Phase Identification of Smart Meters by Clustering Voltage Measurements

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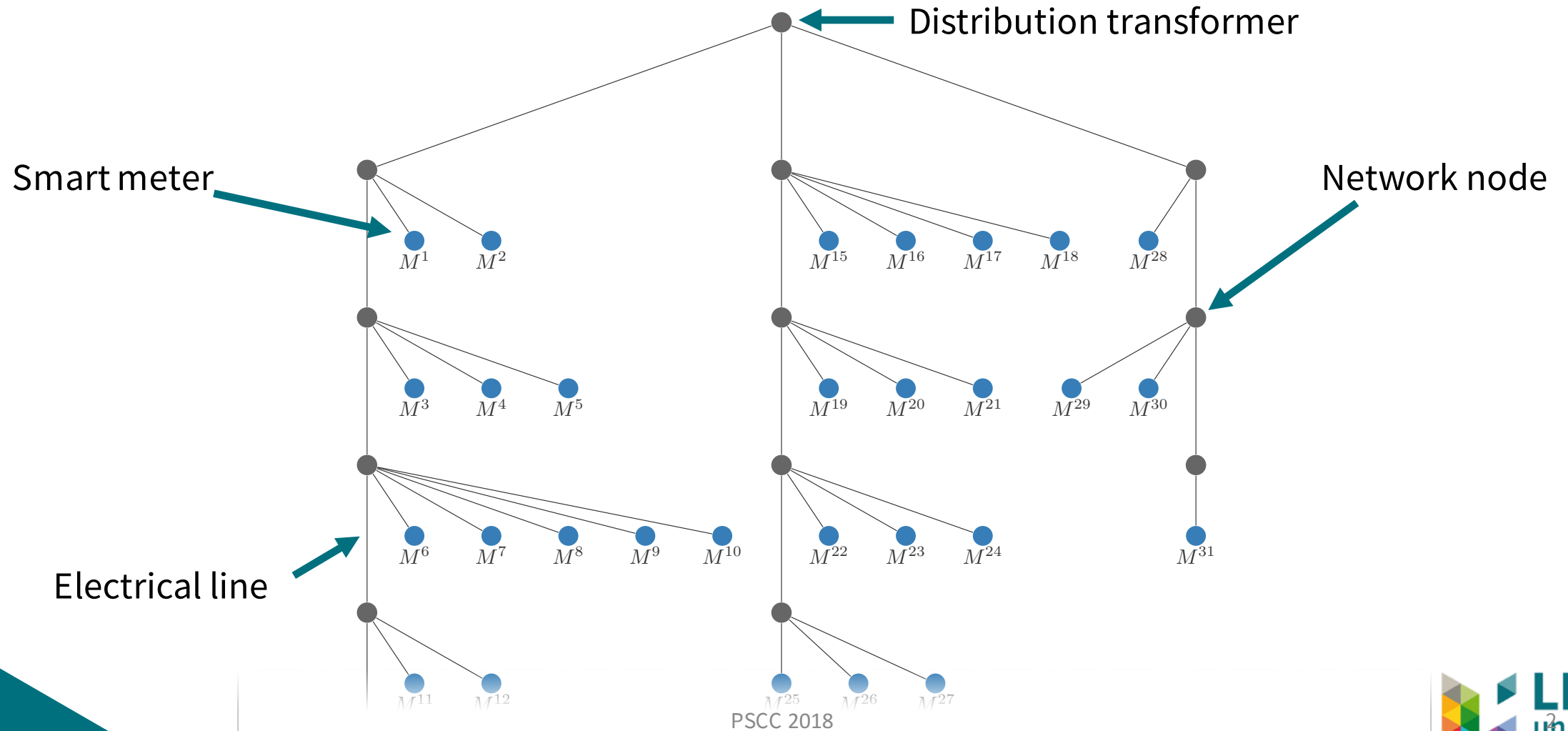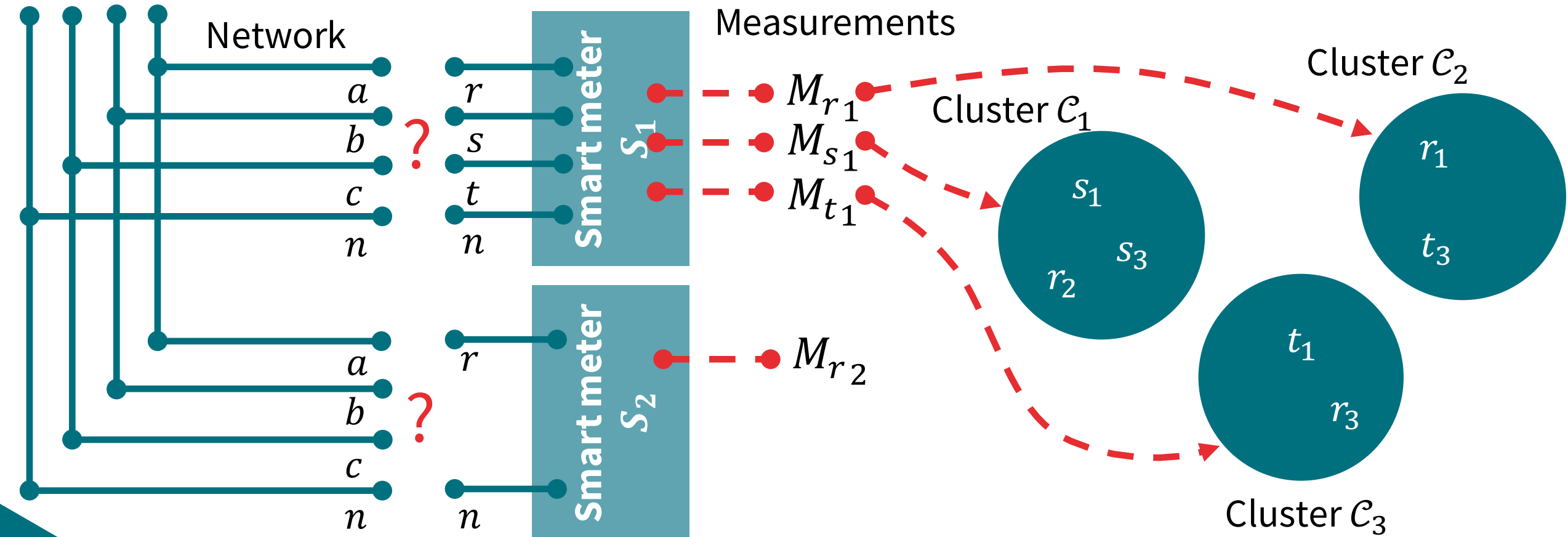Damien ERNST

