ESD Electronic Systems Design
Synthesis Verification Testing Power Communication

Toolchain for Optimal Network Synthesis

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Outline

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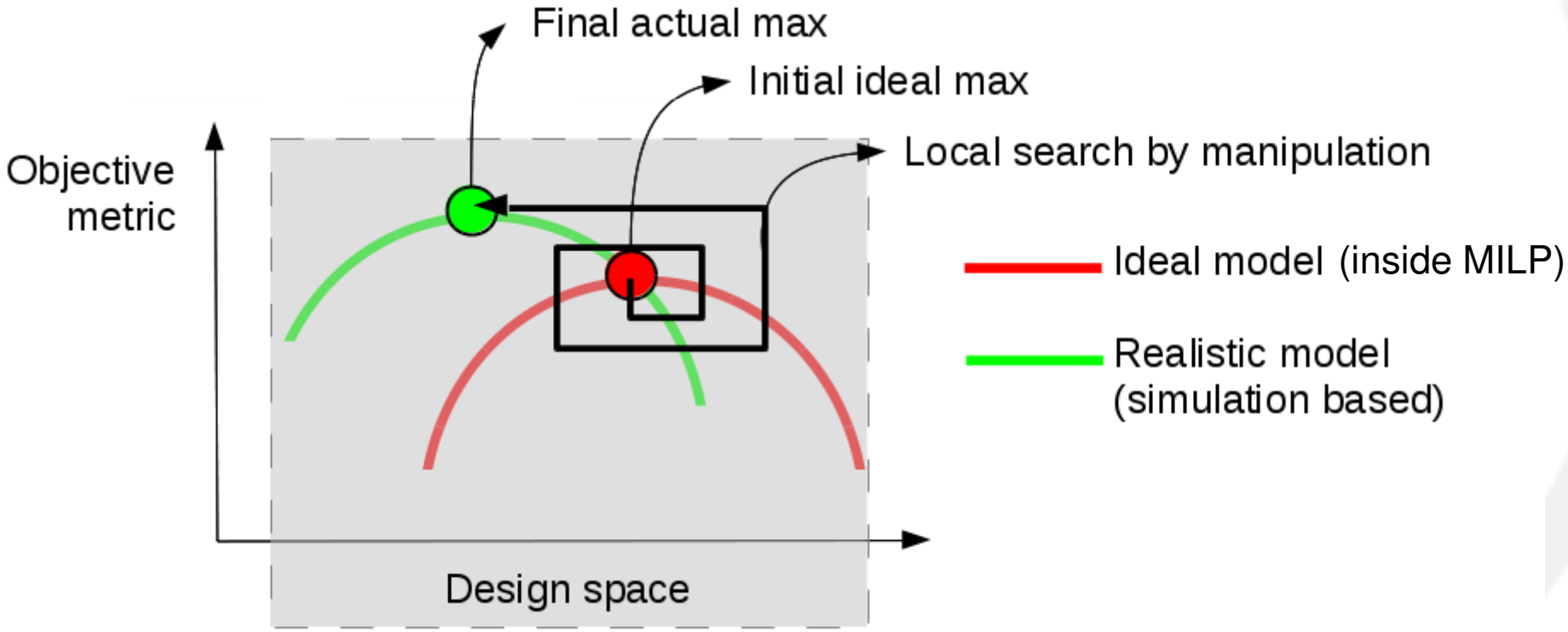
Introduction and motivation

Limits of MILP approach

- MILP with a large number of tasks can be too computational demanding
- Equations inside MILP represent ideal behavior which is different from real behavior (e.g., channel usage as a function of contained dataflows)

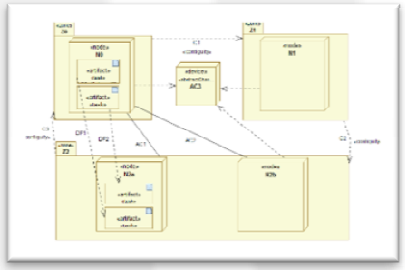


Introduction

- Optimal Network Synthesis
  - Methodology, which, starting from a high level description of the communication infrastructure, finds a network configuration as closest as possible to the optimum with respect to given objectives.
    - This is done by exploring the space of possible solutions through manipulations on the network configuration.
- Network Manipulation
  - Network manipulation is a process that takes a network configuration and generates another configuration which preserves some properties and alters some others, but employs a different combination of channels and nodes.

