ETH zürich

Participatory Sharing Economies via Decentralized Mobile and Cloud Computing

Evangelos Pournaras

Motivation

Data Is the New Oil of the Digital Economy

GEAR | SCIENCE | SECURITY

SPONSOR CONTENT JORIS TOONDERS, YONEGO

DATA IS THE NEW OIL OF THE DIGITAL ECONOMY

Image: verifex/Flickr

DATA IN THE 21st Century is like Oil in the 18th Century: an immensely, untapped valuable asset. Like oil, for those who see Data's fundamental value and learn to extract and use it there will be huge rewards.

We're in a digital economy where data is more valuable than ever. It's the key to the smooth functionality of everything from the government to local companies. Without it, progress would halt.

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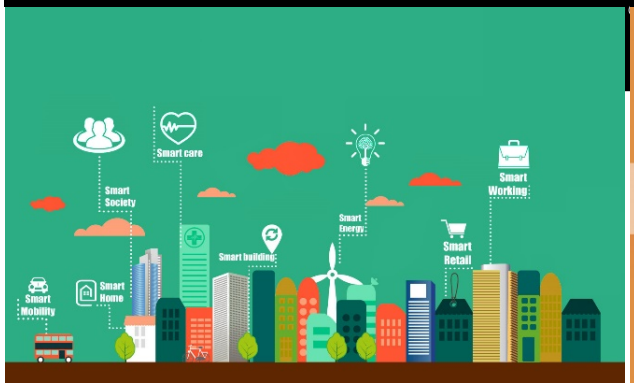
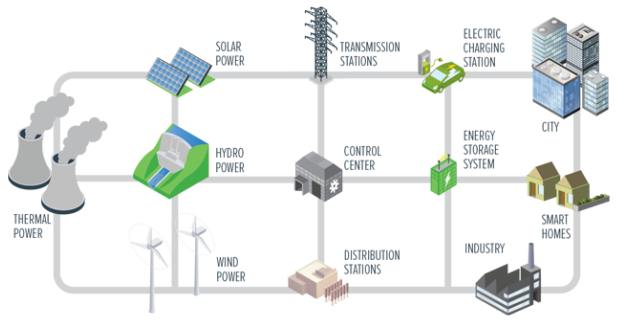
Big Data and Analytics: Here, There, and Everywhere

08 Stories

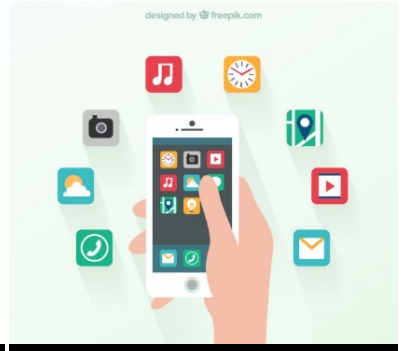
smart cities



wearables



smart grids

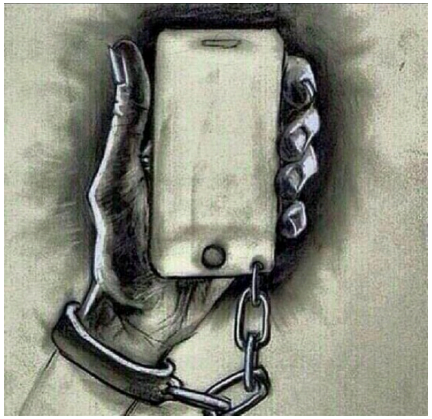


smart phones

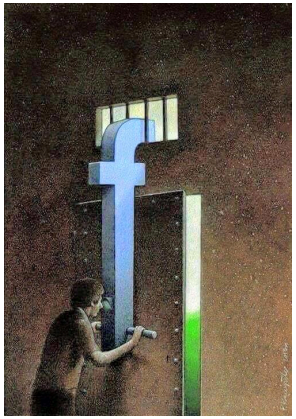
Threats & Challenges

"Your recent Amazon purchases, Tweet score and location history makes you 23.5% welcome here."

Discriminatory big data analysis



Autonomy



Commercial interests

Optimization & Learning

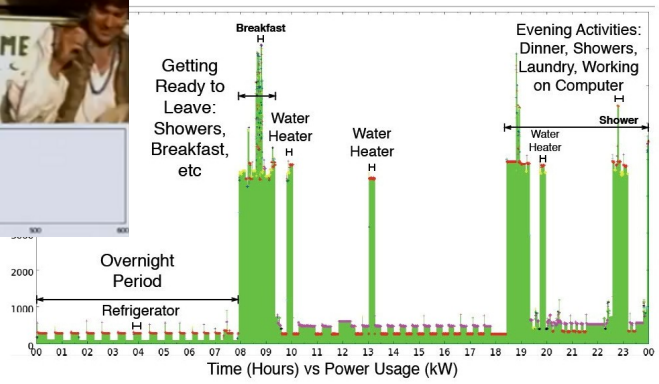
Data Analytics

Data Sharing

Privacy-intrusion, surveillance & profiling

Centralized Design

Beyond scalability



Without detailed knowledge of appliance signatures, intuitive observation with power consumption variations indicates human activity.

Credit: "Private Memoirs of a Smart Meter," Molina-Markham, et.al., 2nd ACM Workshop On Embedded Sensing Systems For Energy-Efficiency In Buildings (BuildSys 2010), Zurich, Switzerland, November 2, 2010.

Decentralized Participatory Design

Decentralization

- Scalability
- Participation: computational resources, sharing economies
- Informational self-determination
- Privacy-by-design
- Autonomy
- Fairness
- Services as public good by citizens for citizens

DEMOCRATIZATION OF MOBILE COMPUTING & INTERNET OF THINGS

COMMENT

IMAGINECHINA/CORBIS

Many choices that people consider their own are already determined by algorithms.

Build digital democracy

Open sharing of data that are collected with smart devices would empower citizens and create jobs, say **Dirk Helbing** and **Evangelos Pournaras**.

Fridges, coffee machines, toothbrushes, phones and smart devices are all now equipped with communicating sensors. In ten years, 150 billion 'things' will connect with each other and with billions of people. The 'Internet of Things' will generate data volumes that double every 12 hours rather than every 12 months, as is the case now.

Blinded by information, we need 'digital sunglasses'. Whoever builds the filters to monetize this information determines what we see — Google and Facebook, for example. Many choices that people consider their own are already determined by algorithms. Such remote control weakens responsible, self-determined decision-making and thus society too.

The European Court of Justice's ruling on 6 October that countries and companies must comply with European data-protec-

our decisions, we need information systems that are transparent, trustworthy and user-controlled. Each of us must be able to choose, modify and build our own tools for winnowing information.

With this in mind, our research team at the Swiss Federal Institute of Technology in Zurich (ETH Zurich), alongside international partners, has started to create a distributed, privacy-preserving 'digital nervous system' called Nervousnet. Nervousnet uses the sensor networks that make up the Internet of Things, including those in smartphones, to measure the world around us and to build a collective 'data commons'. The many challenges ahead will be best solved using an open, participatory platform, an approach that has proved successful for projects such as Wikipedia and the open-source operating system Linux.

predictable. Our behaviour is increasingly steered by personalized advertisements and search results, recommendation systems and emotion-tracking technologies. Thousands of pieces of metadata have been collected about every one of us (see go.nature.com/stoqsu). Companies and governments can increasingly manipulate our decisions, behaviour and feelings[1].

Many policymakers believe that personal data may be used to 'nudge' people to make healthier and environmentally friendly decisions. Yet the same technology may also promote nationalism, fuel hate against minorities or skew election outcomes[2] if ethical scrutiny, transparency and democratic control are lacking — as they are in most private companies and institutions that use 'big data'. The combination of nudging with big data about everyone's behaviour, feelings