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Introduction

Distribution transformer

Smart meter

Network node

Electrical line

M^1 M^2 M^{15} M^{16} M^{17} M^{18} M^{28}

M^3 M^4 M^5 M^{19} M^{20} M^{21} M^{29} M^{30}

M^6 M^7 M^8 M^9 M^{10} M^{22} M^{23} M^{24} M^{31}

M^{11} M^{12} M^{25} M^{26} M^{27}

The phase identification problem

Why is the phase information important?

What are the existing solutions?

What is the algorithm we propose?

Performance and discussions

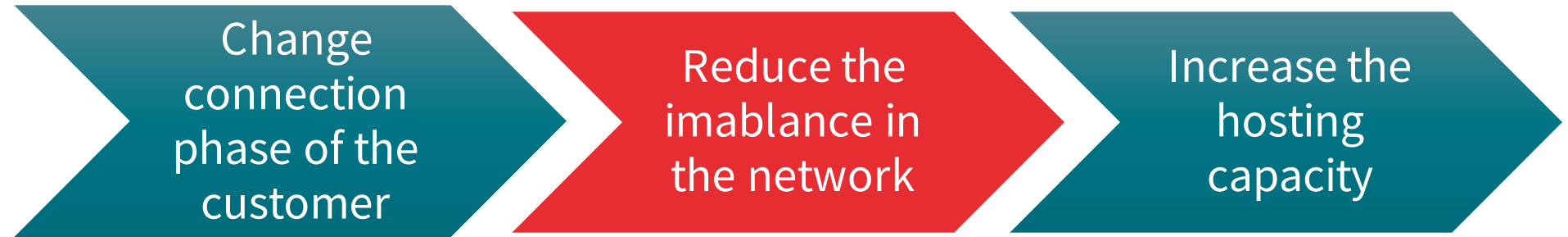LIÈGE université

Why is the phase information important?

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Performance and discussions

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The phase identification is important

If you are
a DSO

Change connection phase of the customer

Reduce the imablance in the network

Increase the hosting capacity

If you are
a researcher

Phase-to-neutral active and reactive power measurements

Three-phase power flow

Comparison between measured and simulated voltages

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Why is the phase information important?

What are the existing solutions?

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Existing solutions

Manual

Phase identifiers

Automatic

Smat meters with PLC

k-means clustering

Graph theory

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Contributions

1. Novel algorithm
   1. Using the underlying structure of the network
   2. Using the advantages of both graph theory and correlation
   3. Identifying the measurements that should be linked together and cluster them.
2. Performance compared to those of a constrained k-means clustering
3. Tested on real measurements from a distribution network in Belgium, in a variety of settings.

Why is the phase information important?

