D.6.1.2b: Operation-oriented application of the dynamic load profiling

Photo: By & Havn / Ole Malling

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Public deliverable	X
Confidential deliverable	☐

Preface

EnergyLab Nordhavn – New Urban Energy Infrastructures is an exciting project which will continue until the year of 2019. The project will use Copenhagen's Nordhavn as a full-scale smart city energy lab, which main purpose is to do research and to develop and demonstrate future energy solutions of renewable energy.
The goal is to identify the most cost-effective smart energy system, which can contribute to the major climate challenges the world are facing.

Budget: The project has a total budget of DKK 143 m (€ 19 m), of this DKK84 m (€ 11 m) funded in two rounds by the Danish Energy Technology Development and Demonstration Programme (EUDP).

Forord

EnergyLab Nordhavn er et spændende projekt der løber til og med 2019. Projektet vil foregå i Københavns Nordhavn, og vil fungere som et fuldskala storbylaboratorium, der skal undersøge, udvikle og demonstrerer løsninger for fremtidens energisystem.
Målet er at finde fremtidens mest omkostningseffektive energisystem, der desuden kan bidrage til en løsning på de store klimaudfordringer verden står overfor nu og i fremtiden.

Budget: Projektets totale budget er DKK 143 mio. (EUR 19 mio.), hvoraf DKK 84 mio. (EUR 11 mio.) er blevet finansieret af Energiteknologisk Udviklings- og Demonstrationsprogram, EUDP.

Project Information

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Task Leader: Carsten Buhl Nielsen, Radius
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List of Abbreviations

Executive Summary

Over the period 2015-2019 the project EnergyLab Nordhavn will develop and demonstrate future energy solutions. The project utilizes Copenhagen's Nordhavn as a full scale smart city energy lab and demonstrates how electricity and heating, energy efficient buildings and electric transport can be integrated into an intelligent, flexible and optimized energy system.

The present document is an opperation oriented adaptation of the online adaptive load clustering algorithm presented in D.6.1.2a. The methodology aims at providing more accurate insights on the demand side in order to manage the demand in a more agile and reactive way. The principal modification is that the clusters are not updated every day but every month which comply better with operational constrains. The change in performance between the online adaptive clustering described in D.6.1.2a and the adaptation presented in this deliverable is evaluated using the data collected from Nordhavn by Radius over the period 2017-04 to 2018-04.

Version Control

Version	Date	Author	Description of Changes
V1.0	2019-06-07	G. Le Ray	Original version
V2.0	2019-11-15	P. Pinson	Corrections after review

Quality Assurance

Author	Reviewer	Approver
G. Le Ray / P. Pinson	M.H. Christensen	WPL group

Status of deliverable		
Action	**By**	**Date/Initials**
Sent for review	G. Le Ray, DTU Elektro	**2019.06.07/gleray**
Reviewed	M.H. Christensen, DTU Elektro	**2019.11.10/mhchris**
Verified	P. Pinson, DTU Elektro	**2019.11.15/ppin**
Approved	WPL group	**2019.11.18/pbrath**

1. Introduction

Radius, formerly DONG Energy Distribution, is in charge of distributing electric power to approximately 960.000 households, businesses and industries in the northeastern part of Zealand. Radius has responsibility related to grid planning and to continuously improve the grid through maintenance and expansion.

In report Task 6.1.2a an online adapative clustering algorithm for load profiling was described and applied on Radius database. In short, it consisted of updating the partition of customers everyday using the last day (at t) metering data collection and the previous day (at $t-1$) clusters centers. From an application point of view, this algorithm suffered from having clusters updated too often which makes it hard to use in operation.

The algorithm described in this deliverable rely on the same principle, but instead of udating the partition on a daily basis, it updates it on a monthly basis.

2. Methodology

The algorithm in presented as a flowchart in Illustration 1. For the full overview of the methodology, we invite the reader to consult the method section of D.6.1.2a.

In the deliverable D.6.1.2a the data was loaded as block $\mathbf{\Omega}^t$ that consisted of daily consumptions $\{x_i^1, ..., x_i^t, ..., x_i^{24}\}$ of all the customers i. In this deliverable, $\mathbf{\Omega}^t$ is a block of the daily consumptions $\{x_{i,d}^1, ..., x_{i,d}^t, ..., x_{i,d}^{24}\}$ of all the customers i and day d. The direct consequence is that the number of clusters is larger over a month than over a day (roughly 3 times more) but the Typical Load Profiles are stable over the course of a month which make it easier to use in operation.

