

COConsumer-centric Privacy in smart Energy grids (COPES)

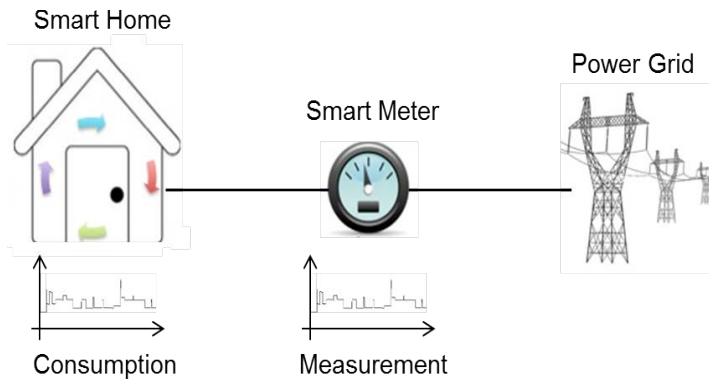
PMG: T. Oechtering (KTH, coordinator), H. Sandberg (KTH),
D. Gunduz (ICL), C. Lauradoux (Inria), G. Hug (ETH)



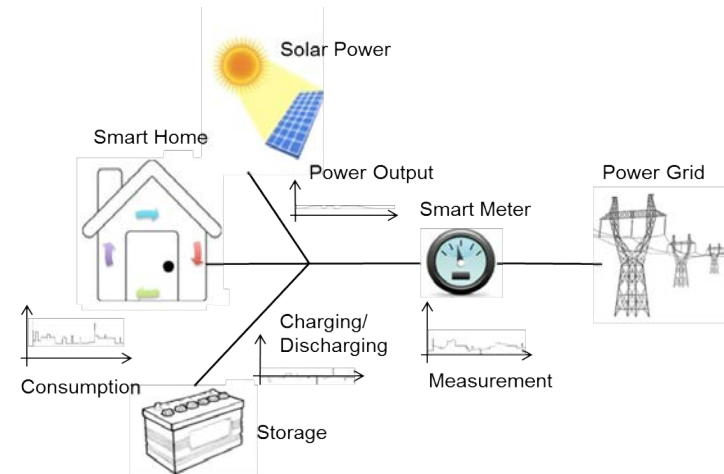
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Innovative Approach of COPES



Traditional: **Privacy risk!!!**



Solution: **Manipulate actual
energy presumption profile!**

COPES core objective

Design of innovative privacy enhancing technologies that

- i. allow utility providers to monitor and control the grid, and
- ii. assure prosumers' privacy.

Energy flow needs to be kept private

- Existing approaches typically focus on the privacy of SM readings.
 - distorting meter readings contradict with the purpose of installing SMs, which is accurate grid monitoring.
- Energy is a physical quantity, and the particular consumption pattern is what users deem private.
 - What if utility provider is not fully trusted?

Privacy can be a show stopper!

- Privacy is relevant for **technology adoption**
- Article 8 of the European Convention on Human Rights protects private life of individuals
 - **Stopped the SM role out in the Netherland**
 - Drastic fines for violation
(EU data protection reform, agreed on Dec'15)
- COPES develops a **technological solution to the SM privacy problem** to assure smart grid potentials!



Research Challenges

Privacy measures (assessment of privacy risk)

- Identify relevant SM privacy measures
 - Differential privacy, privacy measures based on information theory or statistical inference

Privacy enhancing methods (privacy-by-design)

- Innovative energy flow control strategies

Integration and impact on smart grid (efficiency, costs)

- Grid service provision and optimization
- Privacy-utility trade-off

Proof-of-principle tests (demonstration)

Partners and roles

Privacy measures and privacy-enhancing methods

- Information theoretic
- Statistical inference
- Computer science

Inria



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Impact on Smart Grid

- Grid control
- Dynamic Pricing
- Power system operation

ETH



KTH – Communication Theory Dept.

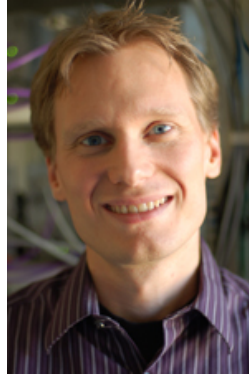
- Lead: Tobias Oechtering
 - PMG member, project coordinator, PI
 - Lead WP5 Project Mgmt, Diss., Exploit.
- Expertise in system design, detection and information theoretic privacy & networked control
- Participates in all technical WPs: Defining detection-theoretic system model & privacy measures, design and evaluation of privacy enhancing methods and utility-privacy trade-offs.





KTH – Automatic Control Dept.

- Henrik Sandberg
– Lead WP1



- Expertise in networked control and estimation, optimization, and security
- Participates in all technical WPs: Optimal control and estimation under various privacy metrics, and corresponding trade-offs

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Electrical and Electronic Eng. Dept.