What are the existing solutions?

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Performance and discussions

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Distances

- Distance between two voltage measurements:
  - Pearson's correlation

$$d(M_l, M_i) = 1 - PC(M_l, M_i), \qquad \forall l, i \in \mathcal{I}$$

- Distance between a voltage measurement and a cluster

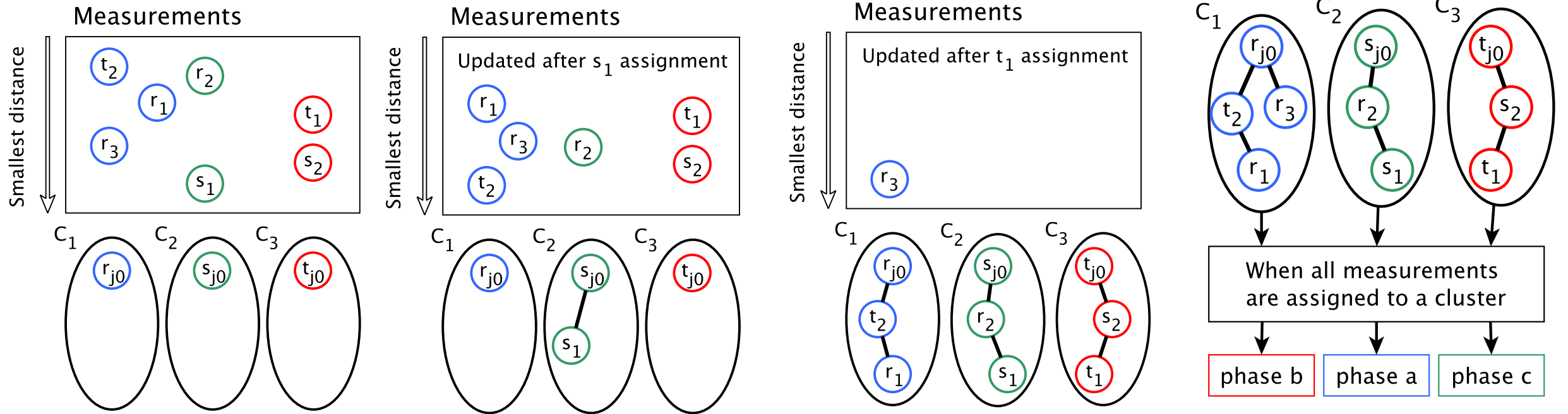$$\Delta(\mathcal{C}_k, M_i) = \min_{l \in \mathcal{C}_k} d(M_l, M_i)$$

Reference algorithm
Constrained k-means Clustering
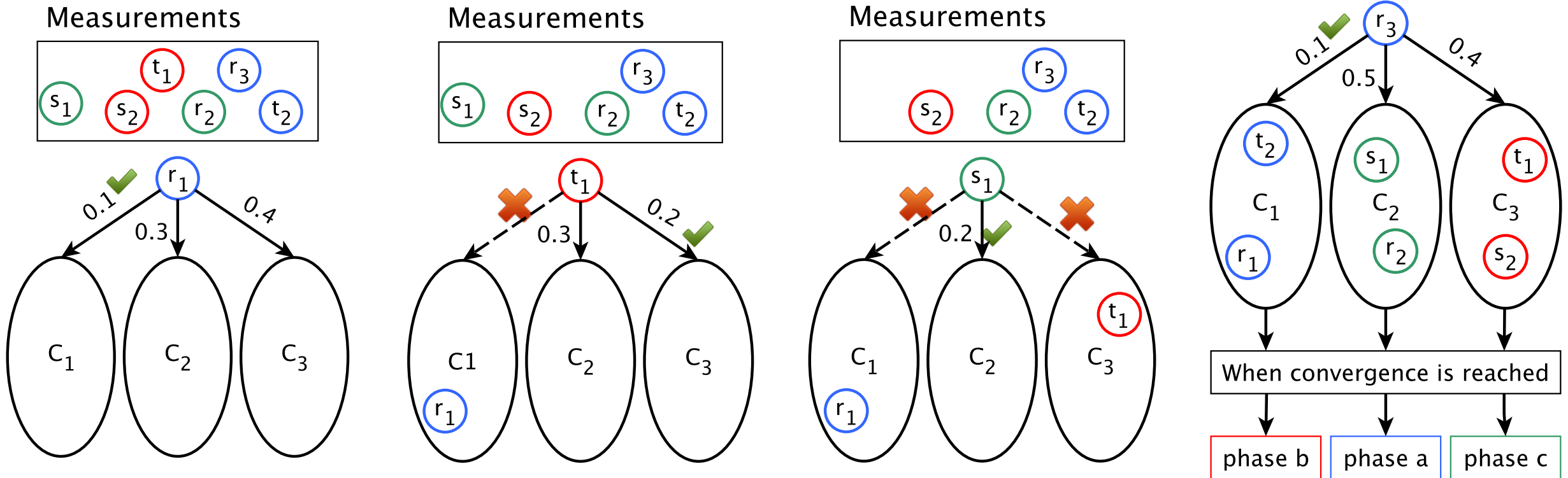
Proposed algorithm
Constrained Multi-tree Clustering