Methodology

Flow for optimal Network Synthesis



Network scenario high-level description

Optimization

- Economic cost
- Power consumption
- Transmission delay
- Error rate

Network scenario simulation model

Optimization Strategies

Optimized Network scenario simulation model

Simulation-based refinement

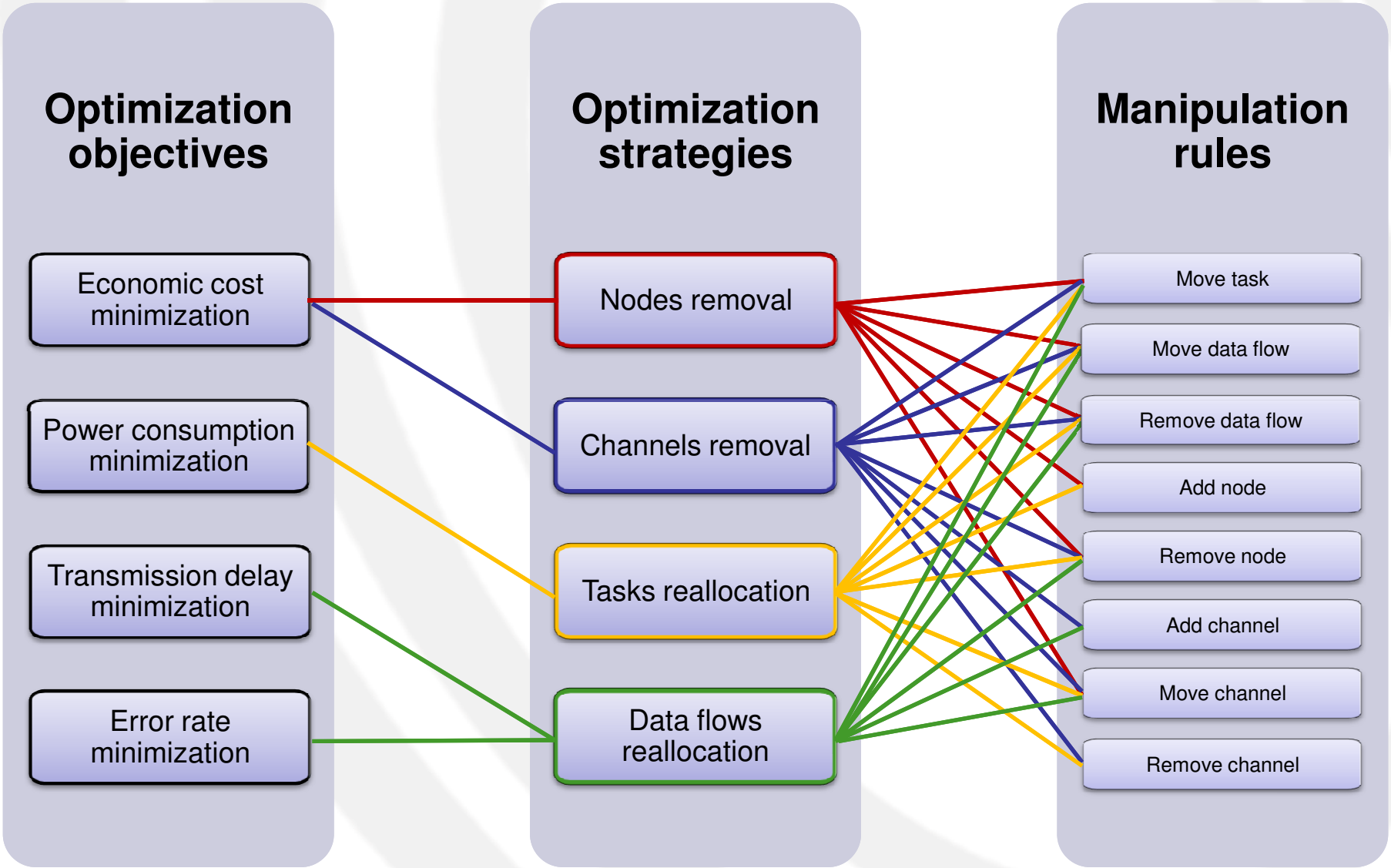
Manipulation

- Move task
- Move data flow
- Remove data flow
- Add node
- Remove node
- Move channel
- Add channel
- Remove channel