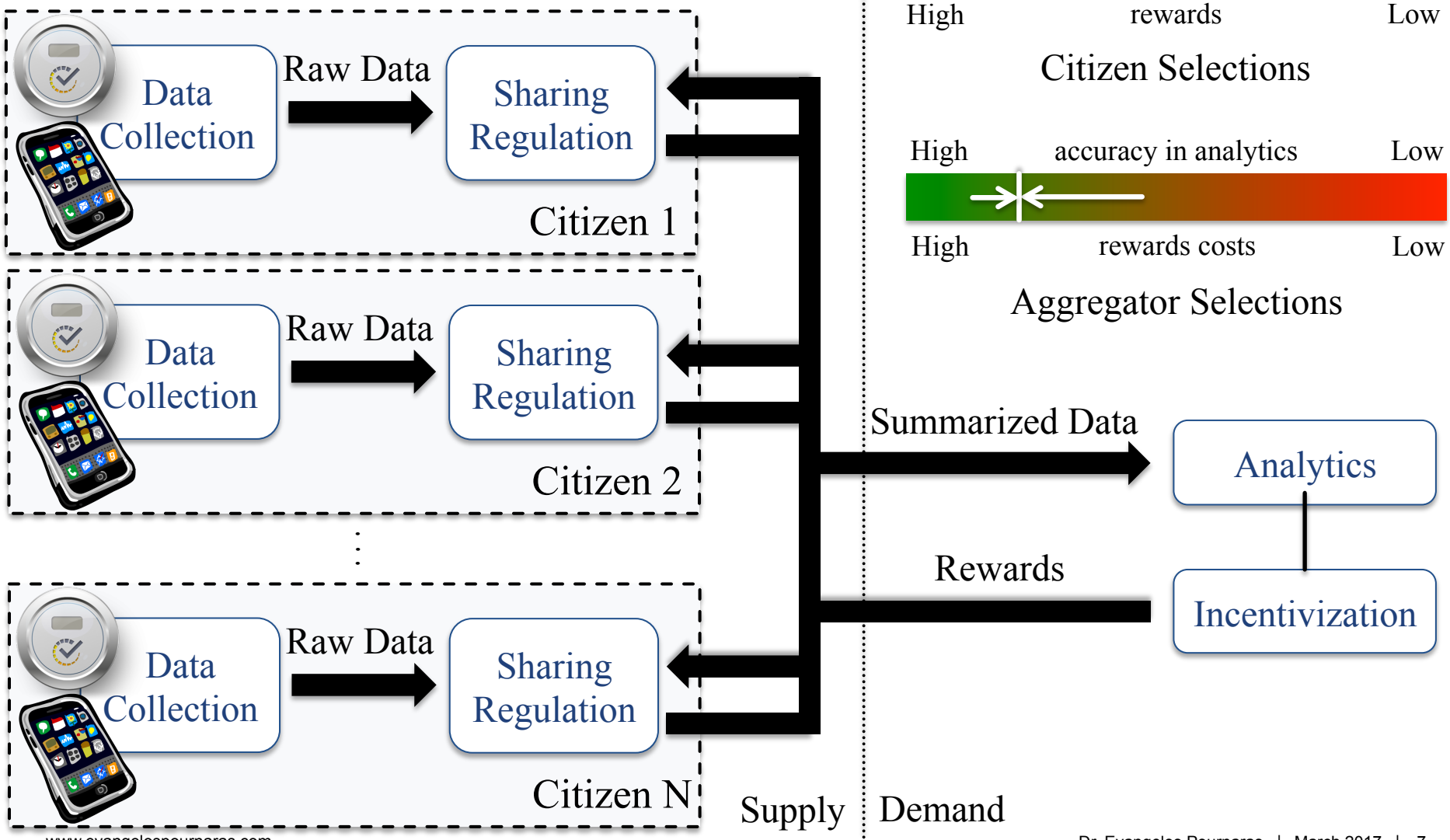
Optimization & Learning

Data Analytics

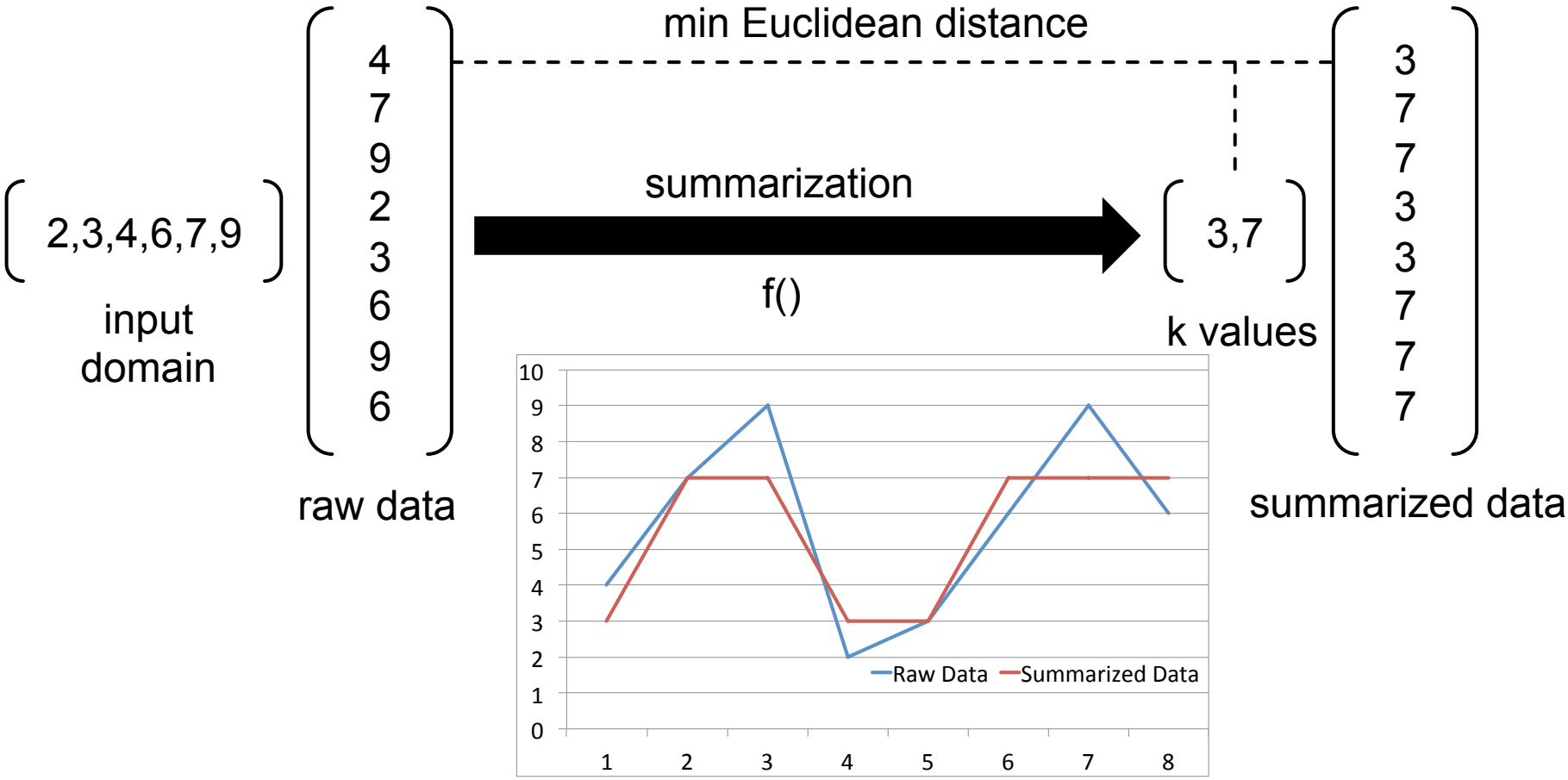
Data Sharing

Data Sharing

Data Sharing



Summarization



Implementation

Unsupervised learning

Several implementation algorithms

Summarization - Clustering

Fixed: Manual selection

Empirical: Citizens' preferences, semi-automated

Customizable – number of clusters

Algorithmic: Fully-automated, data-driven

Survey questions

Privacy preferences

Survey answers ➔ summarization range

My household may decide to be more aware of the amount of electricity used by appliances we own or buy.

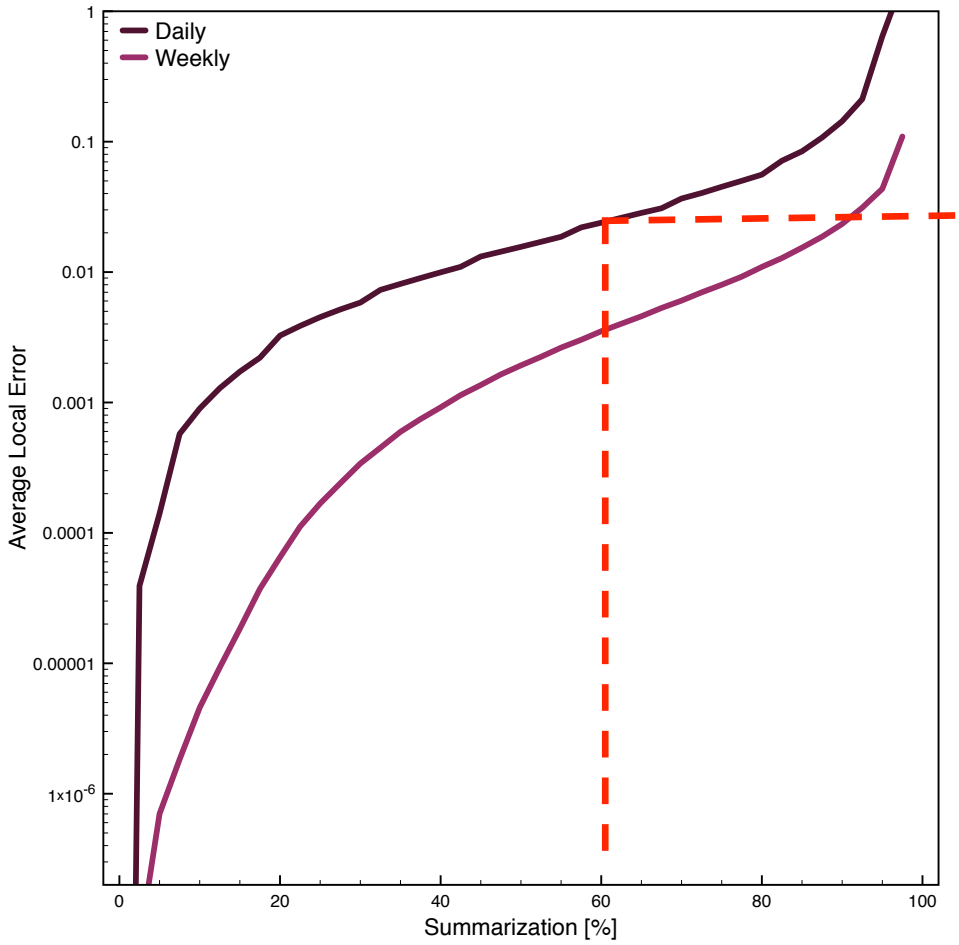
ECBT - Smart Grid
6435 participants
1 sensor
1 year

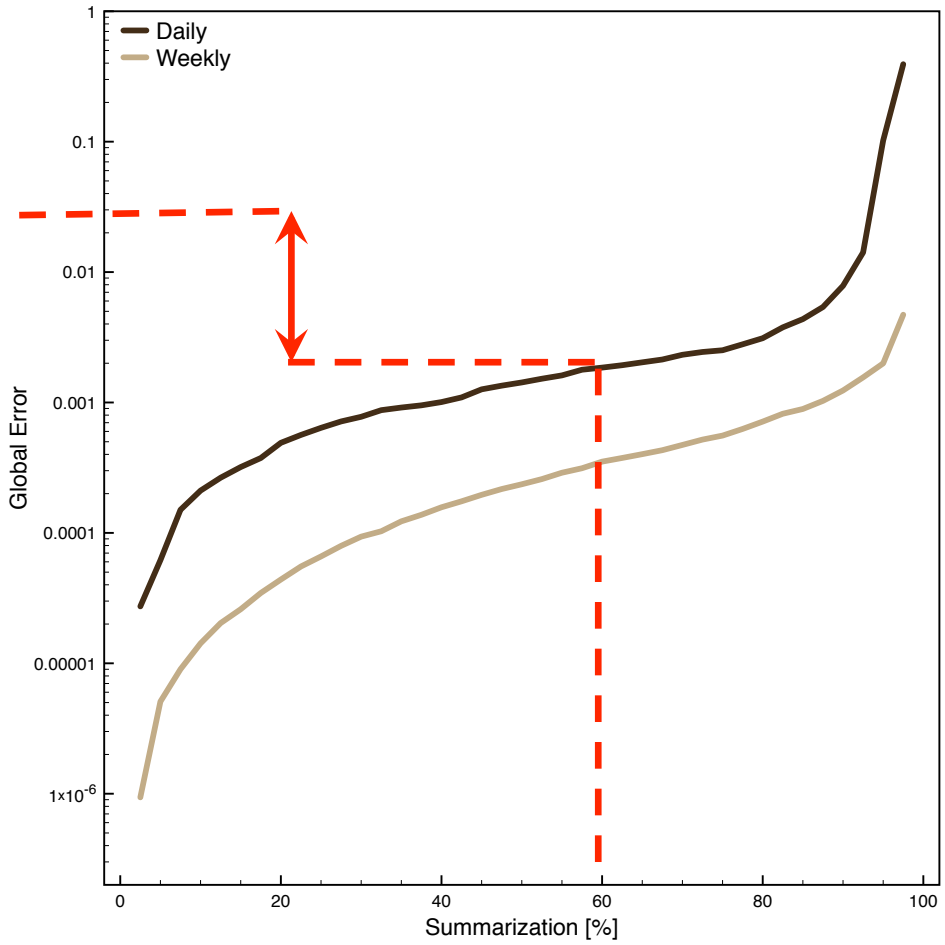
Nervousnet
154 participants
several sensors
4 days

Datasets

Measurements & variables	ECBT	Nervousnet
Privacy	✓	✓
Accuracy	✓	✓
Costs & Rewards	✓	X
Epoch length	daily & weekly	daily
Summarization level	fixed, empirical & algorithmic	fixed & algorithmic
Number of citizens	✓	✓
Several sensor types	X	✓
Analytics	summation	average

