Master's Thesis

Privacy-preserving Smart Metering Using DC-Nets

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Lorem Ipsum

Selbständigkeitserklärung

Hiermit erkläre ich, dass ich diese Arbeit selbstständig erstellt und keine anderen als die angegebenen Hilfsmittel benutzt habe.

Dresden, den **?today?**

Gregor Garten

Abstract

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1 Introduction

1.1 A Section

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Name	Y	Z
Foo	20,614	23 %
Bar	9,914	11 %
Foo + Bar	30,528	34 %
total	88,215	100 %

Table 1.1: Various very important looking numbers and sums.

More text referencing Table 1.1.

1.2 Another Section

Citing [**bellard2005qfa**] other documents [**bellard2005qfa**; **boileau06**] and Figure 1.1. Something with umlauts and a year/month date: [**becher04:ˑfeurigˑhackenˑmitˑfirew**]. And some online resources: [**green04**], [**patent:4819234**]

1.3 Yet Another Section

1.4 Test commands

DROPS L⁴LinuxNOVA QEMU `memcpy` A sentence about BASIC. And a correctly formatted one about ECC.

Figure 1.1: A long description of this squirrel figure. Image taken from `http://commons.wikimedia.org/wiki/File:Sciurus-vulgaris_hernandeangelis_stockholm_2008-06-04.jpg`
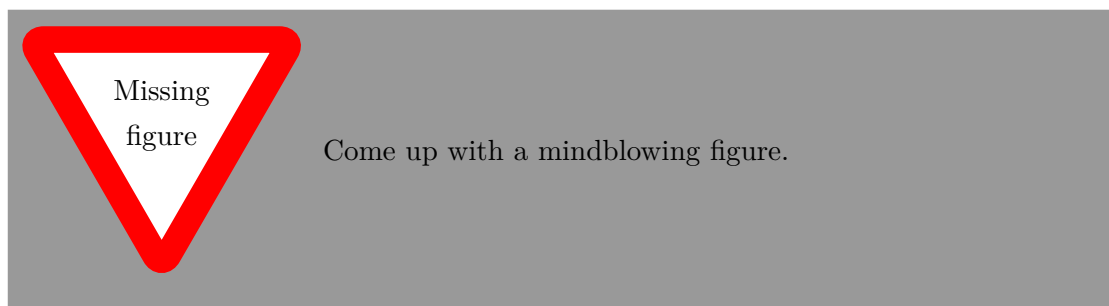

Come up with a mindblowing figure.

Figure 1.2: A mindblowing figure

2 Technical Background

This section introduces an overview of the basic concepts for this work. Therefore, the key components of the smart grid are explained, what structural changes and what challenges the smart grid will bring. In addition, this chapter discusses the current state of research.

2.1 Smart Grid

The original energy network was mainly considered as a transmission system to send electricity from the generators via a elongated network of cables and transformers to the consumers.Instead of a few electricity producers (e.g. nuclear power plants, coal-fired power plants), which were responsible for a large part of the electricity generation, there are now many smaller producers (e.g. wind turbines). However, renewable power generation is often dependent on external environmental factors. In order for the smart grid to be stable despite fluctuations in power generation, smart meters have been introduced. This enables the electricity provider to receive the electricity consumption of a household every 15 minutes. It offers the possibility to get more easily the current electricity demand from the consumers. Previously, the current electricity demand was simulated from load forecasting models. If the demand should increase spontaneously, peaker plants, mainly consisting of coal-fired power plants, would be turned on to quickly meet this demand. This is costly and environmentally unfriendly. Since then, structural changes have been made to optimize the energy grid and make it more intelligent by exchanging information in near-real-time. This allows the demand to be matched to the available supply. The fundamental component of the smart grid are the smart meters, which were already mentioned. They which will be discussed in more detail in the next section.(Quelle:Smart Grid Communications)(Privacy Survey2013)

