A Hardware Testbed for Renewable-Aware Resource Management at the Edge

Bachelor's Thesis

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I hereby declare that the thesis submitted is my own, unaided work, completed without any unpermitted external help. Only the sources and resources listed were used. The independent and unaided completion of the thesis is affirmed by affidavit.

Berlin, May 16, 2022

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Zusammenfassung

Abstract

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Chapter 1

Introduction

Edge computing is a promising, emerging paradigm in the area of distributed systems and while still primarily being a theoretical concept, the rise of new domains like Internet of Things (IoT) establishes numerous areas of application [1]. Because of the decentralized nature of edge computing, new devices at the edge of the network are essential for many of these approaches. In some cases though, edge devices do not have access to the electrical grid and require on-site energy generation. Large-scale data centers already profit from integration of on-site renewable energy generation and are able to achieve significant cost reductions while also reducing their greenhouse gas emissions. [2]. In its current state however, renewable energy generation is rather volatile and unable to supply sufficient uninterrupted power on its own [3], resulting in a problem for edge devices without a connection to the electrical grid. If devices under these circumstances aim to operate self-sufficiently and maximize uptime, their resources need to be managed dynamically, relative to current on-site renewable energy production.

To allow for dynamic resource management, matching the system's energy consumption to the on-site production, numerous approaches for power management pose a viable option. Power management, in this case energy proportional computing, can generally be pursued on a hardware- and software-level [4]. On a hardware-level, dynamic voltage and frequency scaling (DVFS), the dynamic adjustment of both voltage and frequency to reduce dynamic power consumption, is vital for this intention as the CPU traditionally consumes the most power in a system.

Recent Research in the area of energy-aware resource management in edge/fog computing utilizing DVFS for power management mainly relies on simulations to predict a real-world outcome [5, 6, 7]. Most simulators make the assumption that computational load can be adjusted in a way that energy consumption perfectly matches the energy production [8, 9, 10, 11]. While the reasoning for using simulations as opposed to real hardware testbeds may be justified and opportune for most research projects, it remains unclear how close these assumptions are to reality and how this may change the accuracy of the predictions and consequently research outcomes.

1.1 Testbed Requirements

This bachelor's thesis proposes a hardware testbed for renewable-aware resource management in edge computing, capable of dynamically adjusting its computational load relative to the on-site

renewable-energy production. In order to examine the assumption of energy-aware simulators, that computational load is adjustable so that energy consumption is matched to production, this thesis proposes to compare simulations derived from real-world data to this physical hardware testbed. To provide the necessary data to compare the simulations to, a testbed with the following properties is required.

1. Renewable energy is produced and consumed respectively.
2. Excess energy produced, can be stored and retrieved if the production fails to provide sufficient power.
3. $$\frac{P_{\text{load}}}{P_{\text{idle}}} \geq 2.$$

   Adjusting the consumption to current production is more meaningful, in regard to energy savings, if the quotient between the power consumption under load and idle is as high as possible. In order to work properly with the data provided, the lower bound 2 was chosen.
4. The current energy production and resources' power draw can be measured in Volts and Amperes respectively. The amount of stored power can be measured.
5. Resources can be managed dynamically. This is necessary for adjusting the consumption depending on the current production of renewable energy.

1.2 Thesis Outline

Chapter 2

Background

2.1 Edge Computing Paradigms

2.2 Testbeds in Edge Computing Environments

2.3 Dynamic Resource Management

2.3.1 Dynamic Voltage and Frequency Scaling

Chapter 3

Related Work

3.1 Energy-Aware Resource Management with DVFS

3.2 Energy-Aware Simulators

Chapter 4

Testbed

4.1 Hardware Components

4.2 Hardware Assembly

4.3 Software

4.4 Implementation of DVFS

Chapter 5

Evaluation

Chapter 6

Conclusion

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