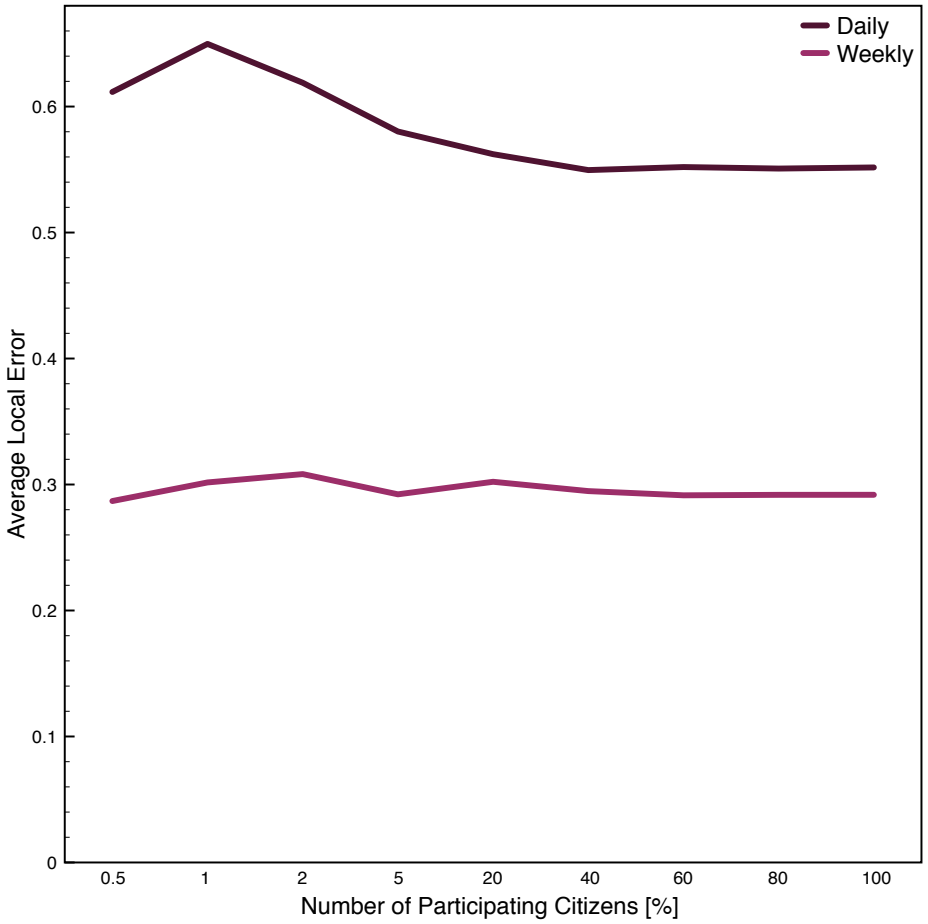
Privacy vs. Accuracy – Smart Grid

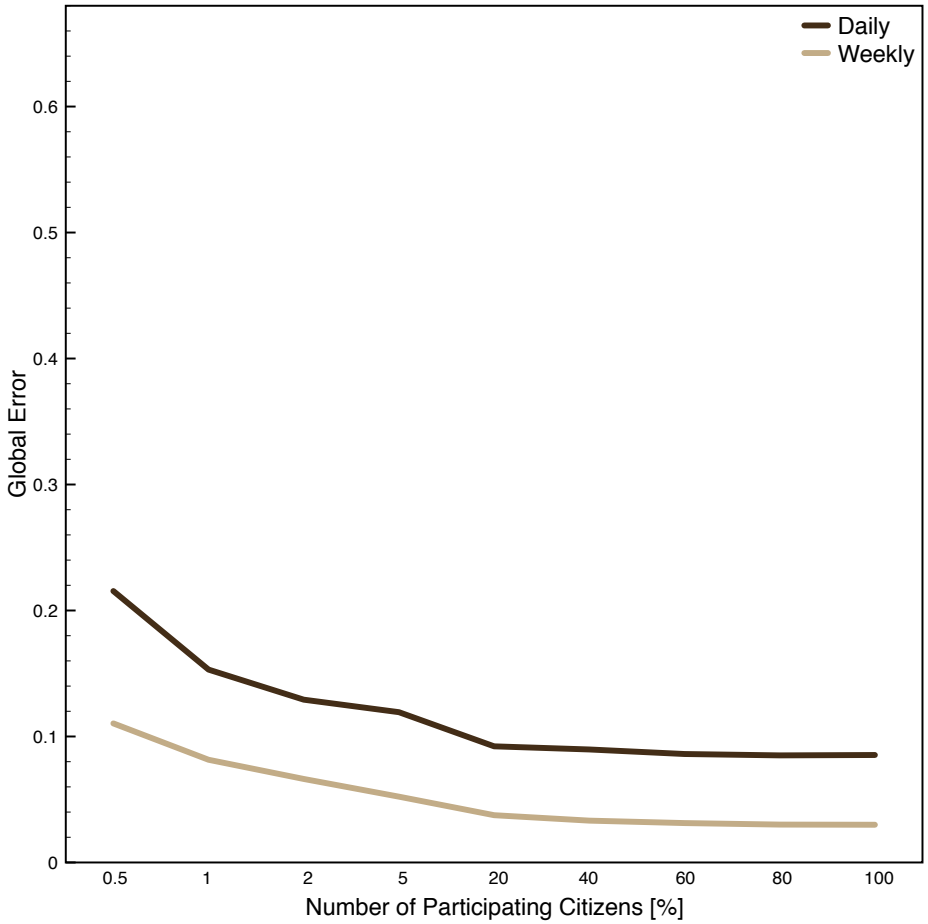




Fixed summarization levels

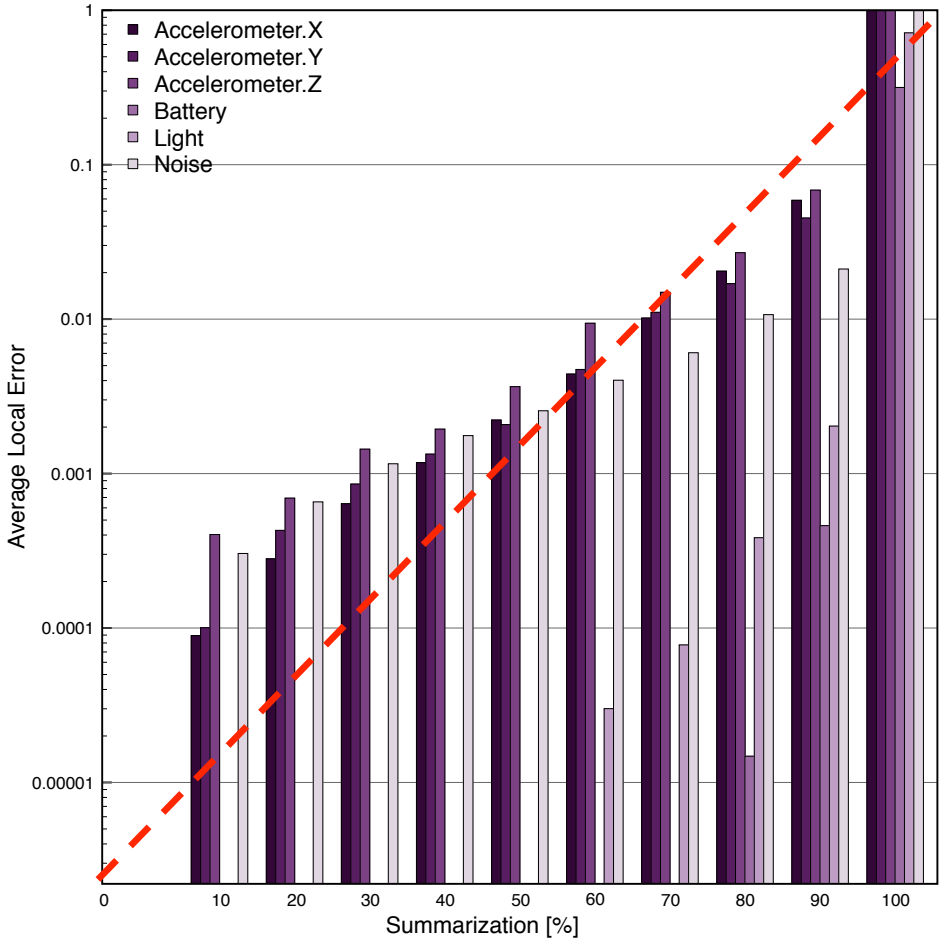
Privacy-preservation – Smart Grid

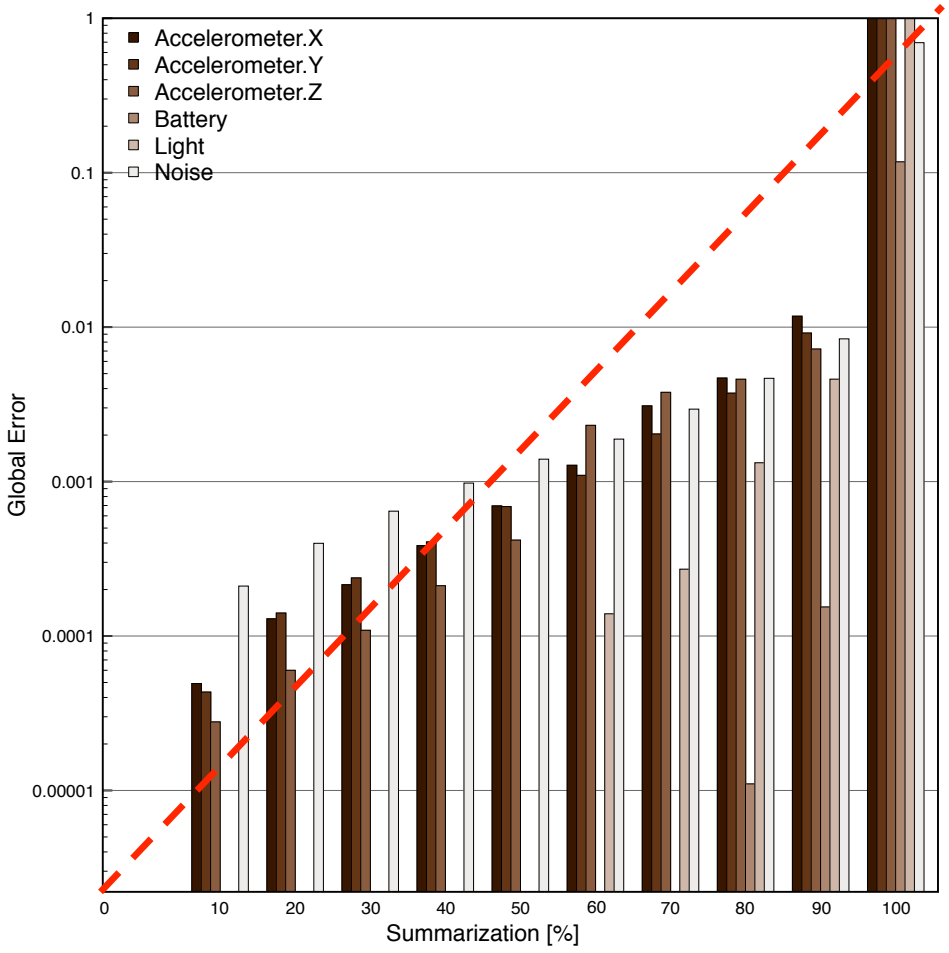




Algorithmic summarization levels

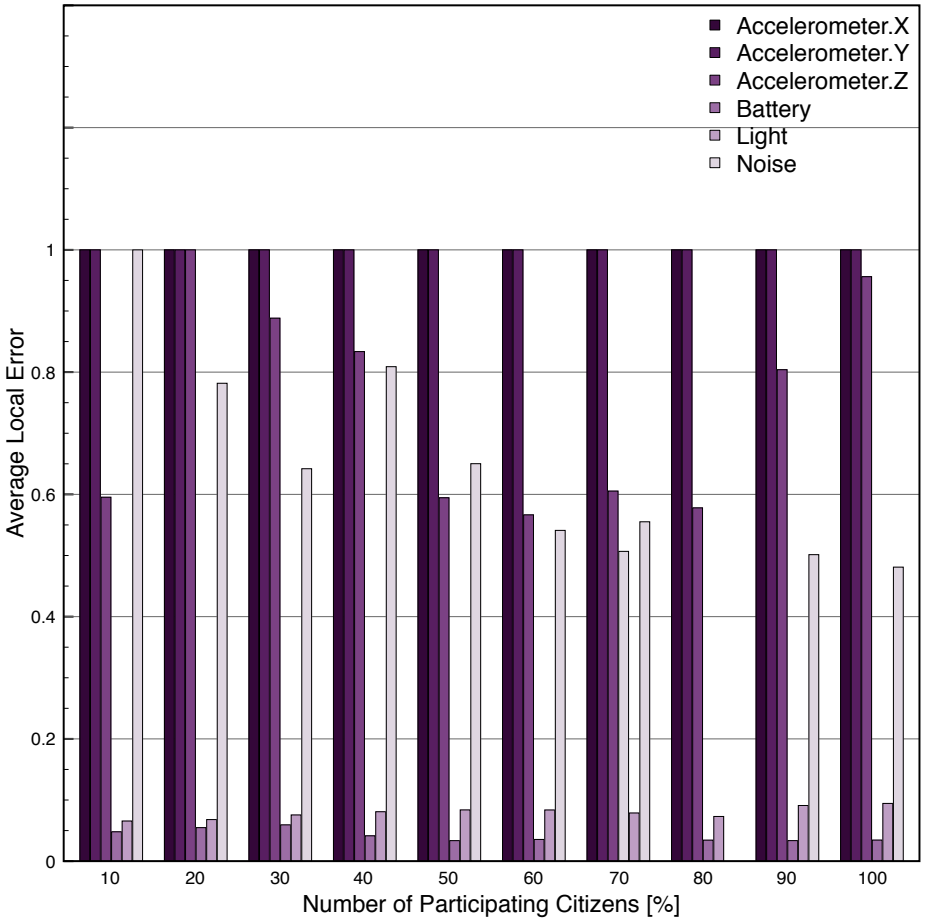
Privacy vs. Accuracy – Nervousnet

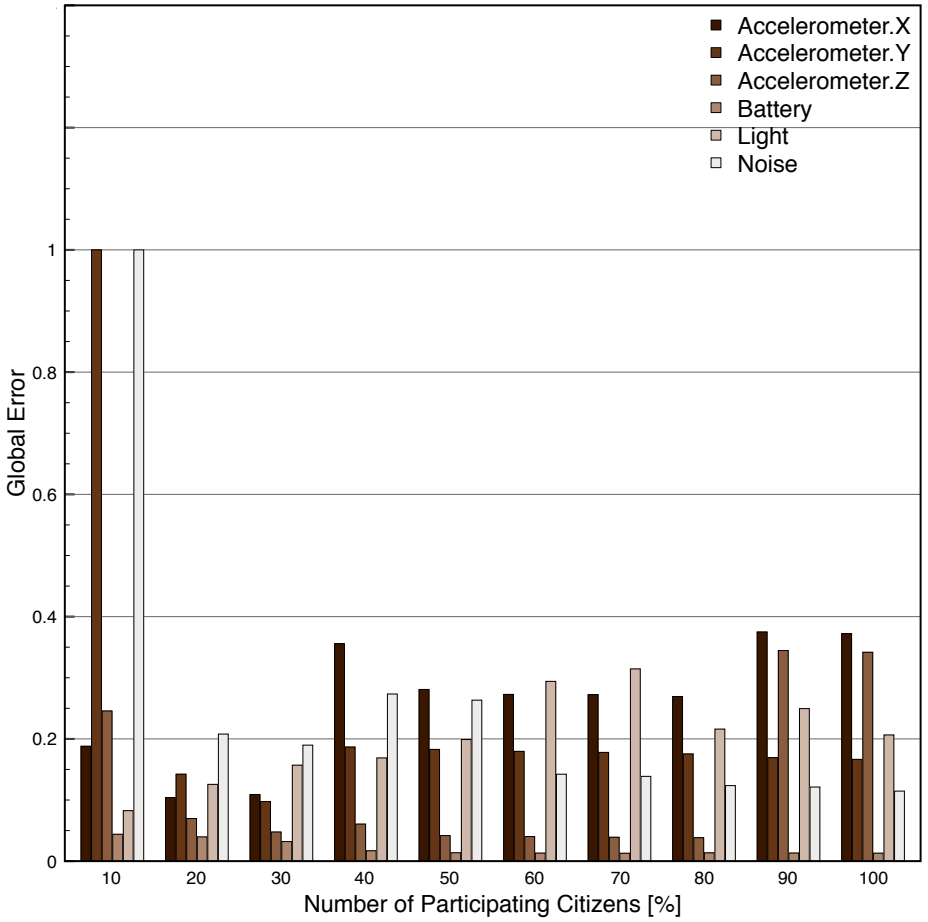




Fixed summarization levels

Privacy-preservation – Nervousnet





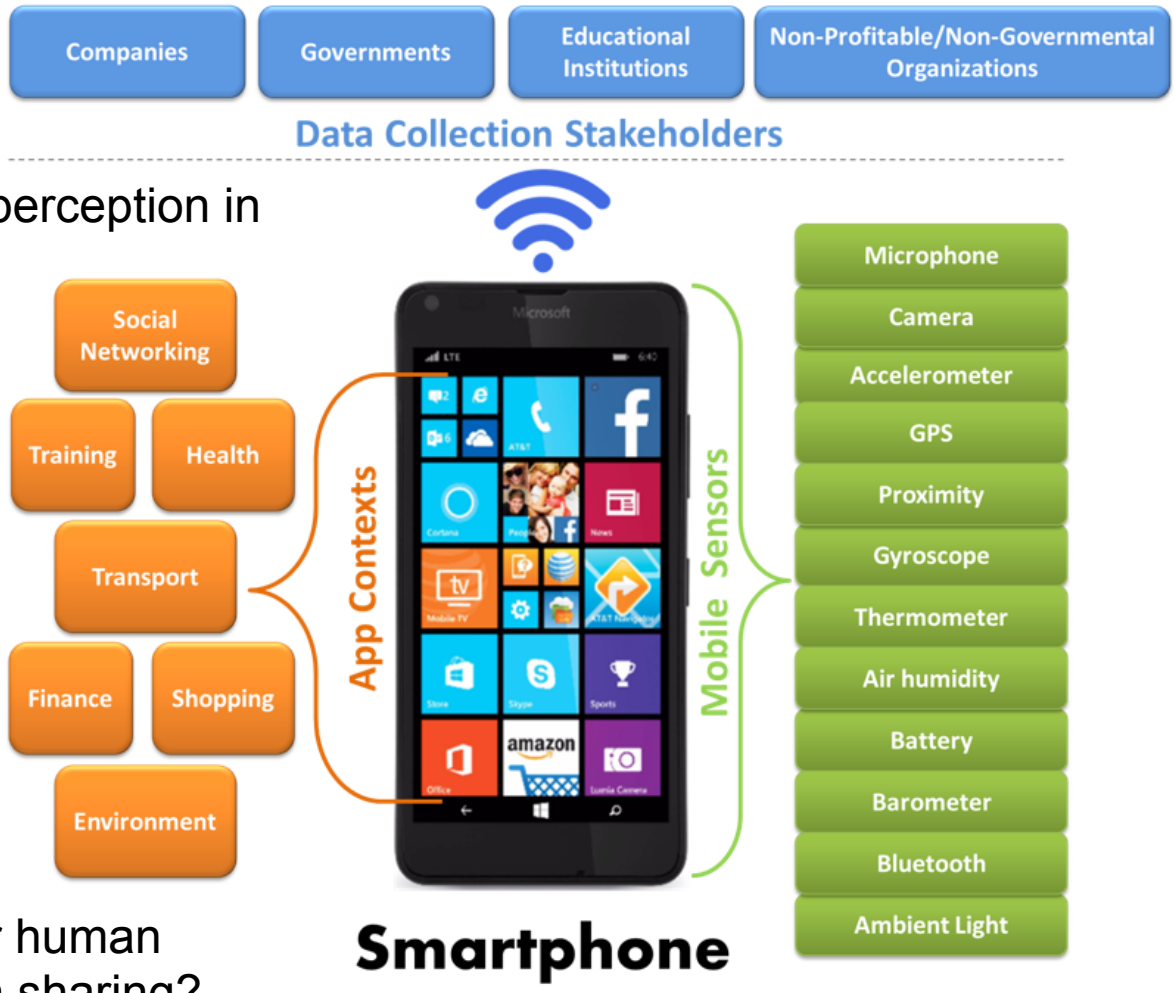
Algorithmic summarization levels