NW-Aware Refinement (1)

- The process consists of 3 steps:
  1. Definition of an ***optimization objective***
  2. Application of the ***optimization strategies*** according to the chosen optimization objective
  3. Use of ***manipulation rules***, driven by the specific optimization strategies

NW-Aware Refinement (2)



Optimization objectives

- Optimization objectives define the metrics that should be taken into account in the network synthesis of DES.
- Examples:
  - Economic cost minimization
  - Power consumption minimization
  - Transmission delay minimization
  - Error rate minimization

Optimization strategies

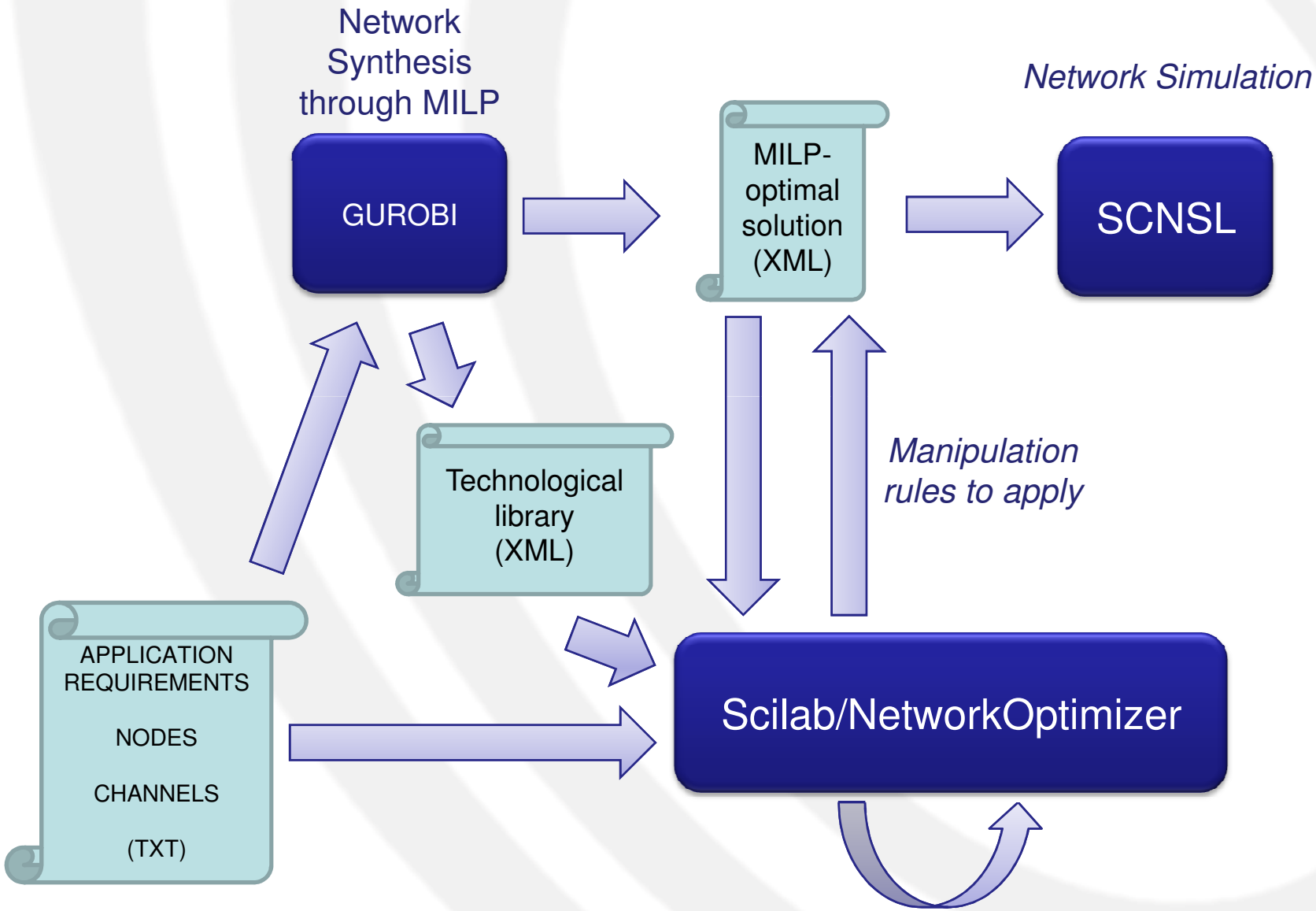
- Optimization strategies are sets of manipulations to apply to the network in order to achieve a certain goal. These manipulations should be used with a certain logic and a certain order, so as to produce a correct and consistent network configuration.
- Examples:
  - Nodes removal
  - Channels removal
  - Tasks reallocation
  - Data flows reallocation

