CRÊPE: Clock Reconfigurability for Preemption Control (Artifact)

Eva Dengler
Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany

Peter Wägemann
Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany

Abstract

With the emergence of embedded system-on-chip (SoC) platforms, the development of energy-constrained real-time systems brings numerous novel challenges for optimal resource consumption. On these modern hardware platforms, complex clock subsystems make it possible to trade-off between temporal performance and energy efficiency by reconfiguring the system, which exceeds the state-of-the-art of existing dynamic-voltage-frequency-scaling (DVFS) scheduling schemes. On embedded real-time systems, the usage of the devices (e.g., transceiver/memory/sensor devices) is an essential component to be able to interact with the surrounding world. Each device has precedence constraints with respect to specific clock sources and their settings. Therefore, to select resource-optimal configurations, we need to adapt the clock subsystem, which becomes especially challenging in the presence of asynchronous preemptions, often found during device interaction.

This artifact evaluation covers the work of CRÊPE, an approach to clock-reconfiguration–aware preemption control on systems with devices. CRÊPE makes use of the target platform's clock subsystem, possible idle modes, and the reconfiguration penalties for adapting the clock subsystem. By combining a hardware model for the device under investigation with an awareness of the required clock configuration for each task, as well as possible interrupts causing preemptions during runtime, CRÊPE employs a mathematical formalization to determine energy-minimal configuration sequences while meeting all given deadlines. Before runtime, CRÊPE solves the mathematical problem with standard mathematical solver tools and generates optimal execution strategies and clock-system reconfigurations before runtime. These offline-generated schedules are then assessed by the dispatcher during runtime, leading to an overall minimized energy consumption with minimal overhead during execution. CRÊPE also consists of an implementation based on a widely-used SoC platform (i.e., ESP32-C3) and an automated testbed for comprehensive energy-consumption evaluations. This artifact evaluation makes use of these to validate CRÊPE's claim of selecting resource-optimal settings under worst-case considerations by reproducing our results shown in the related CRÊPE paper [1].

2012 ACM Subject Classification Computer systems organization → Real-time systems

Keywords and phrases energy-constrained real-time systems, time/energy tradeoff, system-on-chip, energy-aware real-time scheduling, resource minimization, preemption control, worst-case energy consumption (WCEC), worst-case execution-time (WCET), static whole-system analysis

Digital Object Identifier 10.4230/DARTS.10.1.2

Funding This work is funded by the German Research Foundation (Deutsche Forschungsgemeinschaft, DFG) under the project number 502947440 (WA 5186/1-1, Watwa: Whole-System Optimality Analysis and Tailoring of Worst-Case–Constrained Applications).

Related Article Eva Dengler and Peter Wägemann, "Crêpe: Clock-Reconfiguration–Aware Preemption Control in Real-Time Systems with Devices", in 36th Euromicro Conference on Real-Time Systems (ECRTS 2024), LIPIcs, Vol. 298, pp. 10:1–10:25, 2024.
`https://doi.org/10.4230/LIPIcs.ECRTS.2024.10`

Related Conference 36th Euromicro Conference on Real-Time Systems (ECRTS 2024), July 9–12, 2024, Lille, France

Dagstuhl Artifacts Series, Vol. 10, Issue 1, Artifact No. 2, pp. 2:1–2:3
Dagstuhl Artifacts Series
Schloss Dagstuhl – Leibniz-Zentrum für Informatik, Dagstuhl Publishing, Germany

1 Scope

This artifact has the scope of validating the evaluation results of the related paper [1] on the Crêpe approach. The paper presents evaluations, some of them depending on specific hardware setups and components. For the generation of the data, Crêpe uses a custom printed circuit board (PCB) and an energy-measurement unit, namely the JouleScope JS220 [3]. In order to reproduce the respective figures, the raw data of the gathered energy-measurement outputs are included in the artifact, as the process of generating the data goes beyond the scope of this artifact evaluation. To give researchers the possibility to also acquire this raw data, we publicly release the schematics for Crêpe's circuit board, the description of our measurement hardware infrastructure, as well as the code used to collect the data as open-source hardware and software: `https://gitos.rrze.fau.de/crepe`

2 Content

The virtual machine (VM) of the artifact package includes:

- A checkout of `https://gitos.rrze.fau.de/crepe/ecrts24-artifact-evaluation` in `/home/crepe/crepe/`
  The repository contains all required scripts to redo the evaluation.
- Readouts from our hardware setup in `/home/crepe/readouts/`.
- A pre-installed operating system, together with all required software installed.

The `README.md` of the git repository details the single steps to execute the scripts in the VM.

3 Getting the artifact

The artifact endorsed by the Artifact Evaluation Committee is available free of charge on the Dagstuhl Research Online Publication Server (DROPS). In addition, the artifact scripts are also available at: `https://gitos.rrze.fau.de/crepe`, and the VM image at `https://sys.cs.fau.de/research/data/crepe/ecrts24/crepe.ova`.

4 Tested platforms

For a high degree of portability, we prepared an environment inside a virtual-machine image, which is executable using the `VirtualBox` hypervisor [4]. `VirtualBox` is available for all common platforms, thereby reducing the hardware requirements for running the artifact to a minimum. The VM runs a Ubuntu 24.04 operating system, with the necessary tools installed from the standard Ubuntu package manager.

Besides the parts directly included in the VM, the evaluations require a powerful mathematical solver in order to solve quadratic problem formulation. For the Crêpe's experiments, we use `Gurobi` [2]. To use Gurobi, obtaining a license is required: Users from academia (with a respective email address) can request a license free of charge on the `Gurobi` website (`https://www.gurobi.com/downloads/end-user-license-agreement-academic/`).

5 License

The artifact is available under the GPL-v3 license.

6 MD5 sum of the artifact

827049bbcf5755648bec9644e6e320d1

7 Size of the artifact

7.0 GiB

References

1 Eva Dengler and Peter Wägemann. Crêpe: Clock-reconfiguration–aware preemption control in real-time systems with devices. In *Proceedings of the 36th Euromicro Conference on Real-Time Systems (ECRTS '24)*, pages 10:1–10:25. Schloss Dagstuhl – Leibniz-Zentrum für Informatik, 2024. `doi:10.4230/LIPIcs.ECRTS.2024.10`.

2 Gurobi Optimization, LLC. Gurobi optimizer reference manual. `https://www.gurobi.com/`.

3 Jetperch LLC. *Joulescope JS220 User's Guide Precision DC Energy Analyzer*, 2022. Revision 1.3. URL: `https://download.joulescope.com/products/JS220/JS220-K000/users_guide/`.

4 Oracle Corporation. VirtualBox. `virtualbox.org`.