Furthermore, the exponential smoothing used in D.6.1.2a has been removed as we are now following combinations of customers i and day d and not only customers. Hence, it does not make sense to do exponential smoothing over the month for each customer.

3. Data

The data used to illustrate the behaviour the modified online adaptive clustering algorithm are the hourly consumption of 502 domestic customers from Nordhavn. The dataset covers the period from April 2017 to April 2018. The data have been normalized to make

the profiles comparable by dividing each customers time-series by its peak observed over the period so that the data take values between 0 and 1.

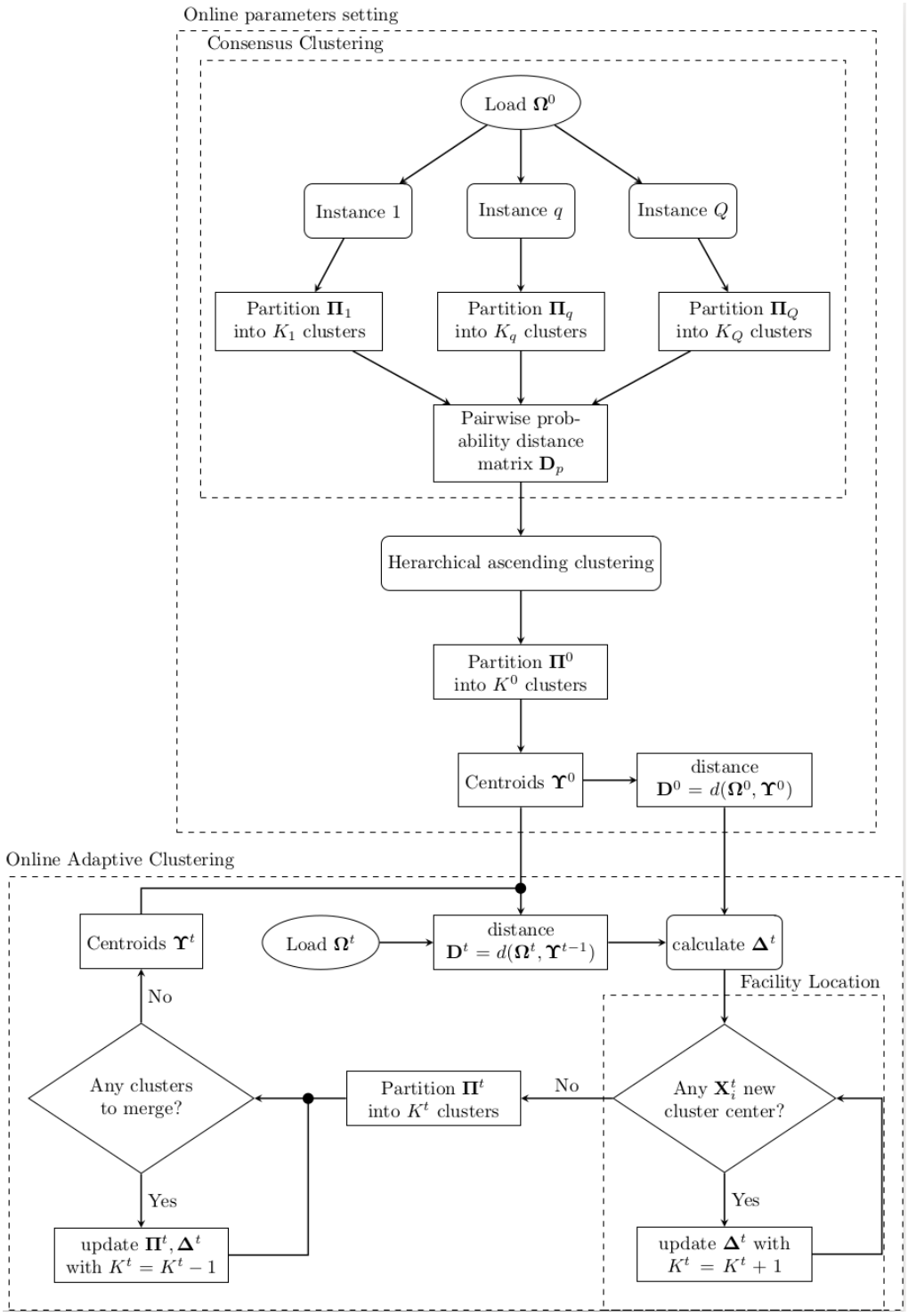

Illustration 1: Flowchart of the online adaptive clustering algorithm

4. Application

Both version of the algorithm have been applied to the dataset.

