ETH zürich

Participatory Self-management Systems for Resilient Smart Cities

Dr. Evangelos Pournaras
Professorship of Computational Social Science

Motivation

Data Is the New Oil of the Digital Economy

GEAR | SCIENCE | SECURITY

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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.

MIT Technology Review

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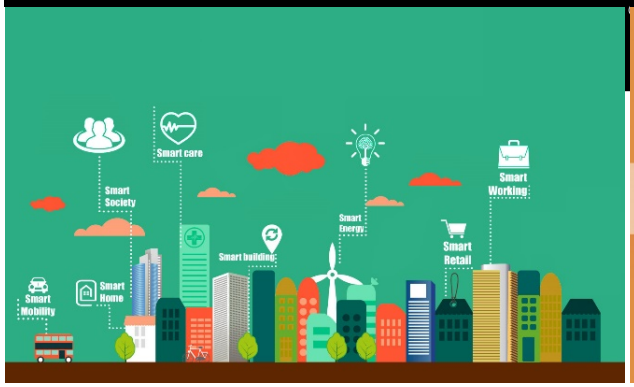
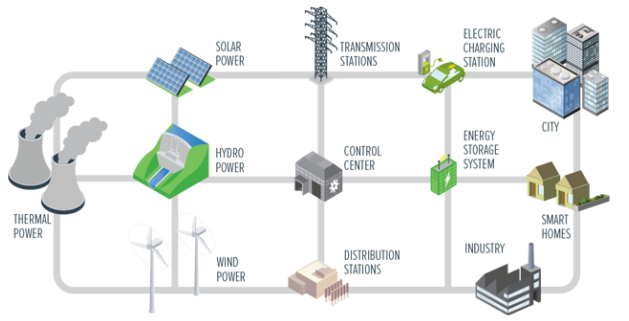
Big Data and Analytics: Here, There, and Everywhere

08 Stories

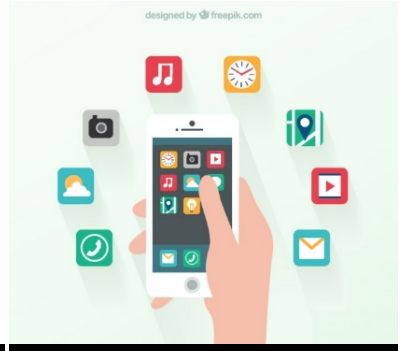
smart cities



wearables



smart grids



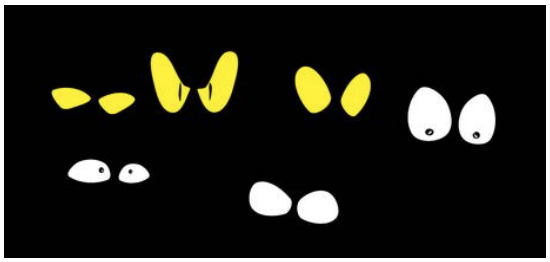
smart phones

Energy

Energy Management Challenges

Negative peaks

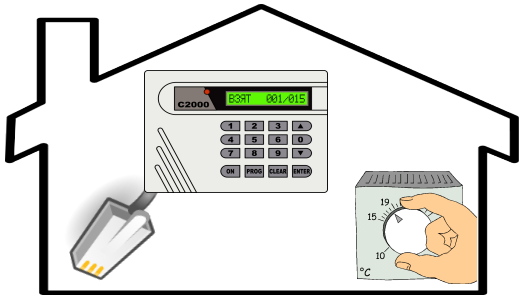
Integration of renewables, battery technologies, electrical vehicles, etc.