2.2 Smart Meter

Smart meters are the key component in a smart grid. A smart meter is an electricity meter that has an interface to the Internet. It enables two-way communication between the control center and the meter. This is also called Advanced Metering Infrastructure (AMI). Two-way communication improves the quality of the power grid and makes it possible to offer services that would not be feasible without a smart meter. For example it's now practicable to detect power outages.As a result, the power grid operator can detect power failures on its own. Previously, the operator was dependent on customer calls to detect power outages. Another new feature is detailed monitoring of power

flows at the smart meter. Before, power flows could only be measured up to substations. This new function enables electricity network operators to quickly detect changes in consumption behavior and react to them without having to use peaker plants, which are costly and environmentally unfriendly. Depending on the setting, smart meters can send electricity consumption to the electricity provider at least every 15 minutes. In combination with the consumption of all users and the current electricity supply, a better price can be achieved. This is also called real-time pricing. So not only can the customer be offered a better electricity contract, in addition the meters no longer have to be read at home by a technician from the electricity provider. This makes billing easier for customers and electricity providers. Furthermore, customers can also check their current electricity consumption via the interfaces provided by the smart meter in order to analyze their own behavior and to reduce their consumption. (Privacy-Aware Smart Metering)

2.3 Smart Meter Privacy

The main advantage of the smart grid is the communication between the consumers and the energy suppliers. It is precisely this communication that solves a lot of structural problems in today's energy system. However, sending user information every 15 minutes allows for new methods that can be used to create accurate behavioral analyses in one's own home. Sending private electricity consumption data is therefore very sensitive information and must to be protected. This is not an easy task, because on the one hand the electricity consumption must be protected and anonymized, and on the other hand the billing and costs must be clearly assignable to a person. In the following paragraphs, we will describe how simple behavioral analyses are generated by electricity consumption. Subsequently, solutions to Metering for Billing and Metering for Operations will be presented, which have been discussed in the scientific community so far.(Privacy-Aware Smart Metering)

2.3.1 Non-intrusive load monitoring

Interpreting power consumption with the intent of identifying devices in the home is called non-intrusive load monitoring (NILM). George Hart and Fred Schweppe were the first to develop non-intrusive load monitors in 1985 and connect them to electricity meters. They were able to record the current power consumption up to every 5 seconds. Then they did the following steps to identify appliances in a household:

1. Edge Detection:
   Look for sharply rising or steeply falling edges in the stored electricity consumption. These edges indicate that a device may have been switched on or off at that moment.

2. Cluster Analysis:
   The events of steeply rising or steeply falling edges are saved. These events are then visualized in a graph with the following characteristics. Each event is ordered
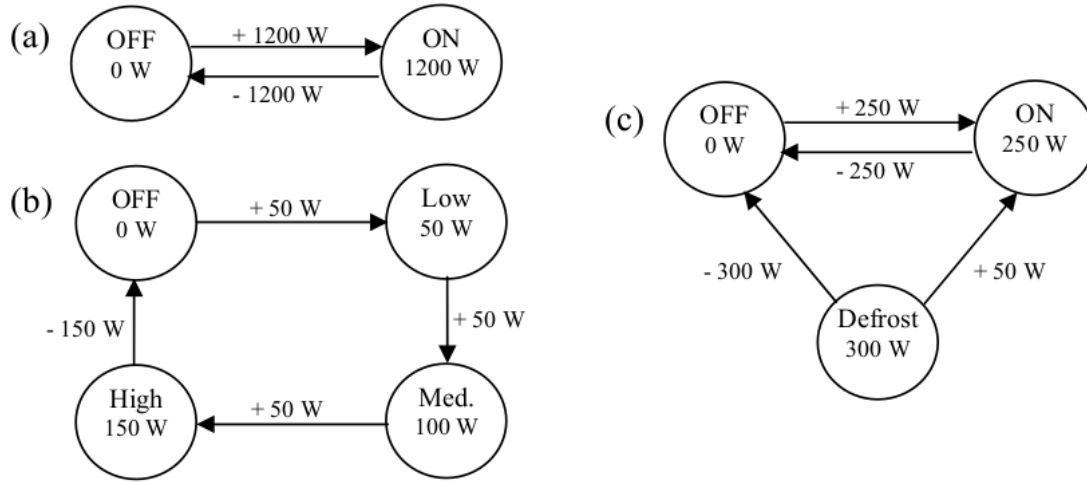
Figure 2.1: An example of a NILM analysis.

according to how much power was consumed or how much power was "released" from the device (e.g. when it was switched off). Essentially, a cluster analysis is then applied to the diagram and each cluster represents a household appliance.

3. Appliance Model Construction
   Since different household appliances have been determined by the clusters, appliance models can now be constructed. In this step, different states in which an appliance can be in, are found based on the different power consumption. An example of how the result of a appliance model looks like can be seen in Figure 2.1.