Social Norms & Human Decision-making

Model decision-making/privacy-perception in data sharing

Novel mixed-mode social experiment at ETH Decision Science Lab

How (monetary) rewards steer human decision-making in information sharing?

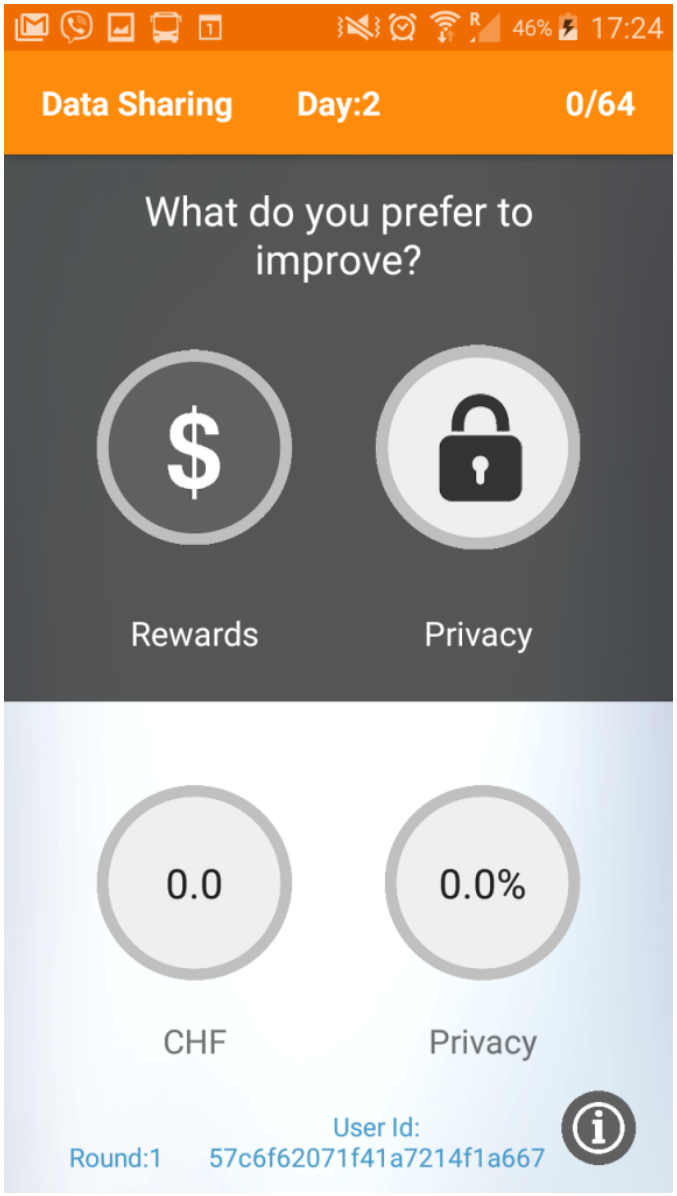


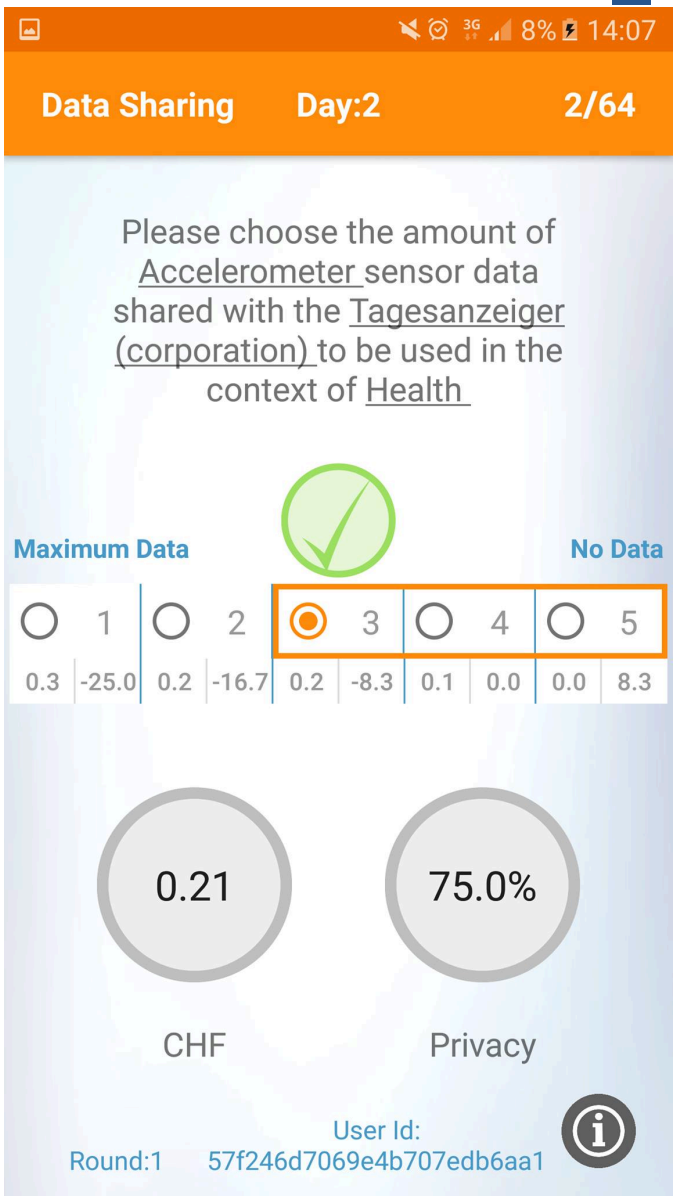
Experiment

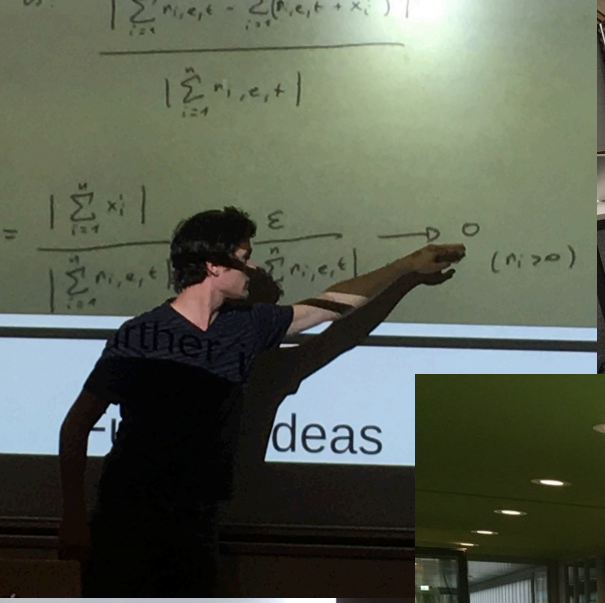
>100 users, >3 months

Real monetary incentives

Adherence to ethical & experimental protocols







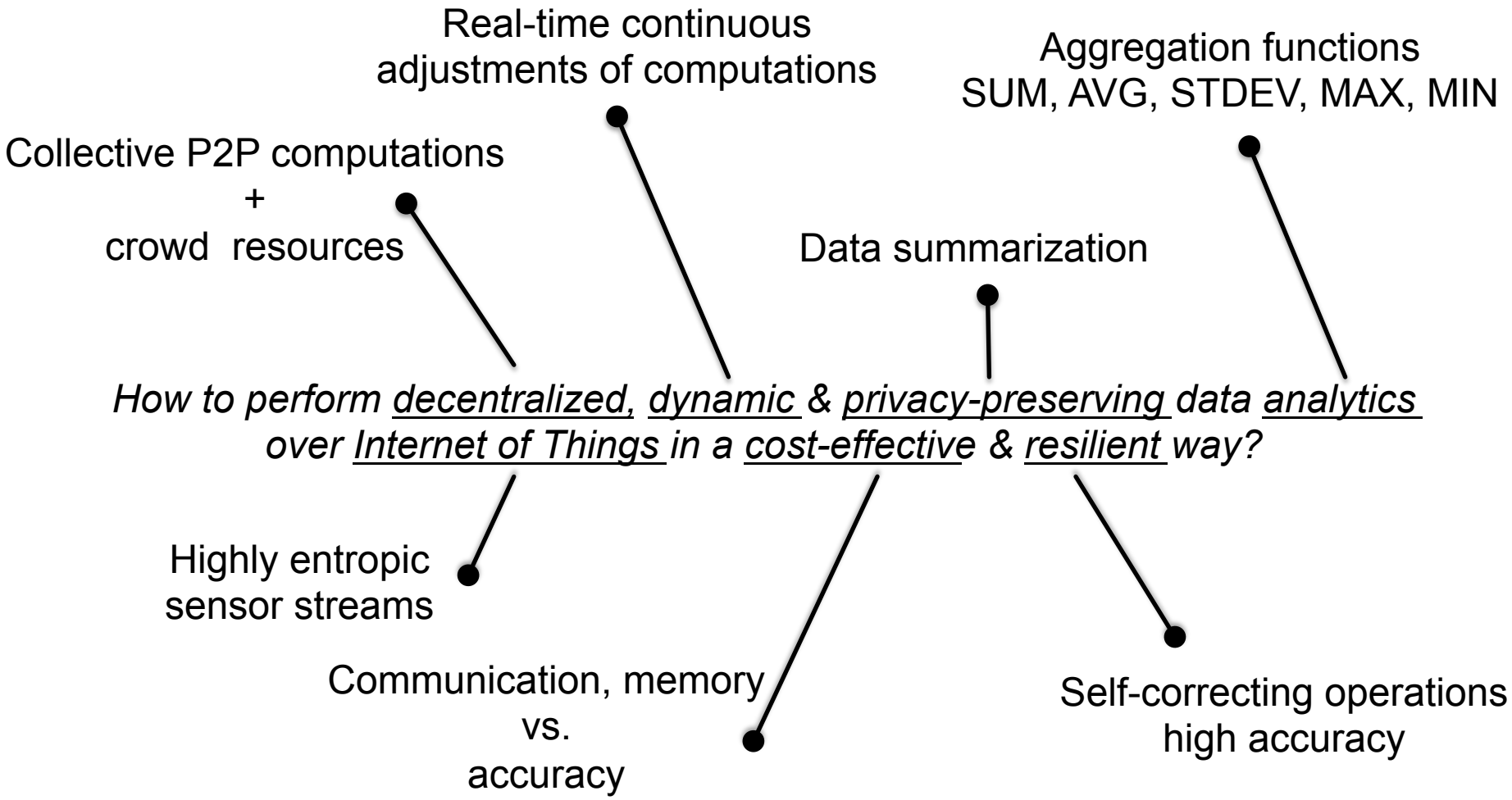
Competing summarization algorithms!