Manipulation rules

- Manipulation rules are basic operations on the network entities of a DES, which alter the current configuration of the network structure. These manipulations on the network topology will be used for design space exploration to find an optimal configuration of the network.
- Examples:
  - Move task
  - Move data flow
  - Remove data flow
  - Add node
  - Remove node
  - Move channel
  - Add channel
  - Remove channel

Toolchain

Network Refinement Toolchain



Tools

- Network Synthesizer
  - Gurobi and MILP
- Network Optimizer
  - Scilab and manipulations
- Network Simulator
  - SCNSL

- SCNSL and Gurobi have been explained in previous lessons

Scilab/Network Optimizer

- `Network Optimizer` is a set of scripts written in the Scilab environment.
  - ***Scilab*** is a free and open source software for numerical computation (including *mathematical optimization*) providing powerful computing environment for engineering and scientific applications.
- Given an optimization objective, the Network Optimizer applies the appropriate strategies to find a set of network manipulations that make the scenario optimal (or near the optimal) with respect to the pre-fixed objective.
- The tool takes in input the XML file describing the network scenario (*i.e.*, the result of `Gurobi`) and returns another XML file containing the list of manipulation rules to be applied.

Workspace Setup

Workspace Setup

- Tools:
  - Gurobi
  - Scilab
  - Scnsl
- It is given for **granted** that Gurobi and Scnsl are already installed (previous lessons).
- However, here are the links to the previous slides:
  - [**Gurobi**] http://www.di.univr.it/documenti/OccorrenzaIns/matdid/matdid923787.pdf
  - [**Scnsl**] http://www.di.univr.it/documenti/OccorrenzaIns/matdid/matdid825163.pdf

Software Download

- Download Scilab from

```
http://www.scilab.org
```

- Untar the compressed file

```
Tar xvf scilab.tar
```

- Move it inside your home directory with name Scilab

```
mv scilab $HOME/Scilab
```

- Add Scilab bin/ directory to your PATH variable

```
export PATH="${PATH}:${HOME}/Scilab/bin"
```

- Go to your home directory

```
cd $HOME
```

- Clone the following repository

```
git clone https://github.com/Galfurian/NetworkSynthesizer.git
```

Exercises

Source Code Structure

- The structure of folders inside your home directory is the following:

```
$HOME
 - /Scilab
 - /NetworkSynthesizer
    - /1_Gurobi_Synthesizer
    - /2_Scilab_Optimization
```

Network Optimization Folder

- "*2_Scilab_Optimization*" contains the following directories:
  - *inputs*
    - XML files generated using the the network synthesizer script, of the Network Scenarios you want to optimize.
    - XML files containing the lists of nodes and channels available from the technological library.
  - optimizations
    - Scripts for optimization objectives, optimization strategies and manipulation rules.
  - *output*
    - XML files generated by the `NetworkOptimizer`, containing the manipulation rules to apply on the initial Network Scenario in order to obtain an optimal configuration of the network infrastructure.