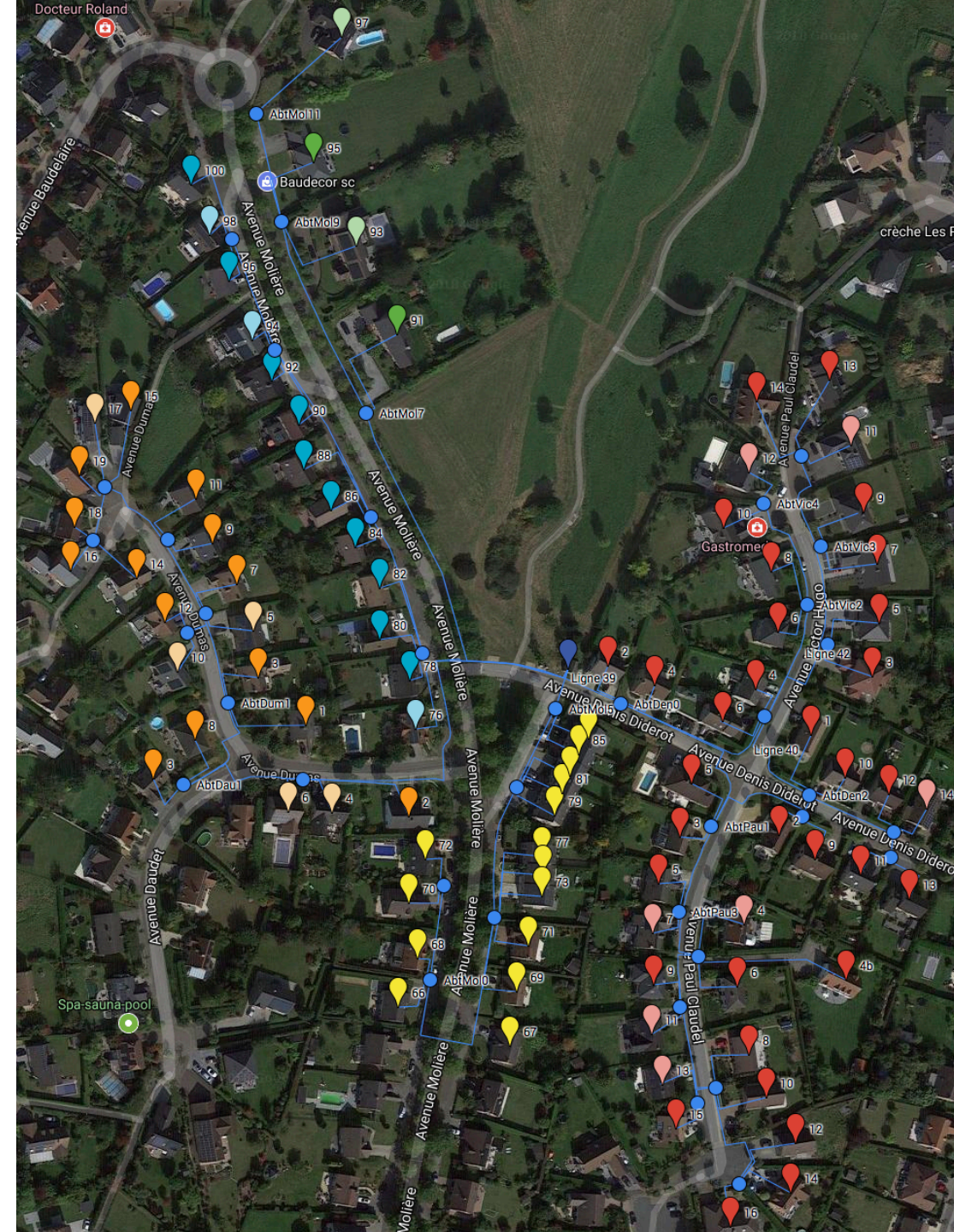Why is the phase information important?

What are the existing solutions?

What is the algorithm we propose?