HACKATHON

http://www.nervousnet.ethz.ch/hackathon/

Data Analytics

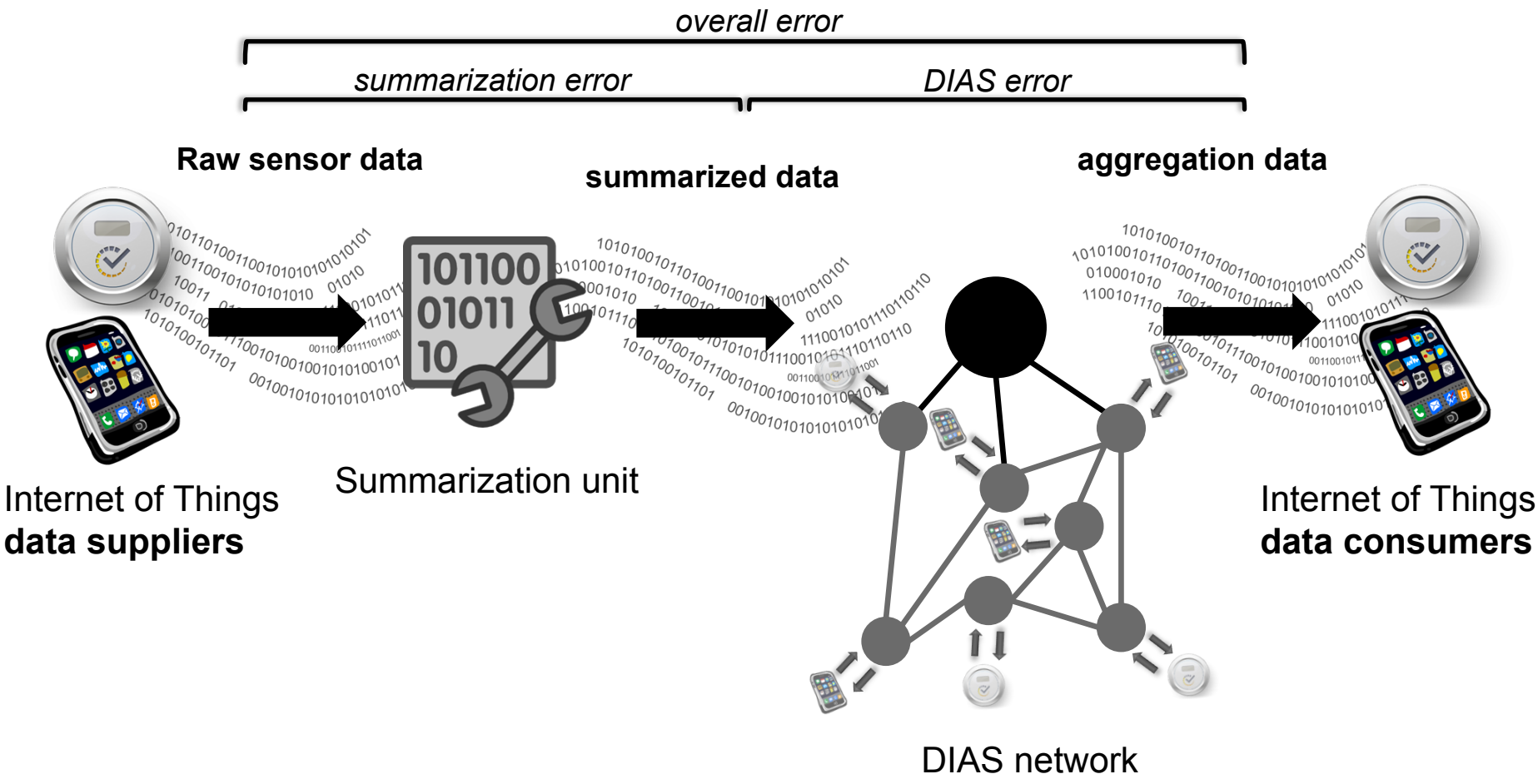
Research Question



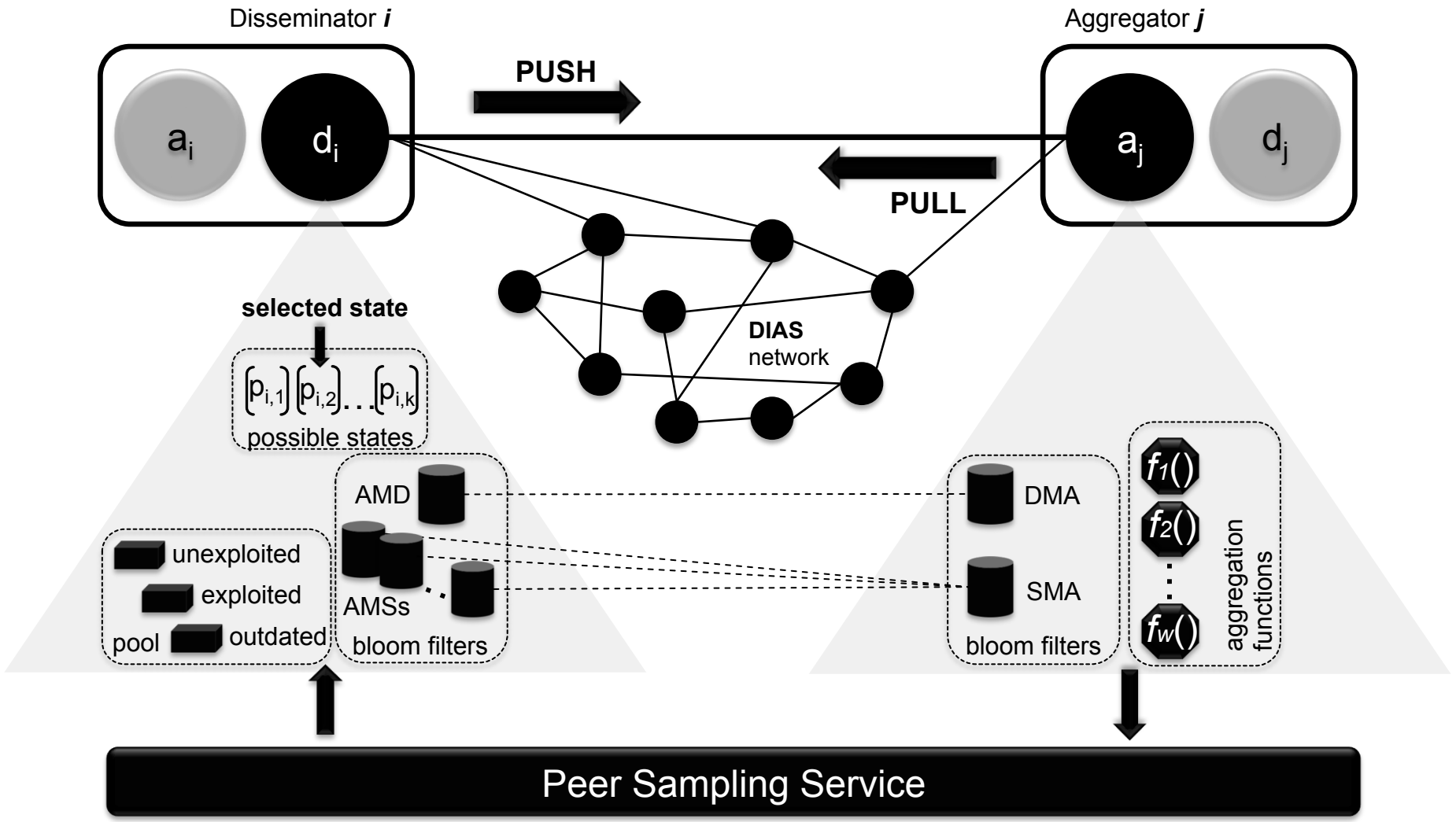
DEMOCRATIZATION OF DATA ANALYTICS

dias-net.org

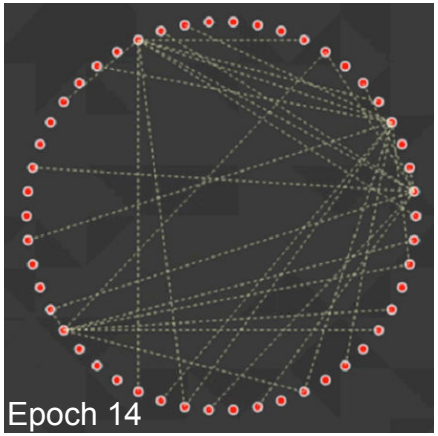
Decentralized Data Management

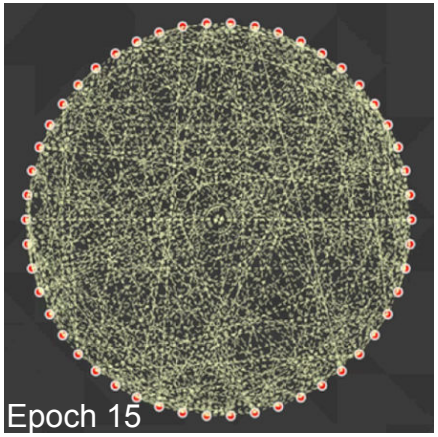


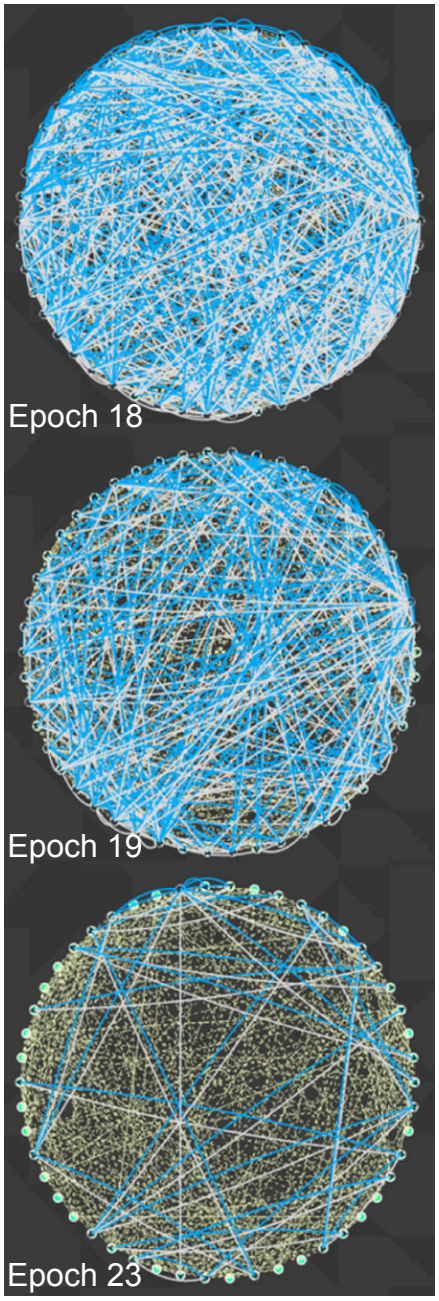
DIAS – How it works!