cascading failures

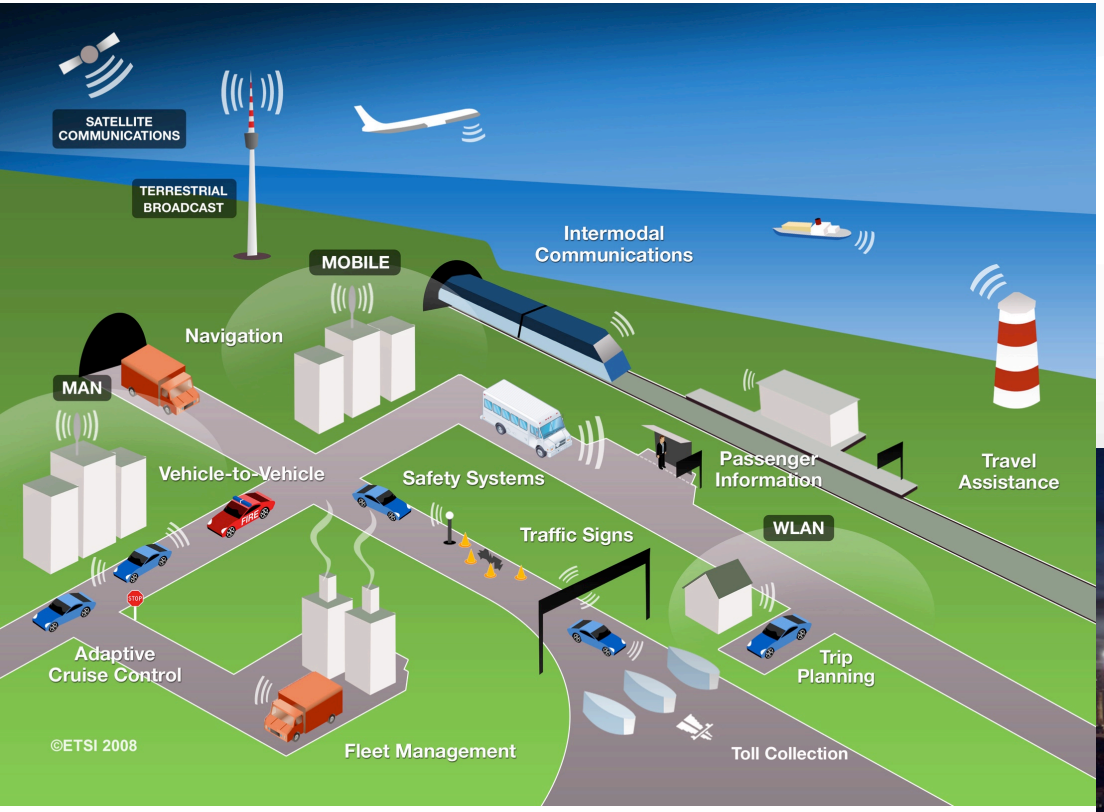
Matching supply & demand

Demand-side energy management

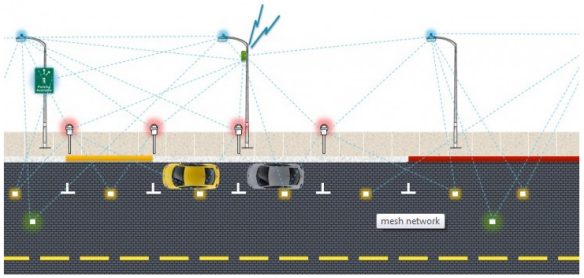


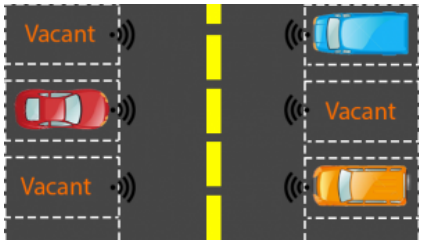
Participation, discomfort & fairness

Transport & Traffic

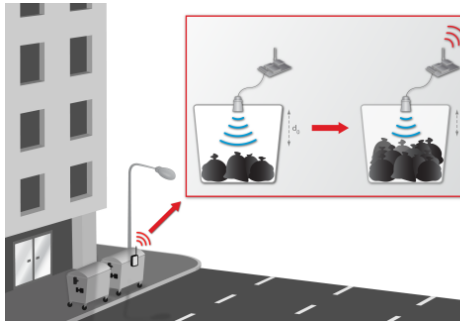


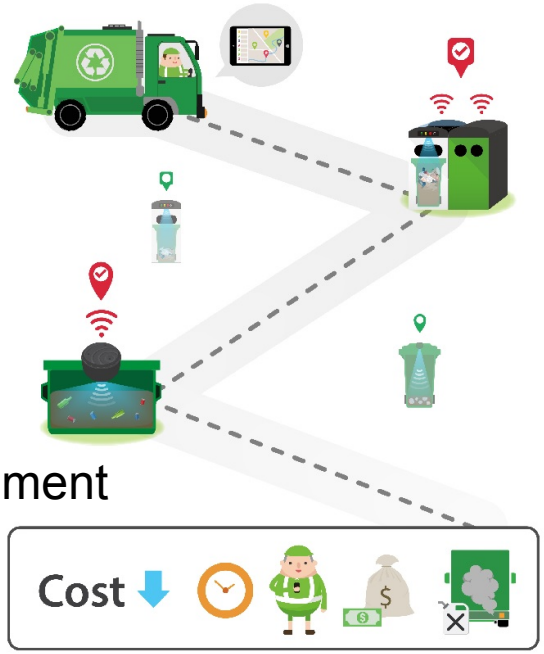
Transport and Traffic Challenges