4. Behavior Analysis:
   Once the majority of the household appliances have been identified, the behaviors of people in the household can be analyzed. In real time, it is possible to track the use of devices, since individual signals can be identified as they occur and do not need to be reconstructed anymore. At this point, several approaches can be taken to provide behavioral analysis. A common approach is to track how long a device has been in use and create statistics on how each device has been used. A daily analysis can be viewed in Figure 2.2.

5. Appliance Saving:
   The last approach is to name the household appliances found(washing machine, etc.) and store them in a database. So that in the case of a further household analysis, it is possible to fall back on appliances that have already been found.

The founder of NILM G. W. Hart himself said in 1989: "Specifically, I recommend that legal restrictions be enacted or clarified so that electric power usage is considered as private as any phone conversation."(Residential Energy Monitoring) Hence, there is a need for a privacy-preserving solution for smart meters. Although the original NILM approach measured power consumption every 5 seconds, there are now methods to
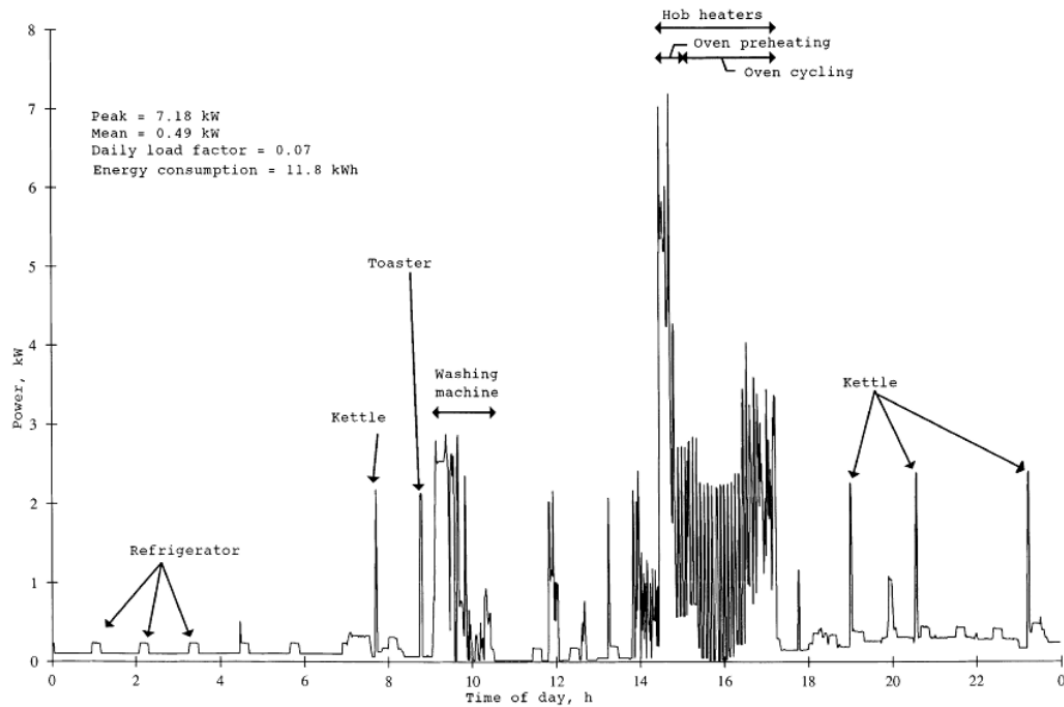
Figure 2.2: An example day of a NILM analysis.

identify household appliances when power consumption is measured every 15 minutes.(A Neuron Nets Based)

2.3.2 Metering for Operations

The paragraph deals with solutions for Metering for Operations, which has been previously discussed in other scientific works. At Metering for Operations, there is currently no established consensus on a solution. Various technical proposals have already been presented in scientific papers, but there is a lack of uniform criteria and often different conditions are set for the power grid, which is why the results can be different. Of course, the different national implementations of smart grids also play a role in the absence of common criteria. In the following, the different approaches are divided into categories and presented conceptually.

Provide Anonymization or Pseudonymization Without Aggregation

write state

3 Design

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4 Implementation

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5 Evaluation

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6 Future Work

. . . future work . . .   write future
                                                                                           work

7 Conclusion And Outlook

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sion