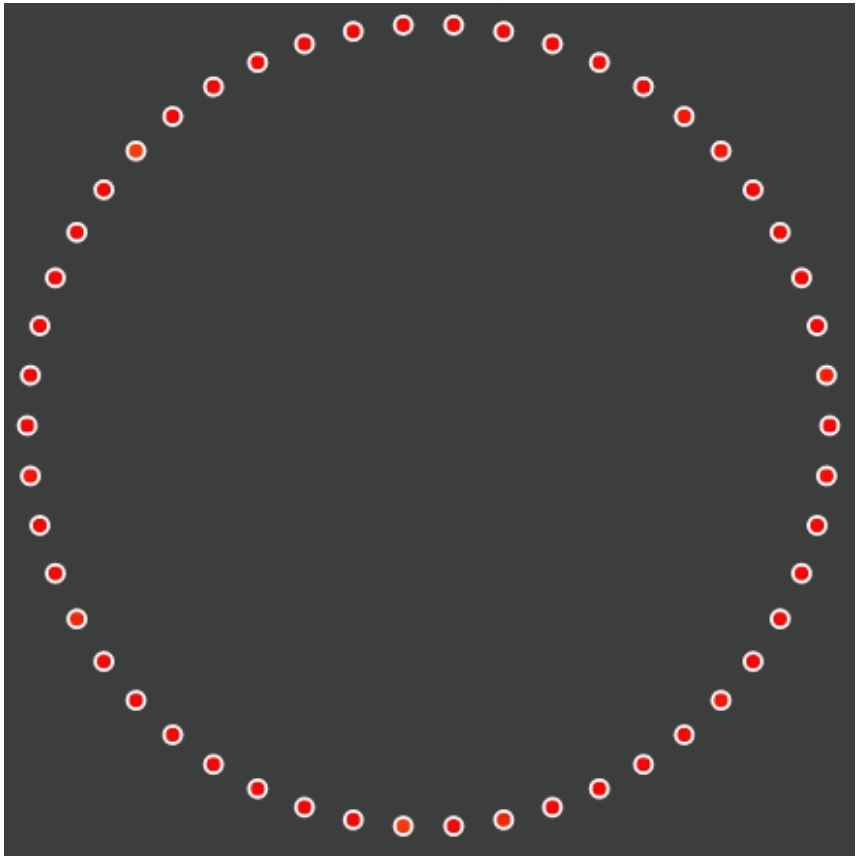


Visualization









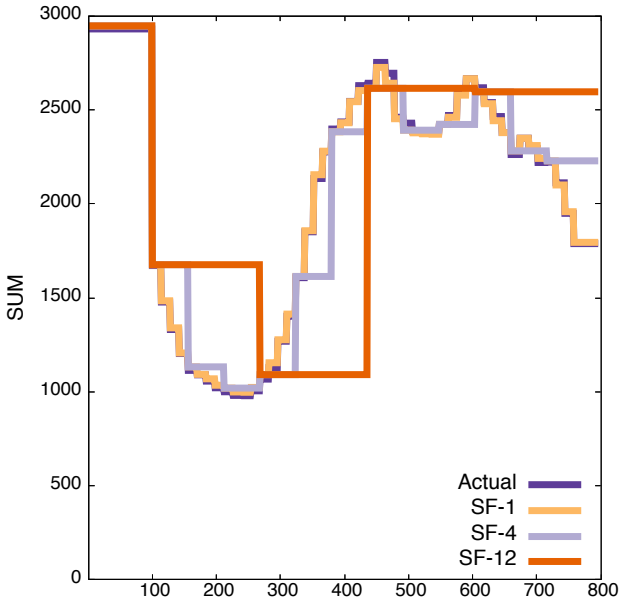
Experimental Evaluation

Implemented with the Protopeer distributed prototyping toolkit

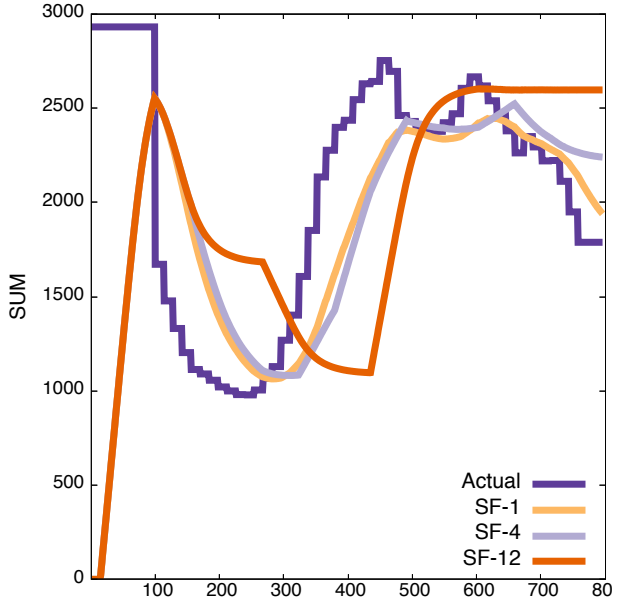
3000 nodes – Extreme scenario: all modes with a data suppliers & consumers

Real-world data: Electricity Customer Behavioral Trial

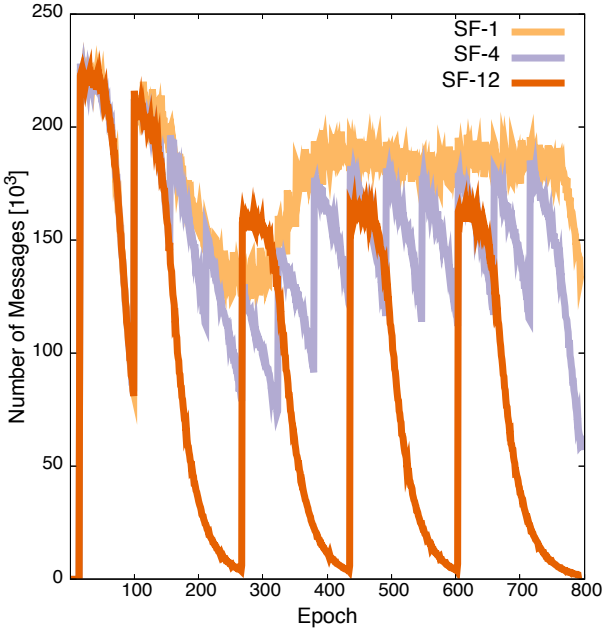
Summarization error

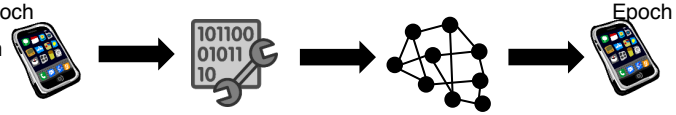


DIAS error

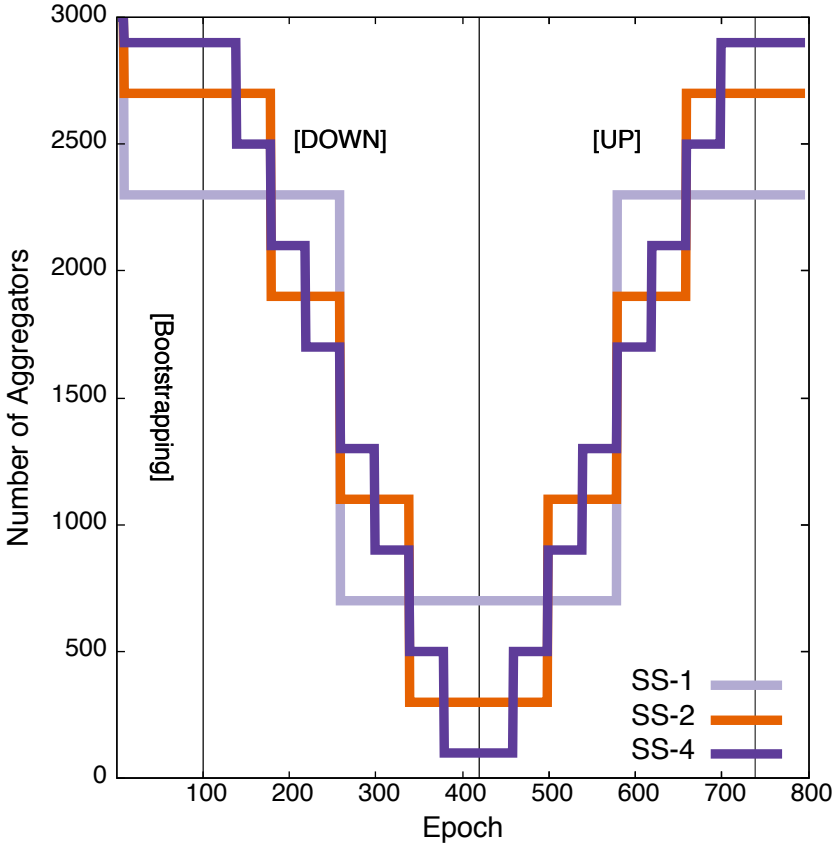


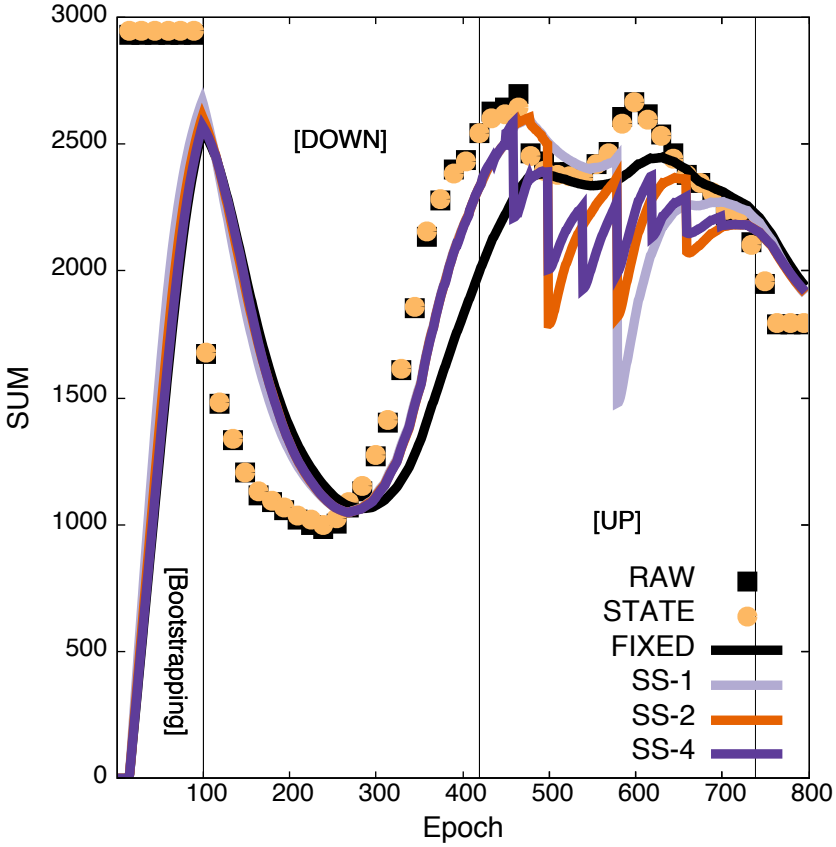
Communication cost





Dynamic Network Settings





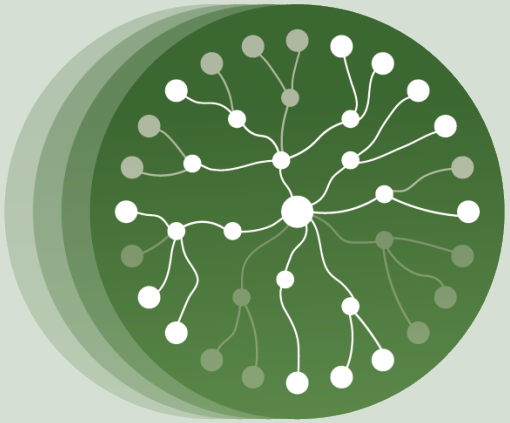
Optimization & Learning

Smart Grids & Smart Cities

Local: make a shower, cook, laundry, charge EV
Global: prevent a blackout,
minimize production costs,
maximize use of renewables

A computational design paradigm for truly decentralized participatory sharing economies?

Local: station to pick or leave a bicycle
Global: prevent overload/underload of bicycle stations
minimize manual bicycle relocations
minimize operational costs
minimize investment costs

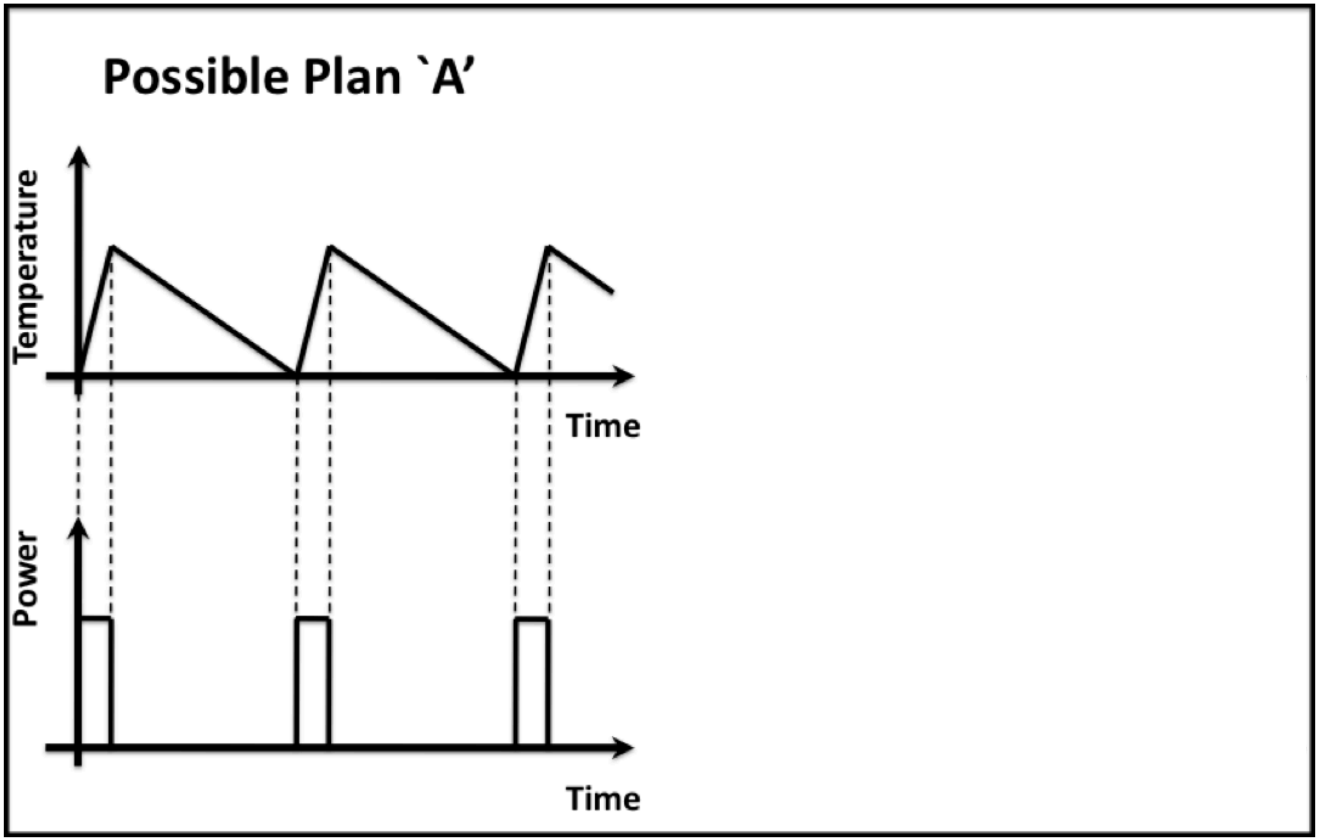


EPOS

epos-net.org

Participation Model

Planning alternative operations: **possible plans**



Technology

LG introduces its first Smart Grid-Ready Refrigerator the DIOS

Category: Environment Household - *Tags:* Household, Lg, Lge, Smart Adapt, Smart Grid, Wi-fi, Wifi

Barely 24 hours Samsung's Smart Grid Ready fridge, LG is now announcing its very own connected Smart Grid-Ready DIOS Fridge in Korea. The new smart refrigerator offers updates and information that can be accessed via smartphones and tablets. It offers three powerful smart savings options: late night saving, preferable time saving and the Smart Grid-ready.