Performance and discussions

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Test system

- Belgium LV distribution network
- 5 feeders, star configuration 400 V
- 79 three-phase smart meters
- 2 single phase smart meters
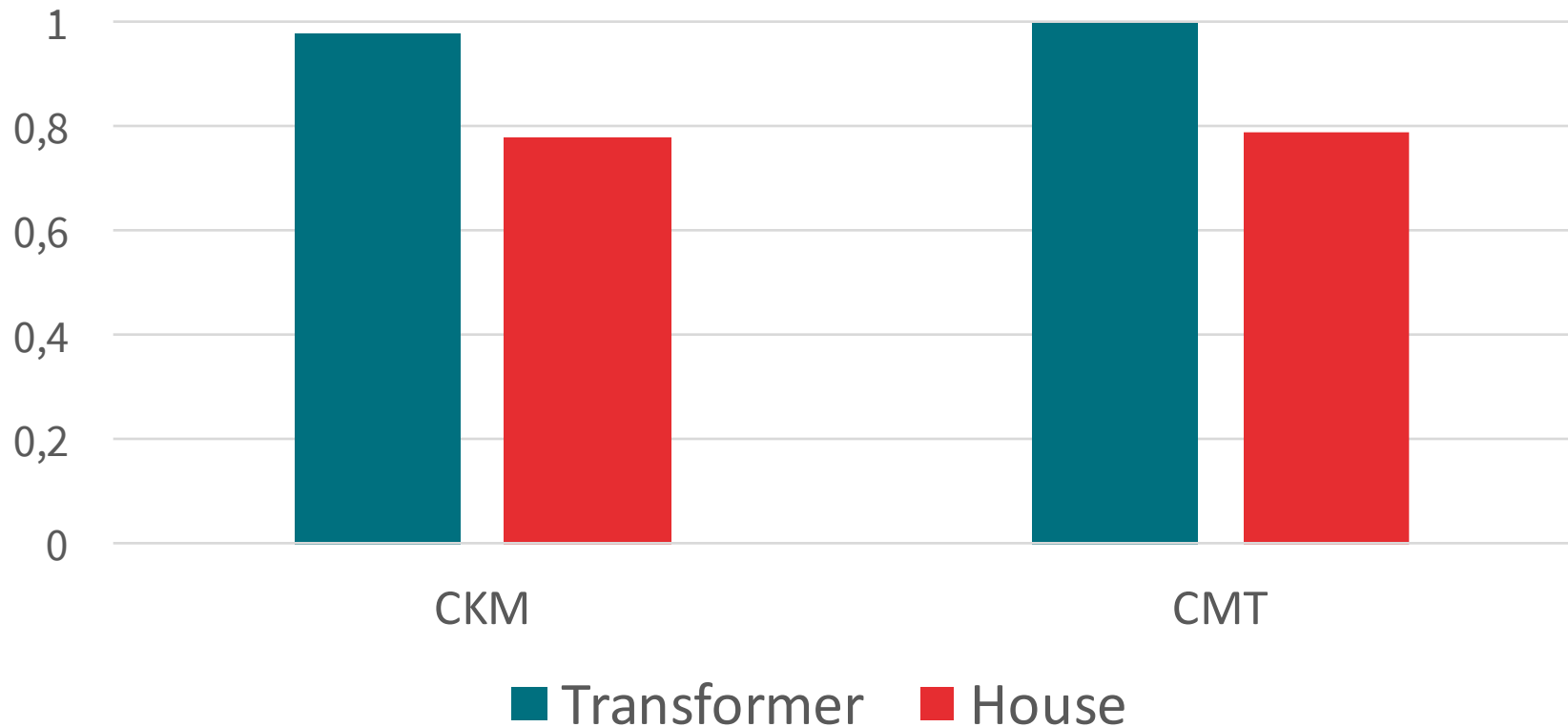- Average phase-to-neutral voltage measurements every minute