4.1 Settings

The daily dynamic load profiling have been implemented with a exponential smoothing of 0.85, with 5 initial clusters, the minimum number of 5 customers to create a new cluster, a facility cost of 25, and a minimum distance between clusters centers set to 0.1.

The monthly dynamic load profiling have been implemented with no exponential smoothing, with 16 inital clusters, a minimum number of 15 customers to create a new cluster, a facility cost of 650, and a minimum distance between clusters centers set to 0.1.

5. Results

The overview of the results of the daily dynamic load profiling is given in Illustration 2. The number of clusters fluctuate between 7 and 15 and the averaged RMSE is bounded between approximately 0.05 and 0.09. This result is in line with the performance observed in D.6.1.2a.

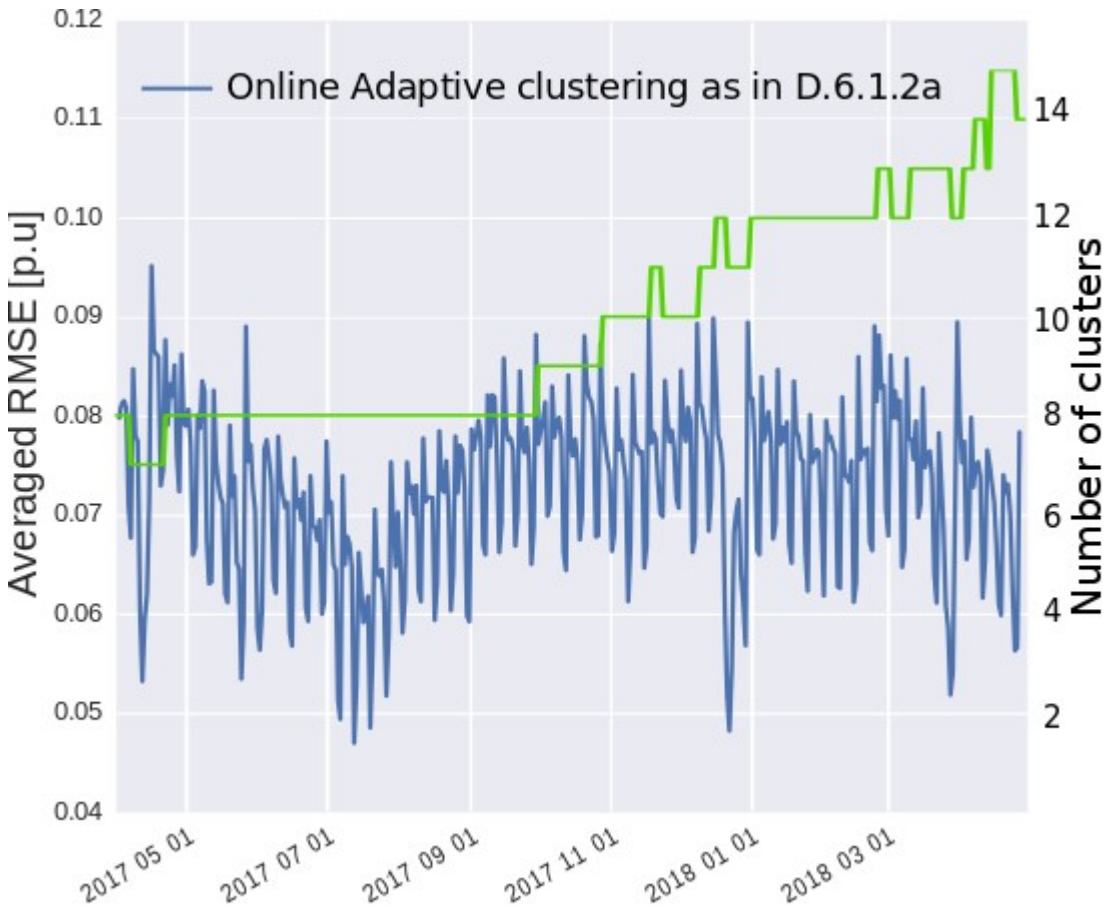

Illustration 2: Overview of the performance of the daily dynamic load profiling

The overview of the results of the monthly dynamic load profiling is given in Illustration 3. The number of clusters increases from 15 to 34 and the averaged RMSE is fluctuated between approximately 0.035 and 0.075. The improvement in performance from daily to monthly is a consequence of the removal of the exponential smoothing that was used in the version in D.6.1.2a . A drawback of not using the exponential smoothing is that the customers