The smart fridge also comes with Smart Adapt, with the latest upgrades, features and options. Th of daily schedules and dispenses regular weather members can turn the fridge's LCD screen into a

Via LGE

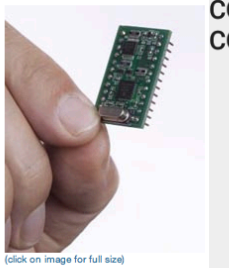
Available Technologies

Grid Friendly Appliance™ Controller

Battelle Number(s): 12782-E, 13538-B
Patent(s) Issued
Available for licensing in all fields

Summary

The Grid Friendly Appliance controller developed at PNNL senses grid conditions by monitoring the frequency of the system and provides automatic demand response in times of disruption.



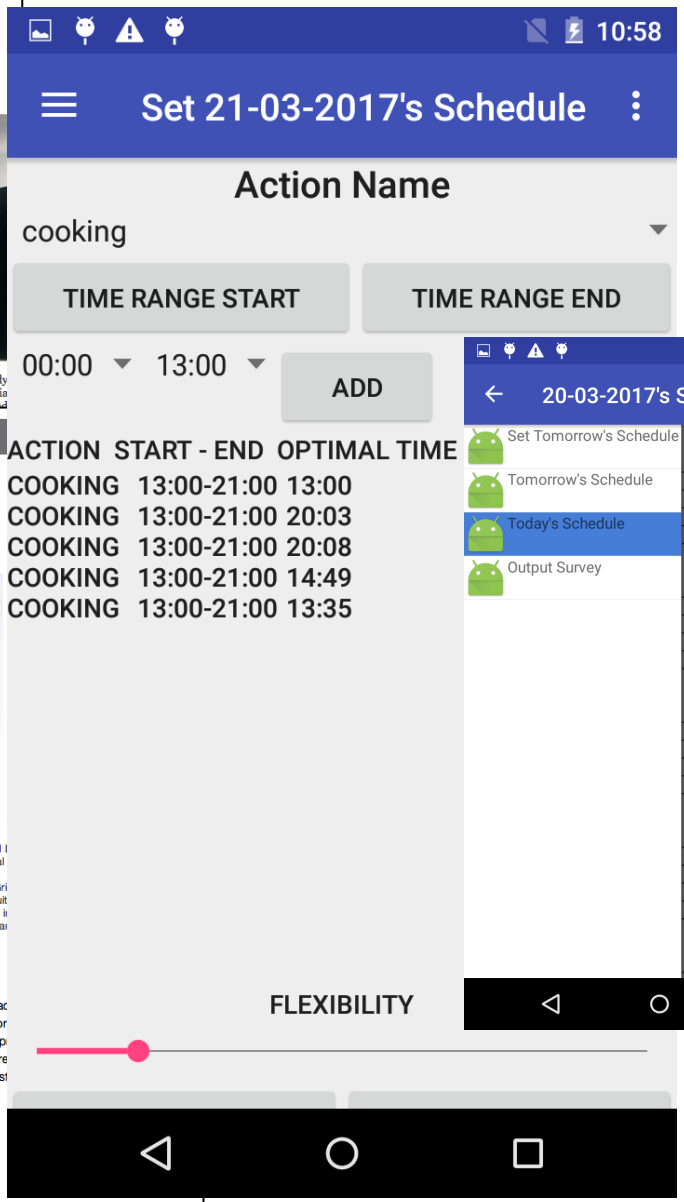
(click on image for full size)

A coin-sized integrated circuit developed researchers at Pacific Northwest National Laboratory may help solve the nation's overworked electricity grid. Called The Gri Friendly™ Appliance Controller, the circuit would turn normal household appliances i that would better regulate energy usage a prevent local and national blackouts.

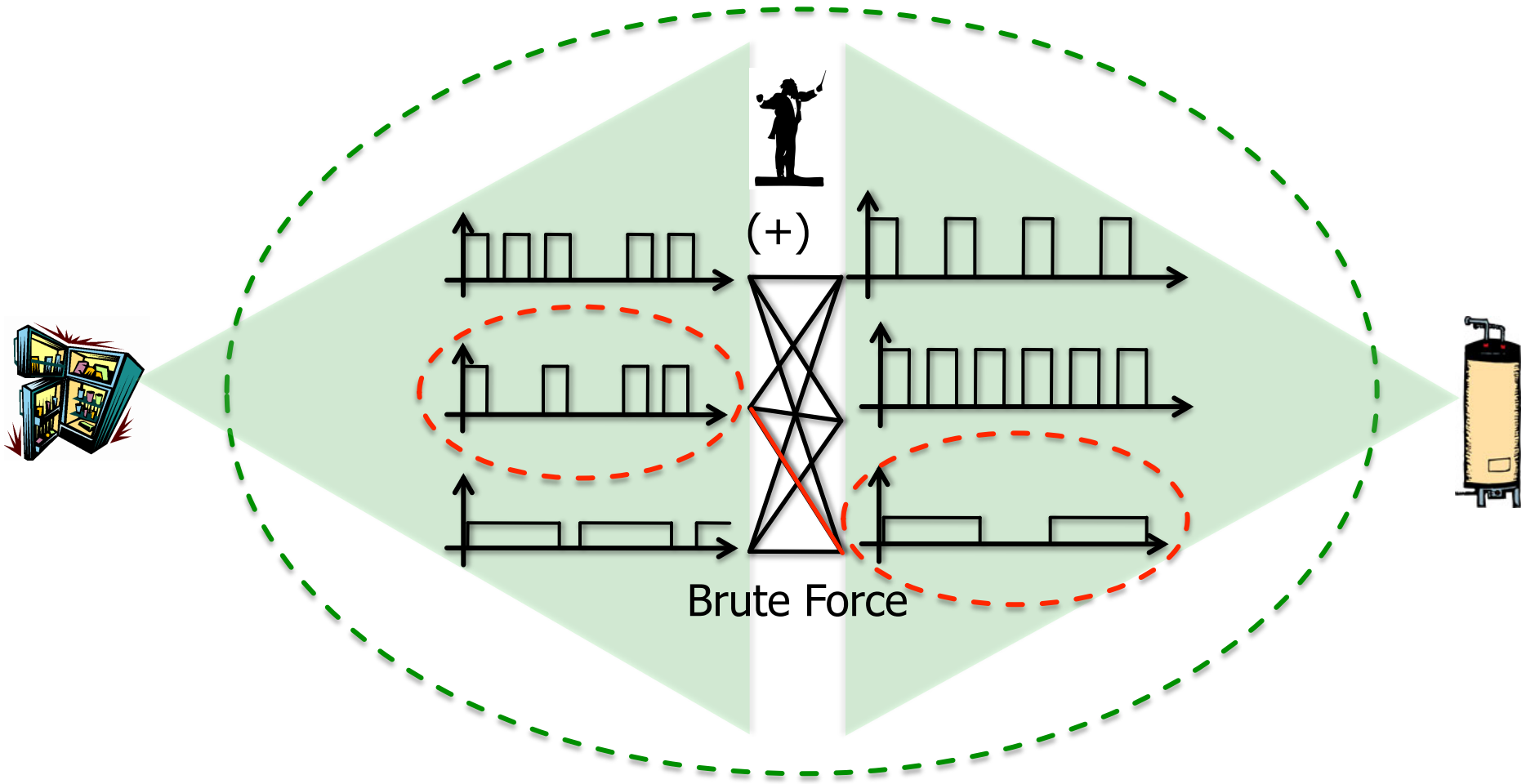
Within the North American power grid a disturbance of 60-Hz frequency is an indicator of serious imbalance between supply and demand that, if unarrested, leads to a blac can be installed in household appliances and turn them off for seconds to allow the grid to stabilize. The controllers can be p in fractions of a second when a disturbance is detected, where come up to speed. They can even be programmed to delay rest after a power outage to ease power restoration.

Advantages

- More reliable power grids are less costly to run
- Smaller electricity bills for consumers
- More efficient power plant use
- Inexpensive
- A foundation for future grid management



Computational Model



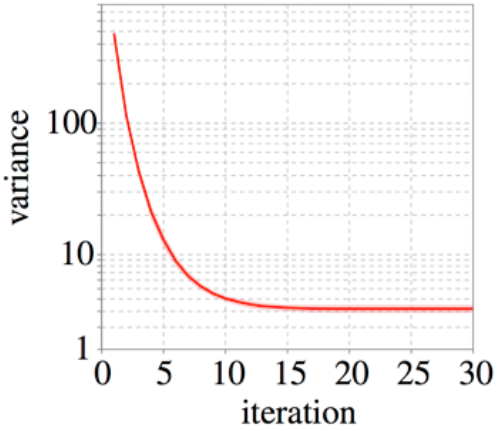
Complexity = # of possible plans$^{\#\ \text{of devices}}$

Decentralized Algorithm

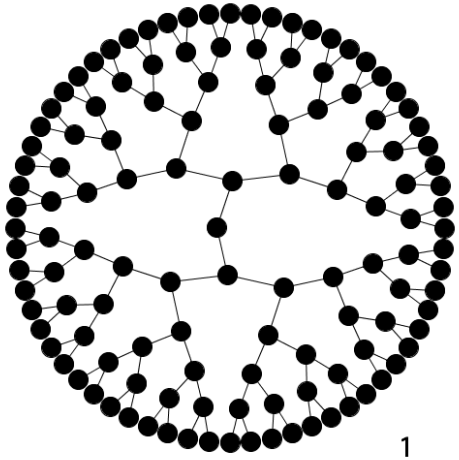
(Self-)organization in a tree topology
bottom-up aggregation & decision-making

Selection function: e.g. Minimum variance, match target signal

1. Bottom-up phase: form candidate solutions
2. Top-down phase: back-propagate effective solutions
3. Repeat to learn



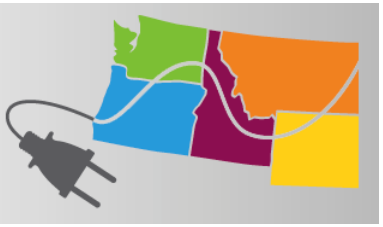
Monotonously improving/learning solutions



Local information
+
aggregate information (branch/tree)

Experimental Evaluation

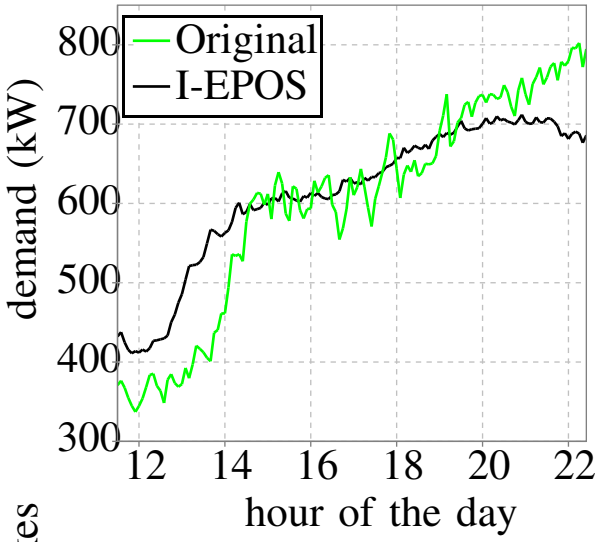
Pacific Northwest SMART GRID DEMONSTRATION PROJECT