Smart Parking

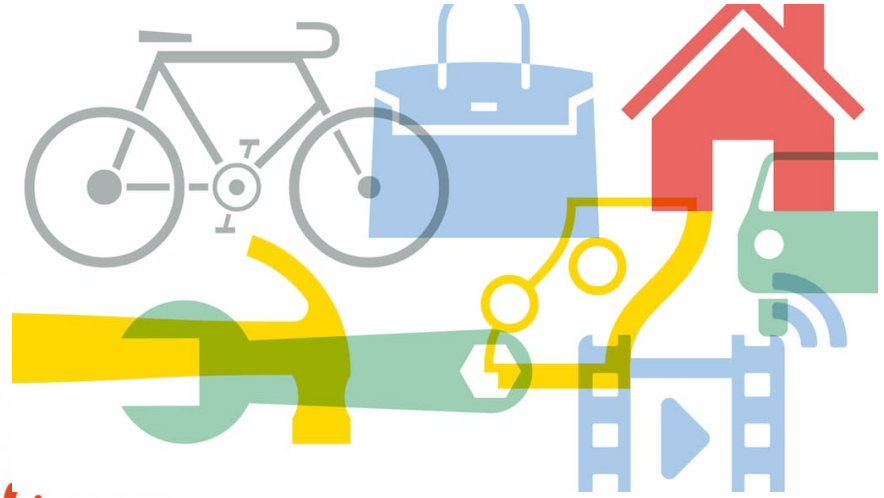




Waste management

Load-balancing of bike sharing stations

Sharing Economies

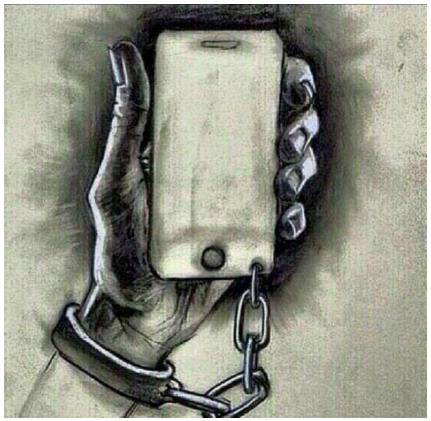


airbnb

Management & Regulation with ICT

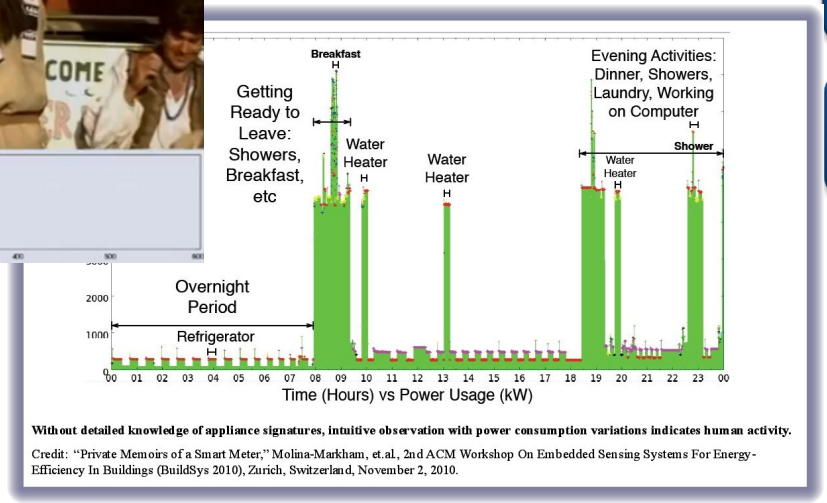
"Your recent Amazon purchases, Tweet score and location history makes you 23.5% welcome here."