- Lead: Deniz Gündüz
 - Imperial PI
 - Lead WP2: **Privacy Enhancing Methods and Theory**
- Researchers: Borzoo Rassouli and Giulio Giaconi
- Expertise in information theoretic privacy, signal processing and optimization.
- Participation in all technical WPs: Define system model & privacy measures, design and evaluate privacy enhancing methods and characterize utility-privacy trade-offs.



- **Privatics team:**

- Lead: Cedric Lauradoux
- Claude Castelluccia



- **Areas of expertise:**

- **Computer science**
- Privacy (data anonymization, privacy preserving cryptography, regulations...)

- **Project contributions:**

- Differential-privacy for smart meters
- Small-scale demonstrator

- Gabriela Hug
– Lead WP4



- Expertise in power systems modeling, operation and optimization
- Participates in all technical WPs: integration into energy management at residential level, interaction with the power grid

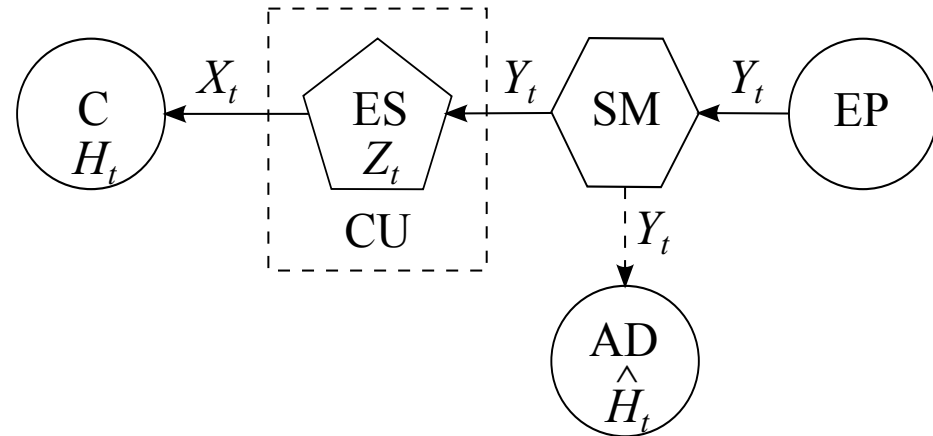
Main scientific results

PUBLICATIONS

- Z. Li, T. J. Oechtering, and M. Skoglund, *"Privacy-preserving energy flow control in smart grids"*, to be presented at 41st IEEE ICASSP 2016, Shanghai, China, March 2016.
- H. Sandberg, G. Dan, R. Thobaben: *"Differentially Private State Estimation in Distribution Networks with Smart Meters"*, in Proceedings of the 54th IEEE Conference on Decision and Control, Osaka, Japan, December 2015.
- Z. Li, and T. J. Oechtering, *"Privacy on Hypothesis Testing in Smart Grids,"* IEEE Information Theory Workshop (ITW), , Jeju, South Korea, October 2015.
- G. Giaconi and D. Gündüz, *"Smart meter privacy with renewable energy and a finite capacity battery"*, to be presented at the 17th IEEE International workshop on Signal Processing advances in Wireless Communications (SPAWC), Edinburgh, UK, July 2016.
- O. Tan, D. Gündüz, and J. Gomez-Vilardebo , *"Optimal privacy-cost trade-off in demand-side management with storage,"* IEEE Int'l Workshop on Signal Proc. Advances for Wireless Comm. (SPAWC), Stockholm, Sweden, Jun.-Jul. 2015.
- G. Giaconi, D. Gündüz and H. V. Poor, *"Smart meter privacy with an energy harvesting device and instantaneous power constraints,"* IEEE International Conference on Communications (ICC), London, UK, June 2015.

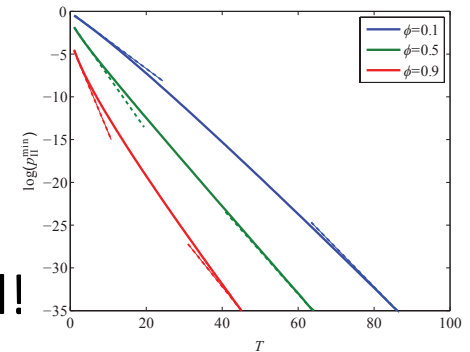
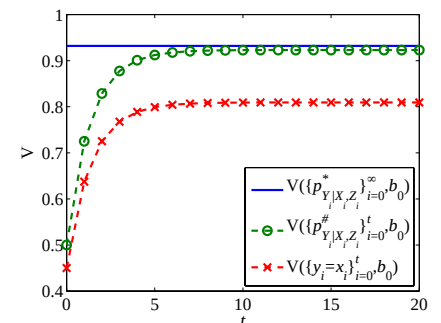
Hypothesis Testing SM Privacy

Test on consumers behavior!
(operational privacy measure)



