Architecture, Model and Analysis of CPS (AMA-CPS)

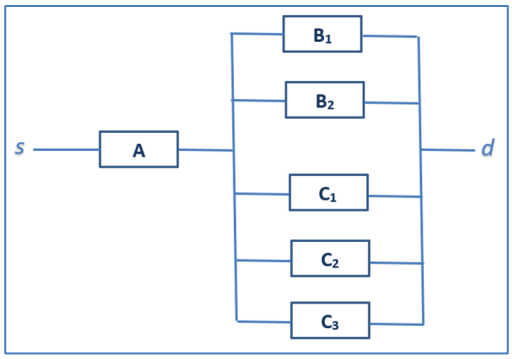
Academic Year 2024-2025

Project on Modelling and Analysis

The project aims to model and evaluate the dependability of a critical system.

System specification.

The system is defined through the Reliability Block Diagram shown in the picture.



The system fails if there is no path between *s* and *d*, otherwise it is working. While the system is failed (not working), the units cannot fail (they are not operational).

- Unit A has a constant (negative exponential) failure-rate equal to $\lambda/4$, and it is repaired with a constant (negative exponential) rate equal to $\mu/4$;
- Each unit B_i, with $1 \leq i \leq 2$, fails with a constant (negative exponential) rate equal to $\lambda/2$, and it is repaired with a constant (negative exponential) rate equal to $\mu/2$;
- Each unit C_i, with $1 \leq i \leq 3$, fails with a constant (negative exponential) rate equal to λ, and it is repaired with a constant (negative exponential) rate equal to μ.

Scenarios (system configurations).

Different scenarios can be built combining the following different options that define i) the conditions for starting the repair of the failed units; ii) the order for repairing the units; iii) the conditions for re-starting the system. More in detail:

- Conditions for starting the repair of the failed units (Options of type R):
  - Option (R1): the units cannot be repaired until the whole system fails (i.e., there is no path between *s* and *d*);
  - Option (R2): the units can be repaired as soon as they fail (even if the whole system is not yet failed).
- Order for repairing the units (Options of type O):
  - Option (O1): repairs are carried out sequentially (one after the other), respecting the following order: first A, then B_1, B_2 and finally C_1, C_2, C_3;
  - Option (O2): repairs are carried out sequentially (one after the other), respecting the following order: first C_1, C_2, C_3, then B_1, B_2, and finally A;
  - Option (O3): repairs can be carried out in parallel (more units under repair at the same time), with no restrictions on the order of repairs.

- Conditions for re-starting the system (Options of type W):
    - Option (W1): the failed system re-starts working as soon as there is again a path between *s* and *d*;
    - Option (W2): the failed system re-starts working only if all the failed units have been repaired.

Each combination of Options R, O and W corresponds to a specific system configuration (scenario) to be analysed.

Objectives of the analyses.

Students must analyse 1 scenario, defined as a combination of Option R, O and W, as previously described.

The metrics to be analysed for the scenario are as follows:

- The probability that the system is continuously working (i.e. it does not fail) in the interval [0;t], given that at the time t = 0 all the units of the system are correctly working;
- The steady-state availability.

Parameters' setting.

The metrics can be computed at varying of the following parameters:

- $\lambda = (10^{-2}, 10^{-3}, 10^{-4})$ failures per hour;
- $\mu = (10^{-2}, 10^{-3}, 10^{-4})$ repairs per hour;
- t = 1, 15, 45, 105, 225, 465 days.

Important Notes:

- The project can be developed **individually** or by a **group of students** (**3 students max** per group).
- **Before working on the project**, one person in each group has to send an email to paolo.lollini@unifi.it for **formally requesting the assignment of the scenario to be analysed**. The email should have the subject "AMA-CPS: project request", adding in cc the email of all the other members of the group (if any), and has to specify the composition of the group that will collaborate and jointly work on the project. In particular, for each member of the group, please specify: name, surname, student ID and email.
  The scenario to be analysed will be assigned to each group by the Teacher.
- Missing system specifications (if any) should be identified and properly addressed, e.g. introducing proper modeling assumptions.

Guidelines for Project preparation and submission:

The result of the project consists of a written report and the implemented models.

The written report must be in PDF format and must have the following minimum content:

- Name, surname and serial number of the student (or of the students forming the group).
- A synthetic (high level) description of the behavior captured by the atomic models, aimed at convincing an external reader that the models properly solve the problem without forcing the reader to analyse all the technical details of the models.
- Definition of reward variables (important - in detail).
- Used solver, with indication of the main parameters.
    - For example, in the case of Mobius specify whether you use the Mobius simulator (Mobius Simulator) or an analytical solver (Transient Solver, Accumulated Reward Solver, Direct Steady State Solver, etc.).
    - Guidelines on how to properly select the analytical solver can be found at: https://www.mobius.illinois.edu/wiki/index.php/Numerical_Solvers.
    - In the case of the Mobius Simulator, specify whether you are performing a Terminating Analysis or a Steady-State Analysis. In the case of Steady-State Analysis it is necessary to specify the initial transient, the batch size, the minimum and maximum number of batches, etc.
- The results obtained from the solver shown in textual form (table, sequence of numbers) or, better, using figures and graphs, with comments that explain and justify the trend of the obtained results (important!).
- Conclusion, highlighting what has been learned from the analysis of the project results.

The model developed with the Mobius tool must be compressed and stored in a single file using the archive command provided by the tool, which generates a file of format tar.gz.
A single tar.gz format file named "AMA-CPS-project-xyz.tar.gz", where x, y, and z are the initials of name and surname of each of the members of the group, should be sent to paolo.lollini@unifi.it containing only TWO files:

- a PDF file for the report;
- a tar.gz file containing the developed model.

Important Notes for the exams on PART II:

- ORAL INTERVIEW: The dates of the oral interviews are available on the Moodle page of the course, section "PART II- Modeling and Analysis". The oral interview will include a discussion on the project and other questions on the arguments covered in the "Modeling and Analysis" part of the course. If possible, all the members of each group should be interviewed in the same day (preferred option, but not mandatory).
- PROJECT SUBMISSION:
    - The project must be sent to the Teacher at least 1 week before the day of the oral interview. Late project submissions will NOT be considered for any reason.
    - Condition for admission to the oral interview is that the project is sufficient. The outcome of the evaluation of the project, whether sufficient or not, will be communicated to students via e-mail before the exam date.
- REGISTRATION FOR ORAL INTERVIEW: students willing to take the oral interview on a given round are requested to register. Info on deadlines for registering and on how to register is available on the Moodle page of the course, section "PART II- Modeling and Analysis".

Formal registration of the whole exam: For passing the whole exam of AMA-CPS, students have to pass both the two parts of the course: the "Architectural" part (with Prof. Ceccarelli) and the "Modeling and Analysis" part (with Prof. Lollini). Then the final score of the exam will be officially registered at the next available formal session (appello) of the course.