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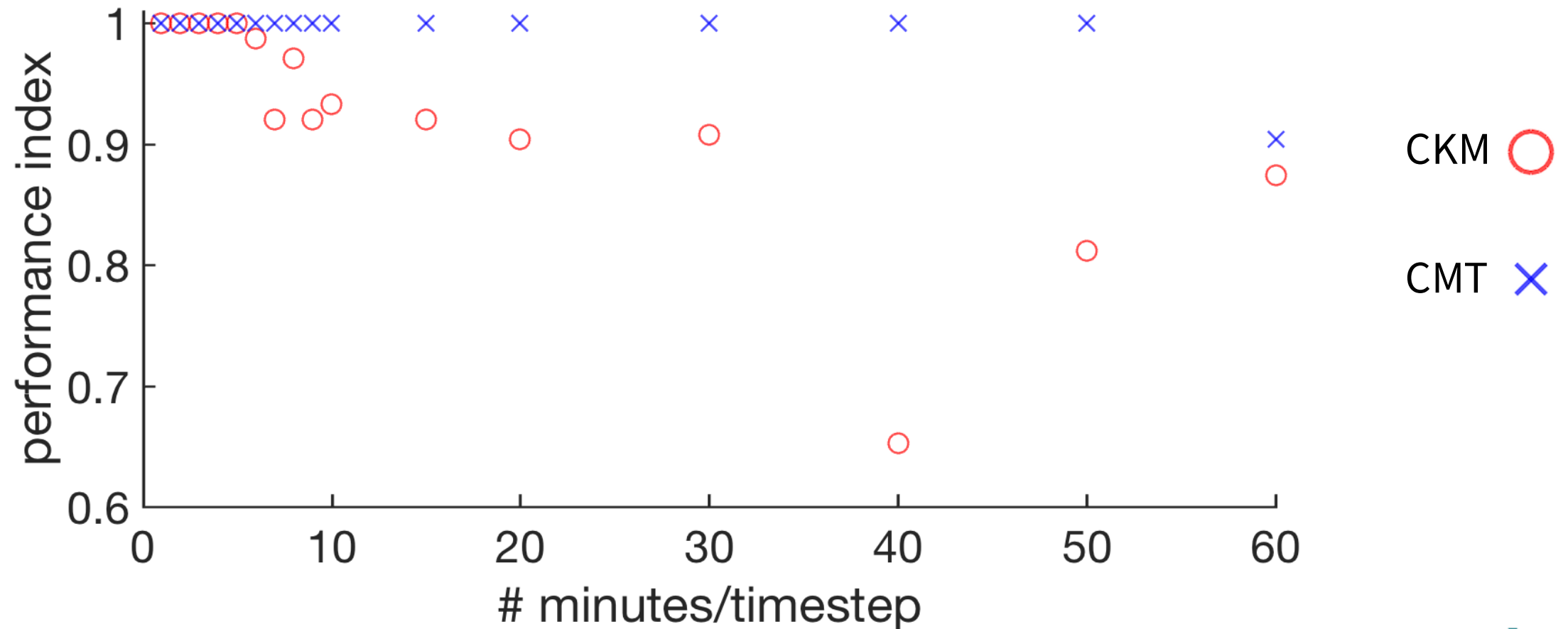# Results for the test sets
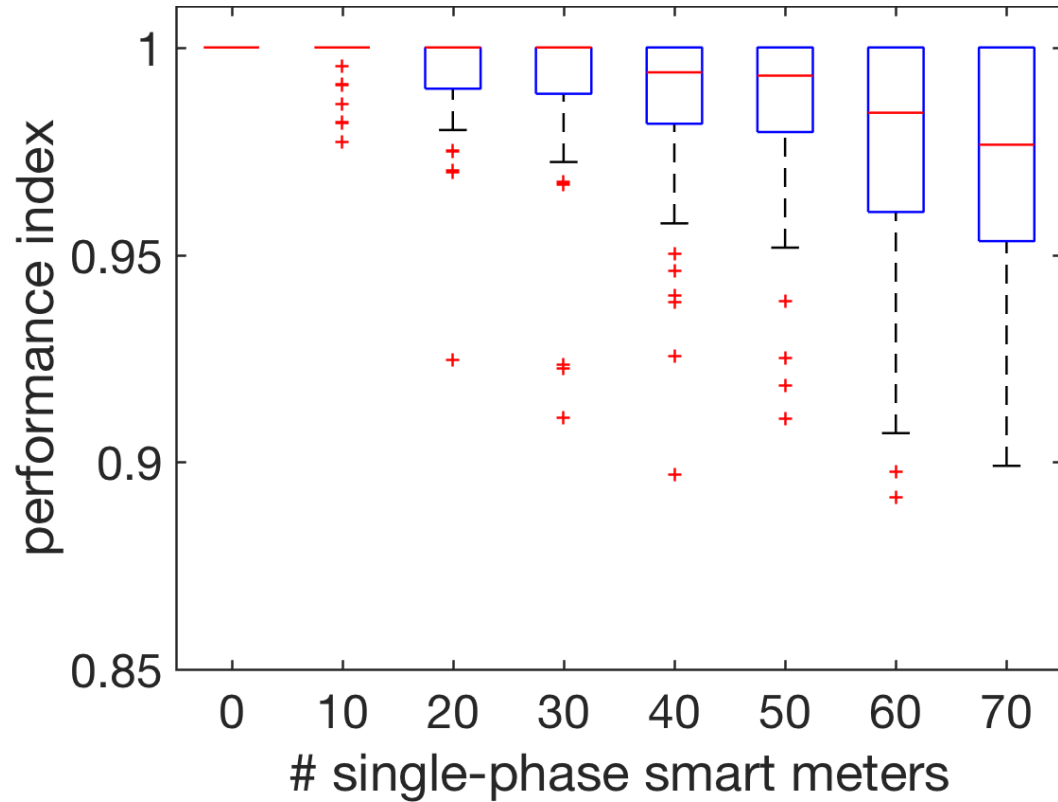## *Discussions on the selection of the root*