Privacy preserving schemes with

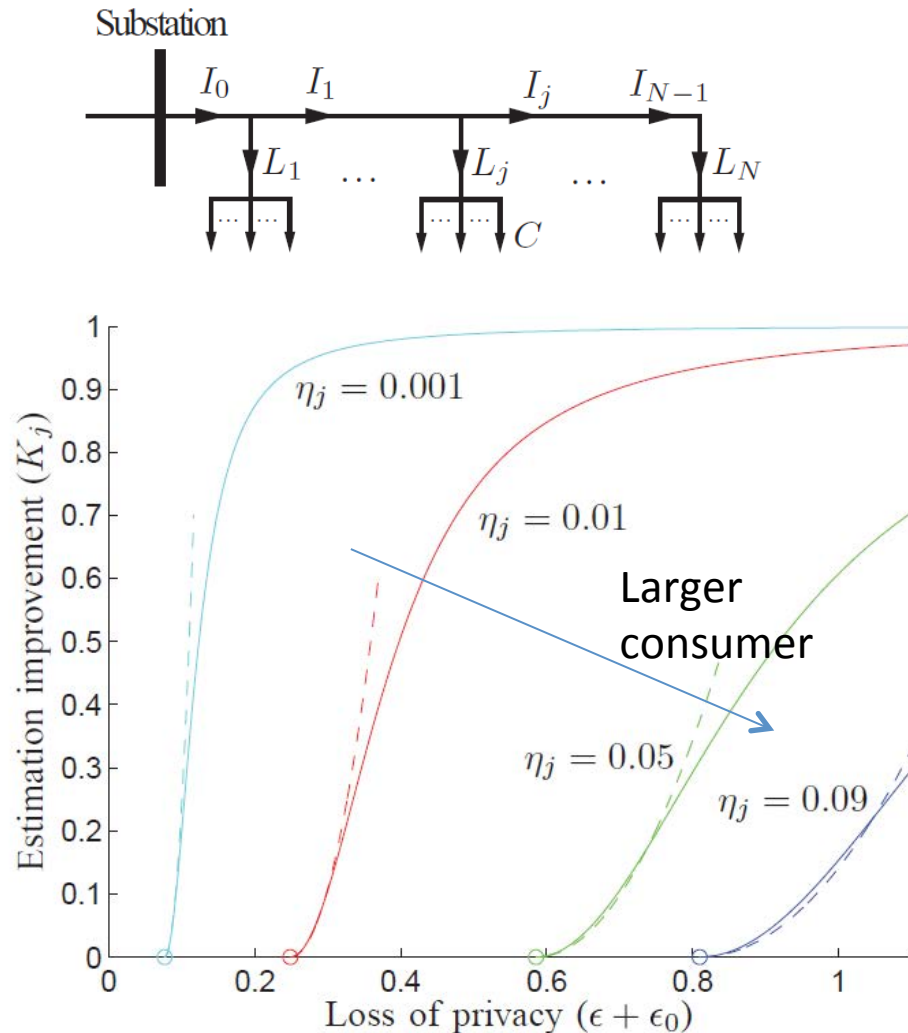
- infinite energy storage capacity (ITW'15)
 - Minimize exponential decay rate of detection performance
 - Strategy with two consumption levels is optimal!
- finite energy storage capacity (ICASSP'16)
 - Belief state Markov decision process framework
 - Tools for the design of optimal energy flow control policy



Differentially Private State Estimation with Smart Meters

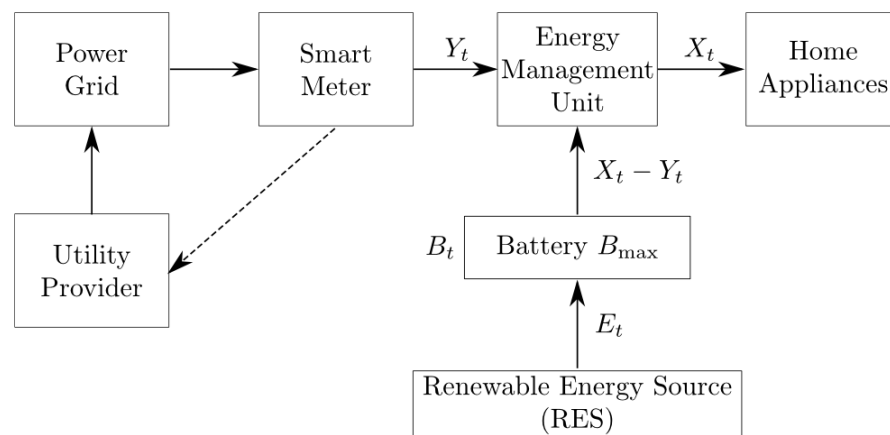
State estimation in distribution grids using real-time smart meter data (CDC'15)

- **Goal:** Monitor voltage profile under unpredictable renewable energy generation
- Consumers add (Laplacian) noise on data to achieve differential privacy
- **Trade-off :** Estimation quality vs. consumer privacy loss



Information Leakage SM Privacy

Minimize the consumption information leakage
(information-theoretic privacy measure)



Include renewable energy source

- Only harvested energy can be stored (ICC'15)
 - Relate problem to rate-distortion theory
- Battery can also store grid energy (SPAWC'16)
 - Stochastic control problem

