2018-00661 - Replication Algorithms for Real-time Tasks with Precedence Constraints [PhD Campaign - Campagne Doctorants Grenoble Rhône-Alpes]

**Contract type:** Public service-fixed-term contract  
**Level of qualifications required:** Graduate degree or equivalent  
**Fonction:** PhD Position

**About the research centre or Inria department**

Inria the French national institute for research in computer science and control, is dedicated to fundamental and applied research in information and communication science and technology (ICST). Inria has a workforce of 3,800 people working throughout its eight research centers established in seven regions of France.

Grenoble is the capital city of the French Alpes. Combining the urban life-style of southern France with a unique mountain setting, it is ideally situated for outdoor activities. The Grenoble area is today an important centre of industry and science (second largest in France). Dedicated to an ambitious policy in the arts, the city is host to numerous cultural institutions. With 60,000 students (including 6,000 foreign students), Grenoble is the third largest student area in France.

**Context**

Project-team leader: Frédéric Vivien


Advisor: Yves Robert, Professor, ENS Lyon  
Co-advisor: Frédéric Vivien, Research Director, INRIA

Place of the research work: LIP, ENS Lyon.

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Website: [http://graal.ens-lyon.fr/~yrobert/](http://graal.ens-lyon.fr/~yrobert/)

The thesis will be conducted within the ROMA project-team at Ecole Normale Supérieure de Lyon, under the co-supervision of Yves Robert and Frédéric Vivien.

**Assignment**

A real-time system is responsible for performing logically correct computations while meeting predefined deadlines. Failing to meet these deadlines often results in catastrophic system failures. Transient faults triggered by cosmic rays or electromagnetic interference have to be tolerated when executing the tasks, which calls for sophisticated replication strategies. However, replication has a high cost in terms of consumed energy, which is a critical resource in embedded real-time systems. Altogether, enforcing all task deadlines while tolerating transient faults and without exceeding a given energy budget is a challenging endeavor.

The thesis will target real-time workflows, i.e., pipelined instances of the same set of tasks whose dependence graph is a given DAG (Directed Acyclic Graph). Instance number 1 is released at time 1/P and must complete by time (1+1)/P, where P is the global period of the problem. The workflow instances are mapped onto a parallel platform with N identical processors.

Each task is subject to transient failures, with some probability that is typically evaluated as a function of the task worst-case execution time. A reliability threshold is enforced, either task by task, or globally, which calls for replicating each task with a different number of replicas. However, when the execution of one replica succeeds, the other replicas are cancelled.

The energy consumed by each replica of each task depends upon the frequency chosen for its execution. The lower the frequency, the less energy consumed, but the longer the execution time; a low frequency may prevent the workflow deadline to be matched. Also, if the execution of the replicas...
of a given task do not overlap, energy consumption will be smaller whenever the first execution succeeds.

Altogether, this calls to designing schedules that achieve several trade-offs. The problem is to find:
(i) a number of replicas for each task
(ii) a frequency for each task replica
(iii) a mapping and scheduling of all these replicas onto the processors
The constraints are to match the reliability threshold and the deadlines, and the objective is to minimize the expectation of the consumed energy.

Main activities

** First research direction

The first research direction is to address the simpler case of independent tasks with the same period. A preliminary study has been conducted in [1], where some heuristics have been introduced. The thesis will assess whether the problem of scheduling the task replicas once the mapping and frequencies are given is NP-complete or not, and will design optimal algorithms (if the problem is polynomial) or efficient heuristics (if is is NP-complete). Then the thesis will investigate approximation algorithms to solve the general problem for independent tasks.

** Second research direction

The next step will be to consider independent tasks with different periods. The scheduling of the tasks becomes less flexible, and the EDF policy (Earliest Deadline First) is usually enforced to guarantee that all deadlines are matched. The thesis will design algorithms and evaluate their efficiency for this problem.

** Third research direction

The thesis will eventually tackle dependence graphs, first of a particular form (chains, fork-joins) and then will address the general problem.

** General methodology

The work will be conducted along three main lines:
- Synthesis of relevant literature,
- Design and analysis of new and multi-criteria algorithms
- Evaluation through simulations and using benchmark workflows.

** Bibliography:

- General references:

- Reference on real-time workflows:


Skills

Basic background in computer science, probability theory, interest in algorithm design and complexity.

Benefits package

- Subsidised catering service
- Partially-reimbursed public transport
- Social security
- Paid leave
- Flexible working hours
- Sports facilities
Remuneration
Monthly salary after taxes: around 1596,05€ for 1st and 2nd year. 1678,99€ for 3rd year. (medical insurance included).