Performance measure

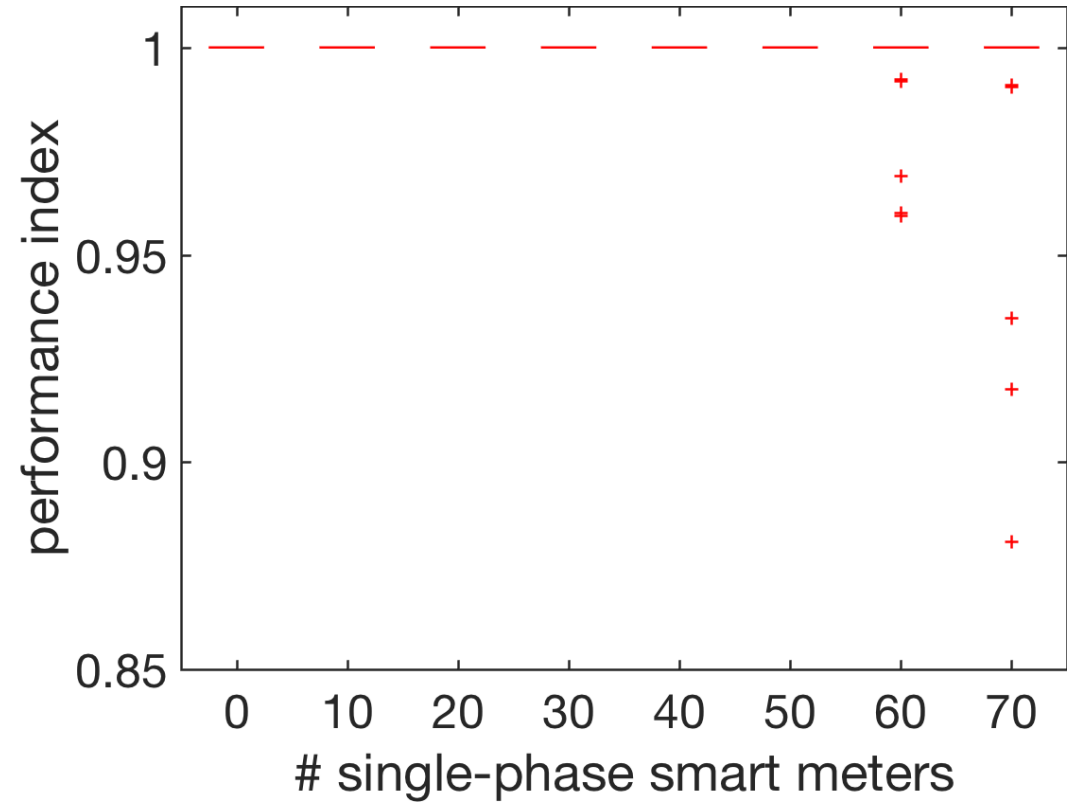The ratio between the measurements correctly identified and the total number of measurements

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Influence of the voltage-averaging period