1000 households

Time: 11:00-23:00

13 plans, generated by load-shifting

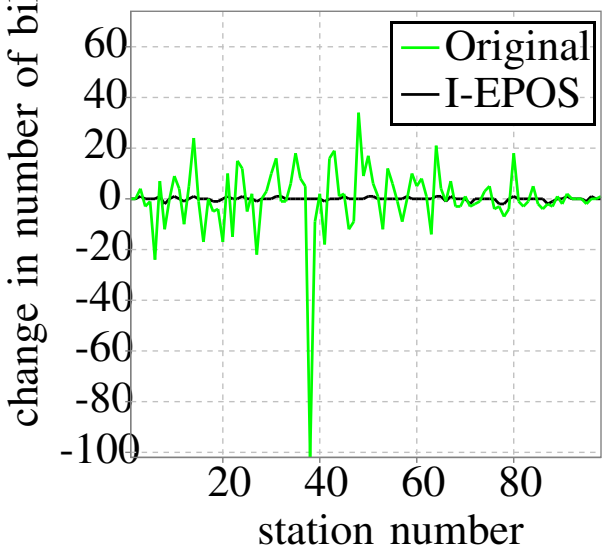


Hubway Data Visualization Challenge

1000 users

Plan generation using historic trips

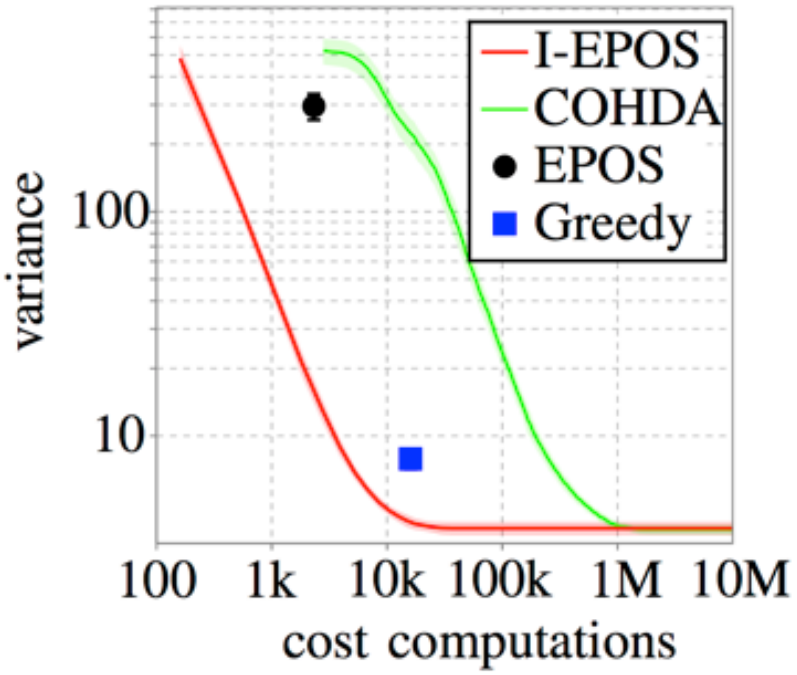
Time: 08:00-10:00



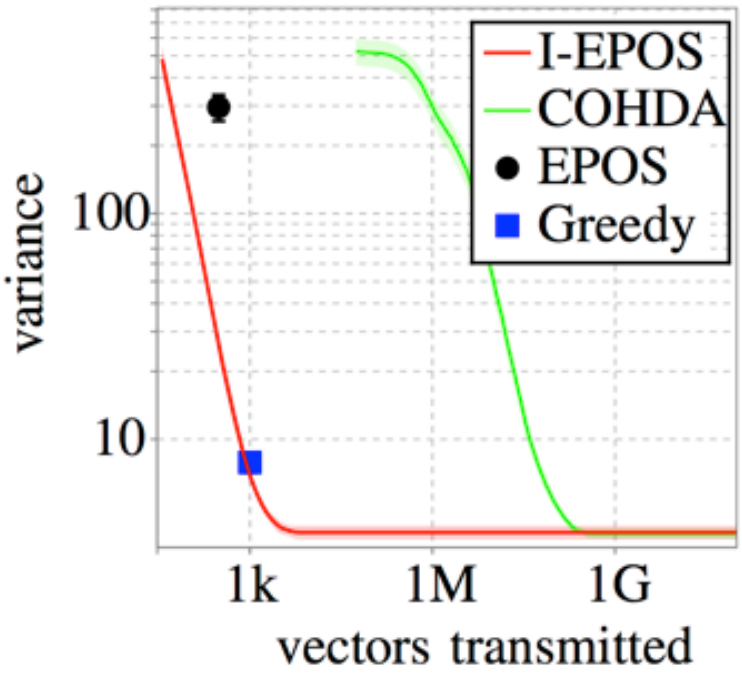
Comparison with Related Work

Superior performance even when compared to systems storing complete information & performing brute-force operations

Computational cost



Communication cost



Future Work & Research Direction

Living lab – Mobile social experiments, hackathons, smart city applications

Community-based cloud infrastructure
personal data stores & **public good services**

Adaptive decentralized **resource allocation in clouds** with EPOS

Fully **decentralized deep learning** algorithms

References

General Relevance

- Dirk Helbing and **Evangelos Pournaras**, *Build Digital Democracy*, Nature, Vol. 527, pp. 33-34, 2015 © Macmillan Publishers Limited

- **Evangelos Pournaras**, *Decentralization in Digital Societies-A Design Paradox*, In Pursuit of the Beautiful Soul, The Public Sphere Salons, 2016

- **Evangelos Pournaras**, *Multi-level Reconfigurable Self-organization in Overlay Services*, PhD Thesis, Delft University of Technology, March 2013

Data Sharing

- **Evangelos Pournaras**, Jovan Nikolic, Pablo Velasquez, Marcello Trovati, Nik Bessis and Dirk Helbing, *Self-regulatory Information Sharing in Participatory Social Sensing*, The European Physical Journal Data Science, 5:14, 2016 © SpringerOpen

- **Evangelos Pournaras**, Izabela Moise and Dirk Helbing, *Privacy-preserving Ubiquitous Social Mining via Modular and Compositional Virtual S*ensors, in the proceedings of the 29th IEEE International Conference on Advanced Information Networking and Applications-AINA-2015, pages 332-338, Gwangju, South Korea, March 2015. © IEEE

Data Analytics

- **Evangelos Pournaras**, Jovan Nikolic, Alex Omerzel, Dirk Helbing*, Engineering Democratization in Internet of Things Data Analytics*, in the proceedings of the 31st IEEE International Conference on Advanced Information Networking and Applications-AINA-2017, Taiwan, March 2017 © IEEE

- **Evangelos Pournaras**, Martijn Warnier and Frances M.T. Brazier, *A Generic and Adaptive Aggregation Service for Large-scale Decentralized Networks*, Complex Adaptive Systems Modeling, 1:19, 2013 © SpringerOpen

Optimization & Learning

- Peter Pilgerstorfer and **Evangelos Pournaras**, *Self-adaptive Learning in Decentralized Combinatorial Optimization-A Design Paradigm for Sharing Economies*, in the Proceedings of the 12th International Symposium on Software Engineering for Adaptive and Self-managing Systems-SEAMS-2017, Buenos Aires, May 2017

- **Evangelo**s Pournaras, Matteo Vasirani, Robert E. Kooij and Karl Aberer, *Decentralized Planning of Energy Demand for the Management of Robustness and Discomfort*, IEEE Transactions on Industrial Informatics, Vol. 10, Nr. 4, pp. 2280-2289, 2014 © IEEE

Questions?

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The Trade-off of Data Sharing

Symbol	Interpretation
i	An agent index
e	An epoch index
t	A time index within an epoch
T	Epoch duration
$R_{i,e}$	Sequence of raw data
$r_{i,e,t}$	A record of raw data
$S_{i,e}$	Sequence of summarized data
$s_{i,e,t}$	A record of summarized data
$f_s()$	Summarization function
j	An index for a possible summarization value
$c_{i,e,j}$	A possible summarization value
$k_{i,e}$	The number of possible summarization values
l	Number of epochs
$\alpha_{i,e}$	Summarization metric
$D_{i,e}$	Sequence of raw or summarization data
$H(D_{i,e})$	Entropy
$p_{i,e,j}$	Probability of a possible value occurring in an epoch
n_t	Occurrence or not of possible value at time t
$\beta_{i,e}$	Diversity
m_t	Change or not between two consecutive time periods t and $t+1$
$\epsilon_{i,e,t}$	Local error
$\varepsilon_{i,e}t$	Global error
n	Number of participating citizens
$\epsilon_{e,t}$	Average local error among citizens
γ_e	Total rewards that data aggregators are willing to provide
$P_r()$	Probability density function for rewards
z	Number of discrete participation levels
$P_s()$	Probability density function for summarization
$\gamma_{i,e}$	Rewards provided to agent i

Average local error

$$\epsilon_{e,t} = \frac{1}{n}\sum_{i=1}^{n}\epsilon_{i,e,t}$$

$$\epsilon_{i,e,t} = \frac{|r_{i,e,t} - s_{i,e,t}|}{|r_{i,e,t}|}$$

Entropy

$$H(D_{i,e}) = -\sum_{j=1}^{k_{i,e}} p_{i,e,j}\log_2 p_{i,e,j},$$

$$p_{i,e,j} = \frac{1}{T}\sum_{t=1}^{T} n_t, \quad n_t = \begin{cases} 1 & \text{if } c_{i,e,j} = d_{i,e,t}, \\ 0 & \text{if } c_{i,e,j} \neq d_{i,e,t}, \end{cases}$$

Diversity

$$\beta_{i,e} = \frac{1}{T-1}\sum_{t=1}^{T-1} m_t, \quad m_t = \begin{cases} 1 & \text{if } d_{i,e,t} = d_{i,e,t+1}, \\ 0 & \text{if } d_{i,e,t} \neq d_{i,e,t+1}, \end{cases}$$

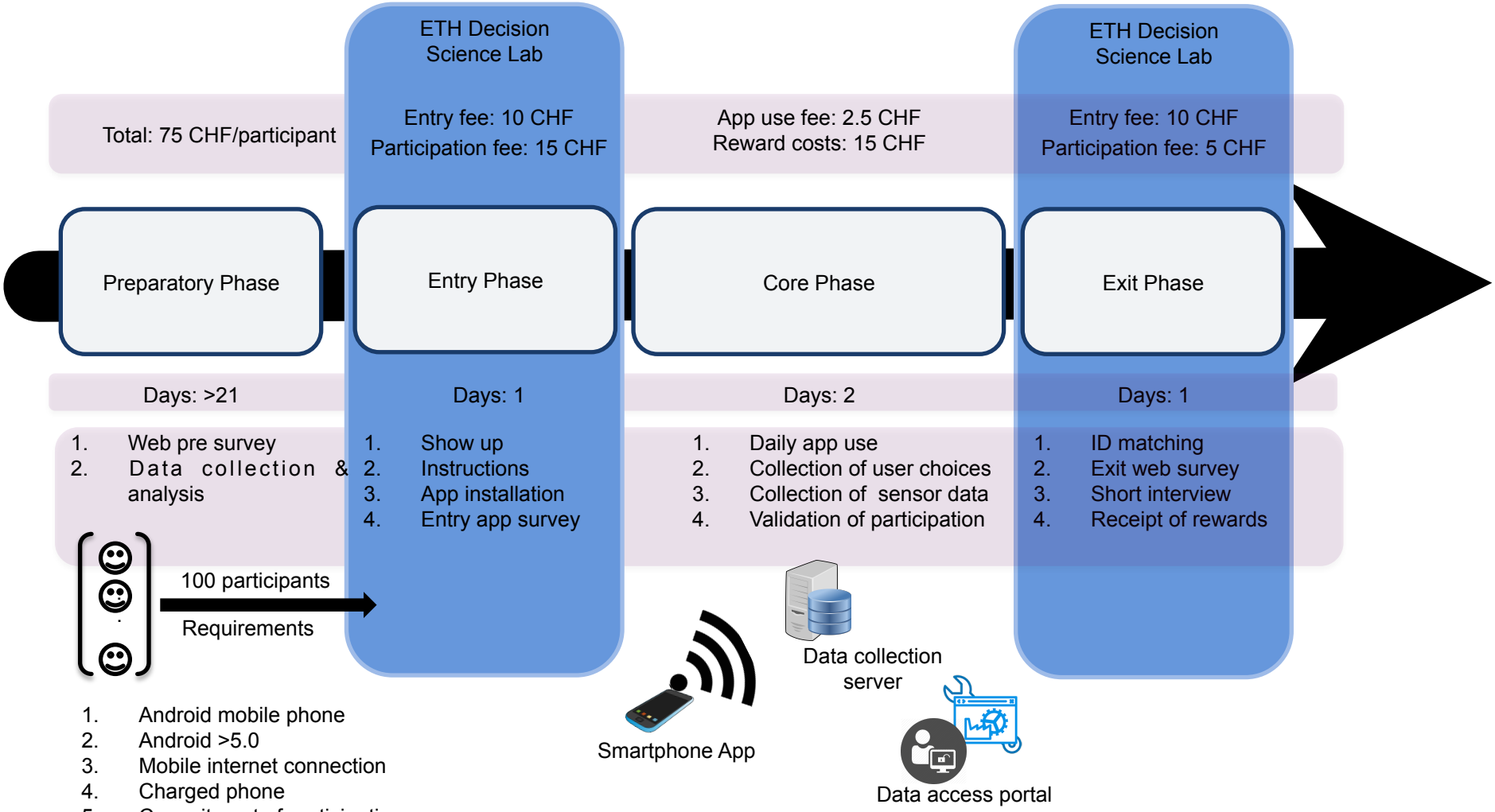
Global error

$$\varepsilon_{e,t} = \frac{|\sum_{i=1}^{n} r_{i,e,t} - \sum_{i=1}^{n} s_{i,e,t}|}{|\sum_{i=1}^{n} r_{i,e,t}|},$$

Rewards

$$\gamma_{i,e} = \frac{\gamma_e * P_r(\alpha_{i,e})}{n * P_s(\alpha_{i,e})}.$$

Experimental Process



1. Android mobile phone
2. Android >5.0
3. Mobile internet connection
4. Charged phone
5. Commitment of participation in entry, core & exit phases