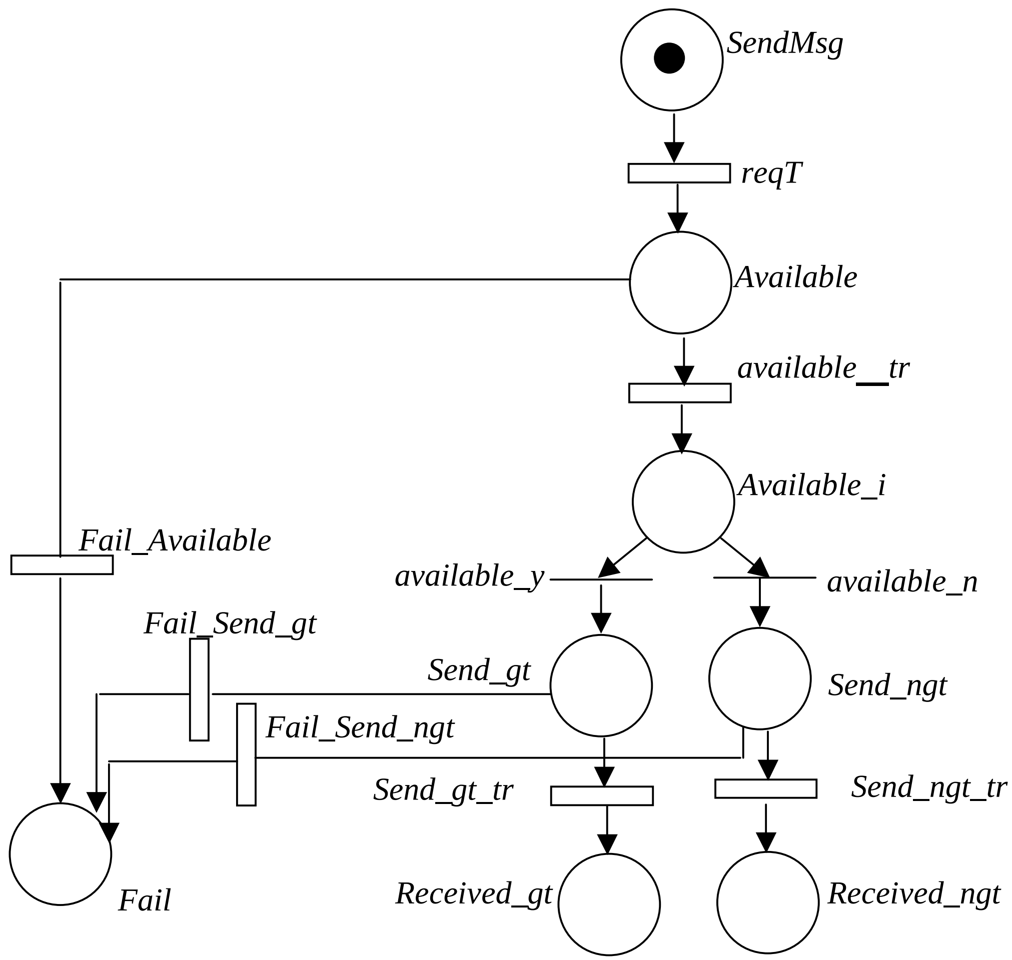
Case Study: Telecom Application

Translation from SDL Specification to SRN Model



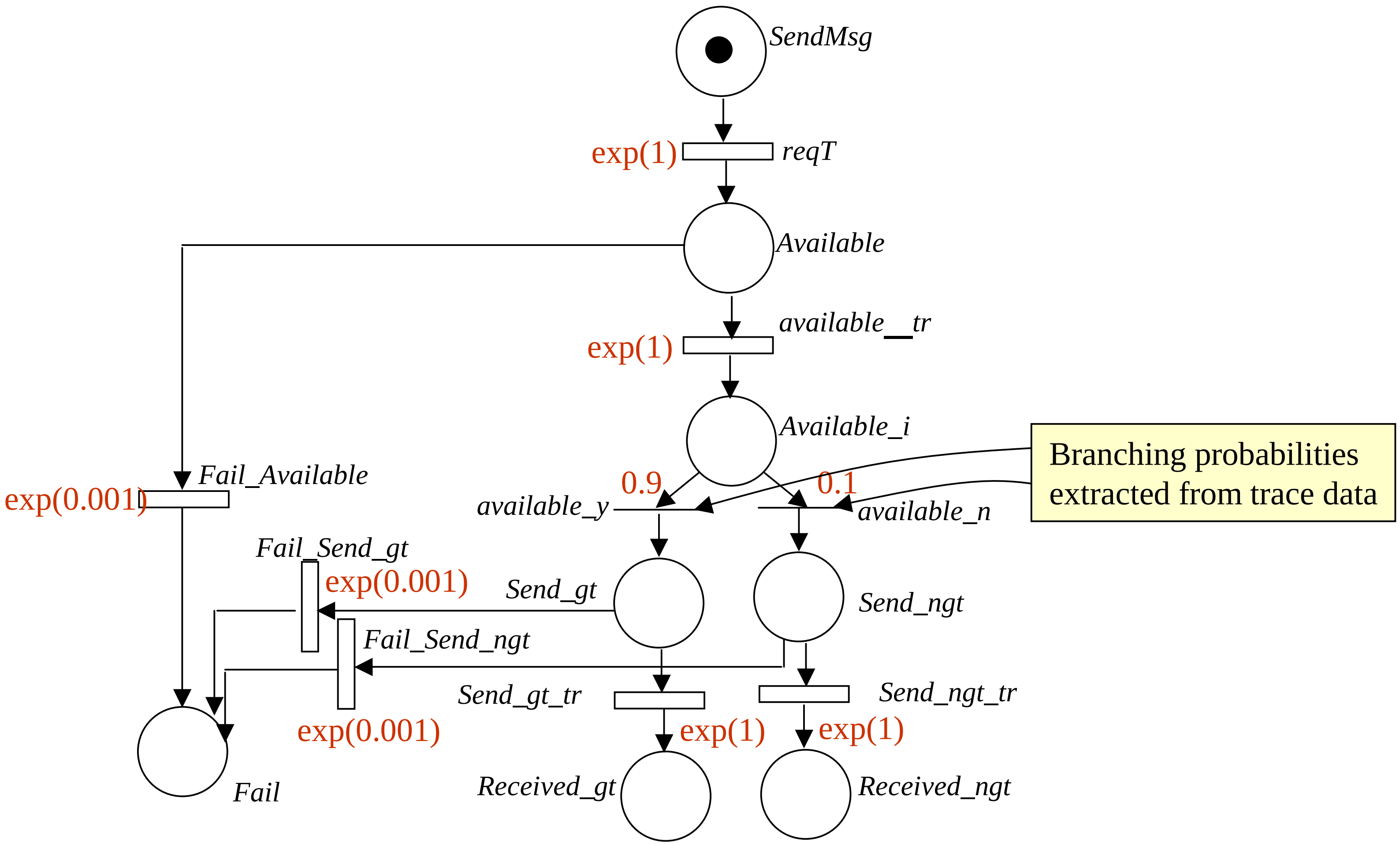
Case Study: Telecom Application

SRN Model of Process TMgr



Case Study: Telecom Application

Parameterized SRN Model of Process TMgr



Case Study: Telecom Application

Performance and Dependability measures

Dependability measures:

Probability of resource availability : 0.82 } Probability of success
Probability of resource unavailability: 0.09 }
Probability of failure : 0.09

Performance measures:

Mean Time to Absorption (MTTA) : 1001.99

Outline

- Introduction and motivation
- Discussion of the methodology
- Demonstration of the methodology using a case study

➢ Conclusions and future research

Conclusions and Future Research

- Proposed a methodology to parameterize the performance and dependability models constructed from architectural specifications in SDL based on the trace data collected during the simulation/execution of the specification.
- Proposed methodology seeks three-way integration of:
  - Architecture specification,
  - Specification simulation/execution and
  - Performance and dependability analysis.
- Demonstrated the methodology using a case study of a Telecom Application.
- Future research includes continued development of methods to estimate parameters of analytical models from simulation, testing and historical data.