CKM ◯

CMT ✕

Influence of ratio single-phase – three-phase smart meters
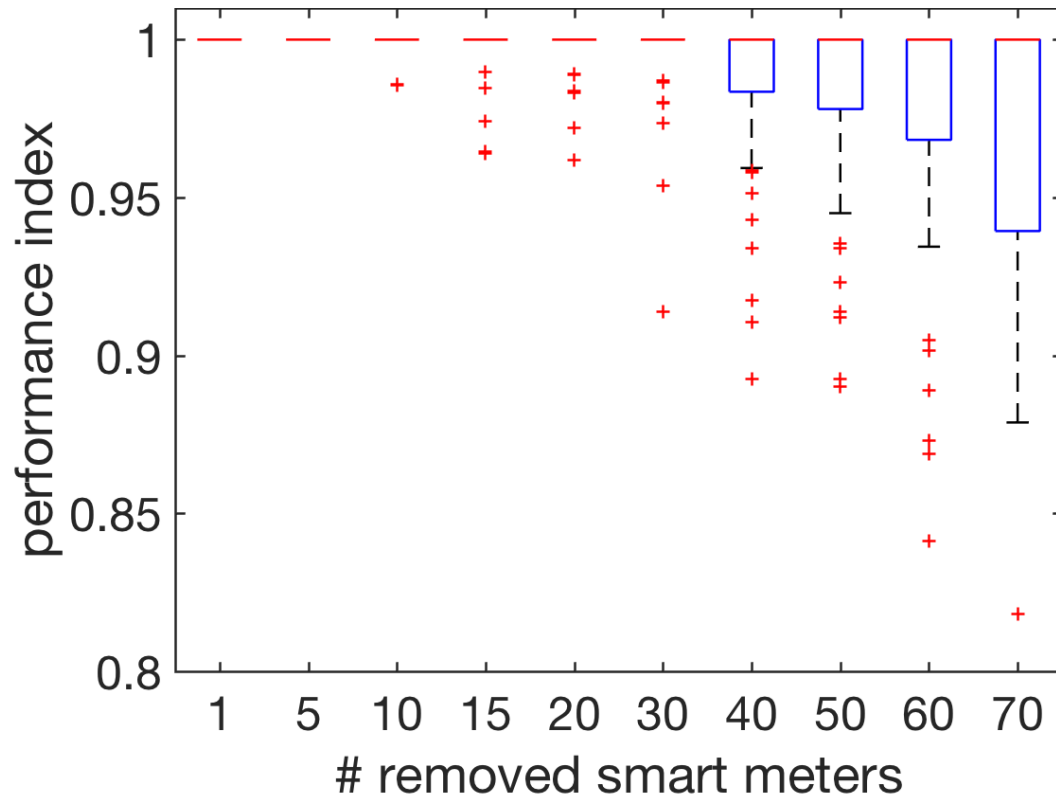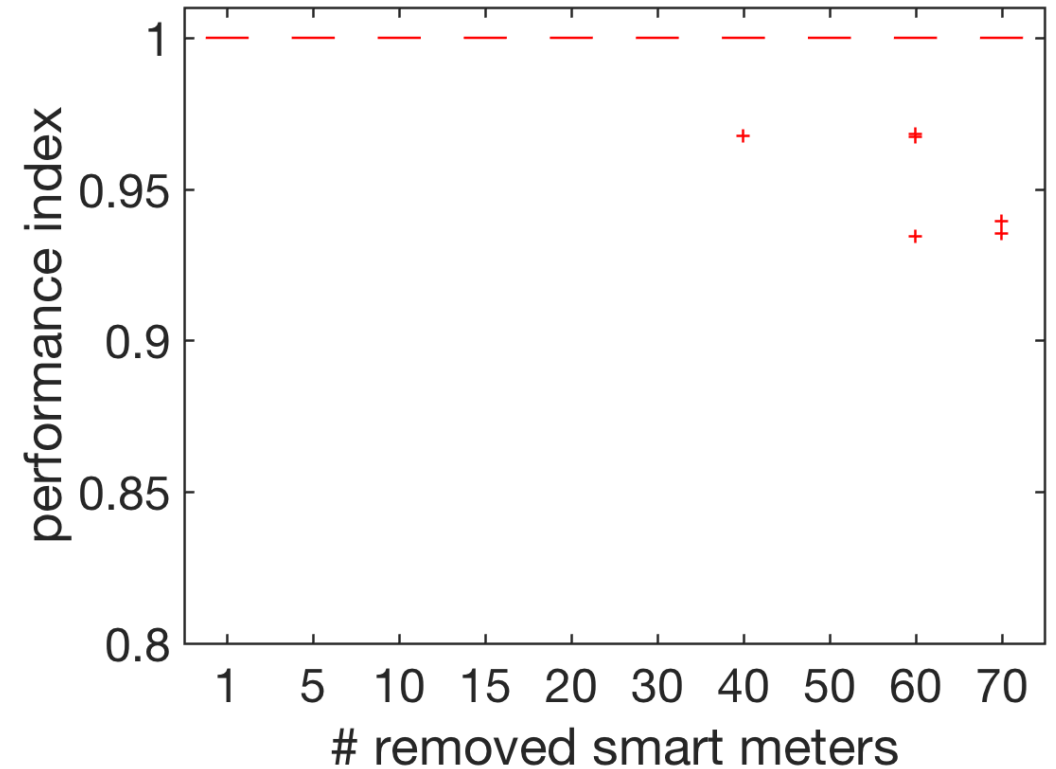

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Influence of the number of smart meters

CKM

CMT

Conclusion

- Novel method to identify the phases of smart meters in LV distribution networks

- Clustering the voltage measurements using graph theory and the correlation between measurements

- A root smart meter as input upon which the clustering process is done

- Better performance than Constrainted k-means clustering

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Future works

- Use this novel method to infer network topology.
- Test the algorithm on measurements from other network configurations, such as
  1. 3-phase 4-wire with grounded neutral,
  2. 3-phase 3-wire (3x230V) and no ground.

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