Exercises Setup (1)

- Move to the today's class exercise folder, which resides in your cloned repository:

```
cd $HOME/NetworkSynthesizer/1_Gurobi_Synthesizer
```

- Execute the python script on TestCase1, with the goal of minimizing the global cost:

```
./Synthesize.sh TestCase1 1 1
```

- N.B.: The second parameter (=1) allows to generate two files:
  - `TestCase.xml and TestCase.techlib.xml`
- Copy both XML files inside the **inputs** folder inside the network optimizer forlder:

```
cp TestCase.xml          ../2_Scilab_Optimization/inputs
cp TestCase.techlib.xml  ../2_Scilab_Optimization/inputs
```

- Go to the optimizer folder:

```
cd ../2_Scilab_Optimization
```

Exercises Setup (2)

- Execute scilab as a command line interpreter:

```
scilab -nw
```

- Execute the network optimizer script:

```
exec('networkOptimizer.sce', 0)
```

- Select as optimization objective the Economic Cost Minimization

```
--> 1
```

- Provide the name of the test case file contained inside the inputs directory:

```
--> TestCase
```

- Provide the name of the associated technological library:

```
--> TestCase
```

- Quit Scilab

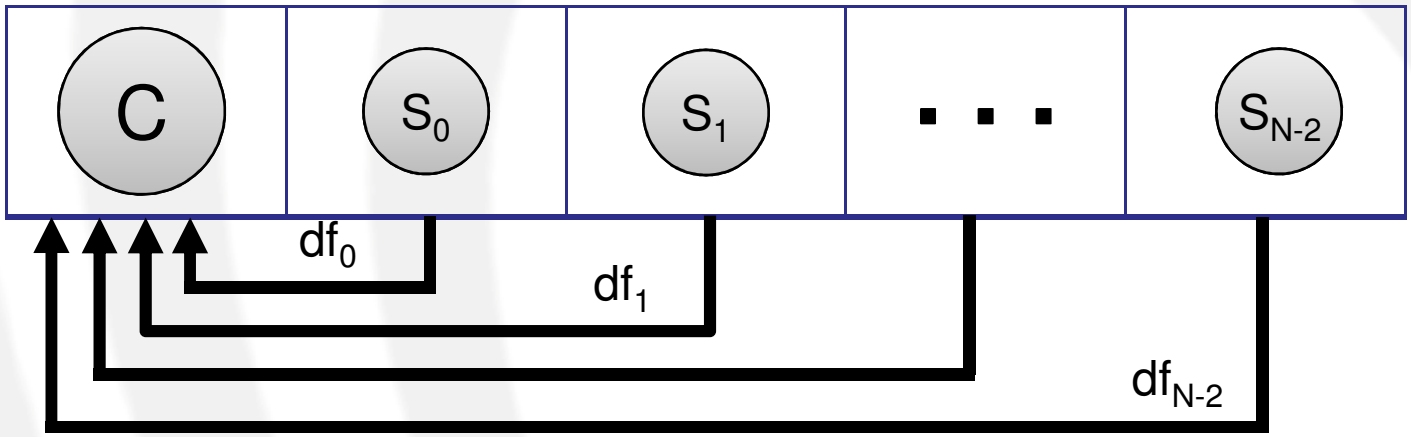
```
--> quit
```

- The output of the refinement process are inside the **outputs** folder.

Notes

- The Gurobi script generates always files with the same name:
  - TestCase.xml
  - TestCase.techlib.xml
- So, avoid using synthesized networks with previous or incorrect technological libraries.

Exercise 1



- Model using Gurobi the Temperature Monitoring Example.
- Each task is connected through a dataflow to the collector task with characteristics: Band=5 Delay=Error=50.
- Increase the number of tasks and measure the elapsed time required by the MILP to find the solution with the economic cost minimization (USER + SYS).
- You can use the channels and nodes provided by the test case BuildingTemperature which you can find inside the repository.

Exercise 2

1. Take the largest scenario tested in Exercise 1 and implement it with SCNSL.
    1. Do not use 802.15.4 protocol.
    2. Set the channel capacity equal to the bandwidth of the channel choosen by the MILP.
2. Run the simulation.
3. Compute the Packet Loss Rate (PLR) using the previously provided script.
4. Does it work? (Why?)

Exercise 3

1. Modify the SCNSL example in order to find a better and working solution.
2. How have you changed the network setup?

Exercise 4

- Apply Scilab optimization to the generated Test Case using the economic cost as optimization objective.