may change more often clusters. Further test should be run to estimate how long the period to take cluster on should be (e.g. 3 months, 6 months). The rule of thumb is that the longer the period the larger the number of cluster will be. It also means that statistically a customer will be able to visit many more clusters (as the number is larger). The benefit of the methodology remains that it is not require to take holidays or week ends into accounts as they will be clustered together if they display the same profile.

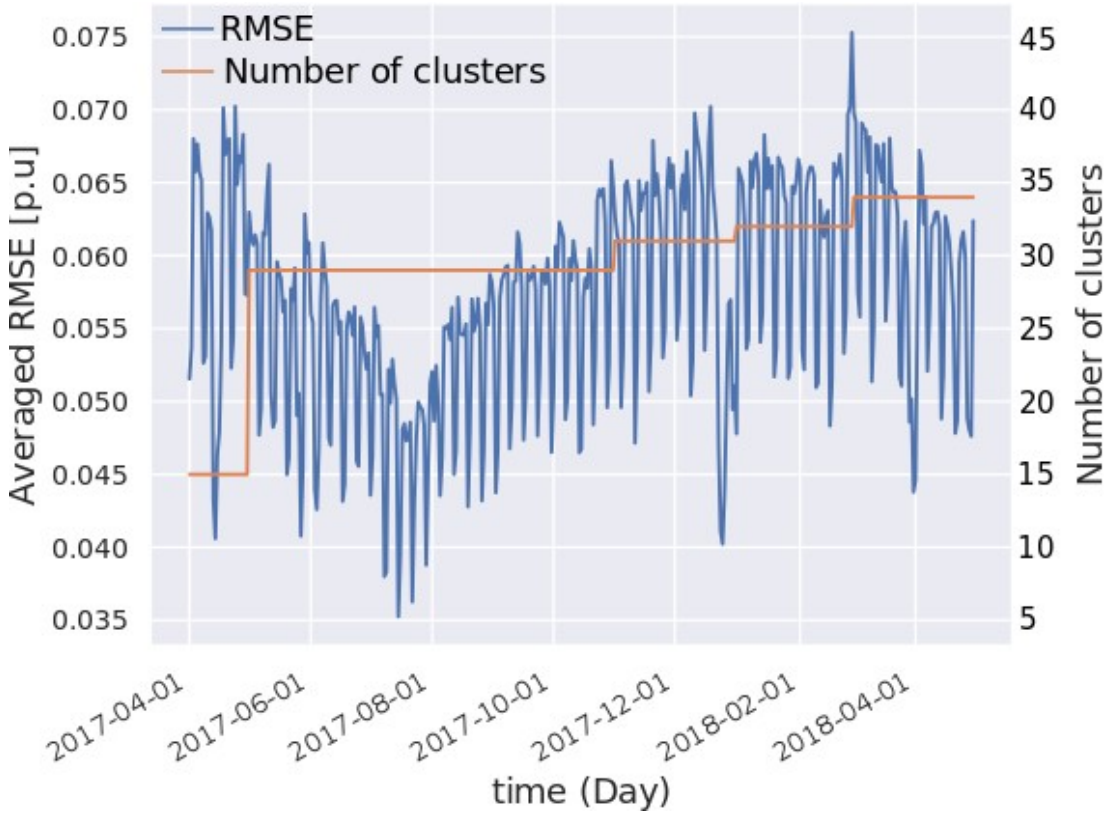

Illustration 3: Overview of the performance of the monthly dynamic load profiling

6. Conclusions

The algorithm presented in D.6.1.2a has been modified to generate typical load profiles over a month. The consequence is that the exponential smoothing used to avoid

customers changing too much clusters has been removed as it could not cope with the new data structure. In practice, the clustered objects are no longer customers, but a day for a customer instead.. Nervertheless the performance of the monthly dynamic profiling with a limited number of clusters (from 15 to 34) is comparable (even slightly better) to the performance of the alogorithm with the daily dynamic load profile. Hence, monthly update can be used in operation. The period could be longer, but the number of clusters should be also larger.