Discriminatory big data analysis



Autonomy

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.

Optimization & Learning

Data Analytics

Data Sharing

Privacy-intrusion, surveillance & profiling

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 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

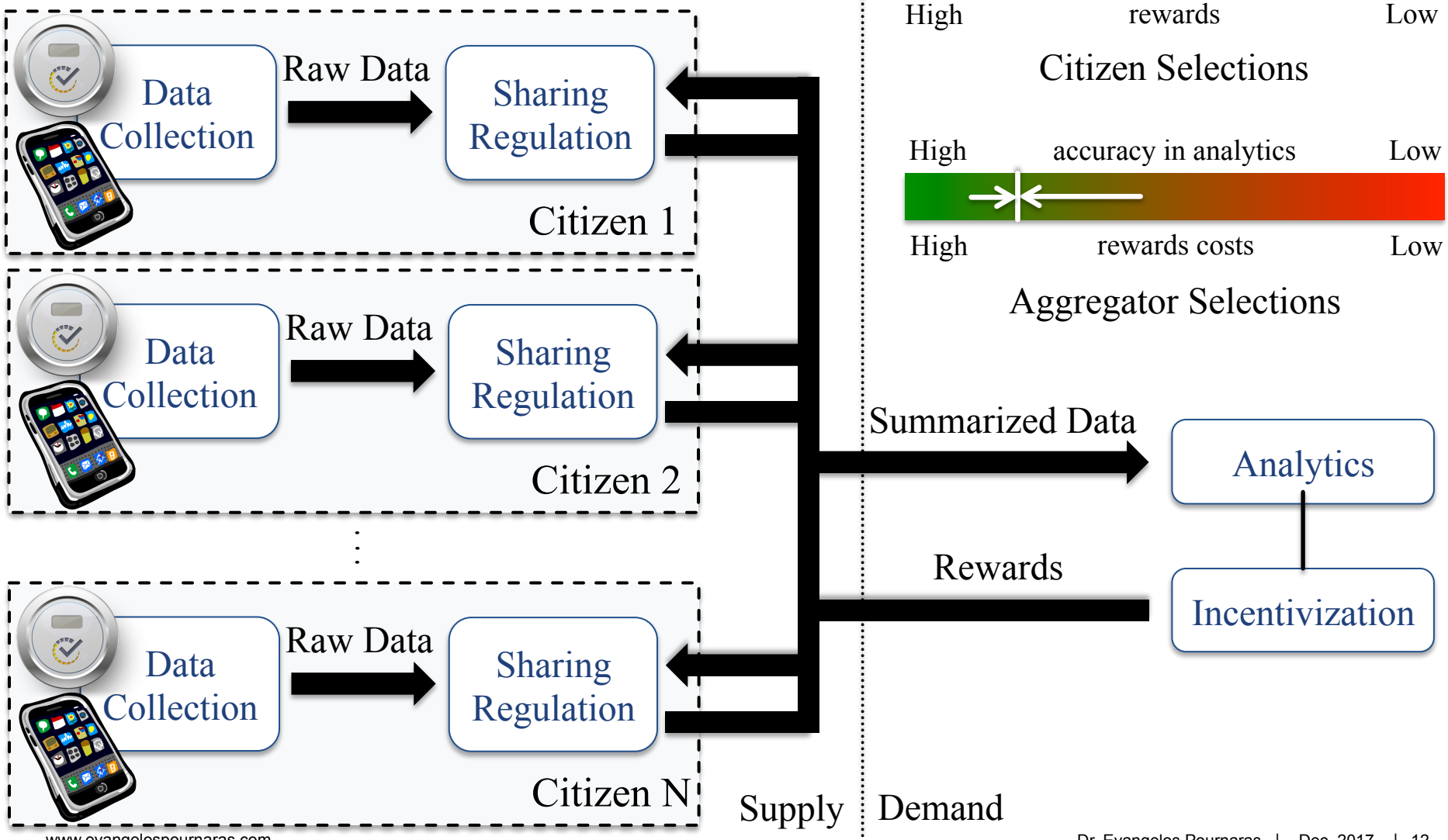
Optimization & Learning

Data Analytics

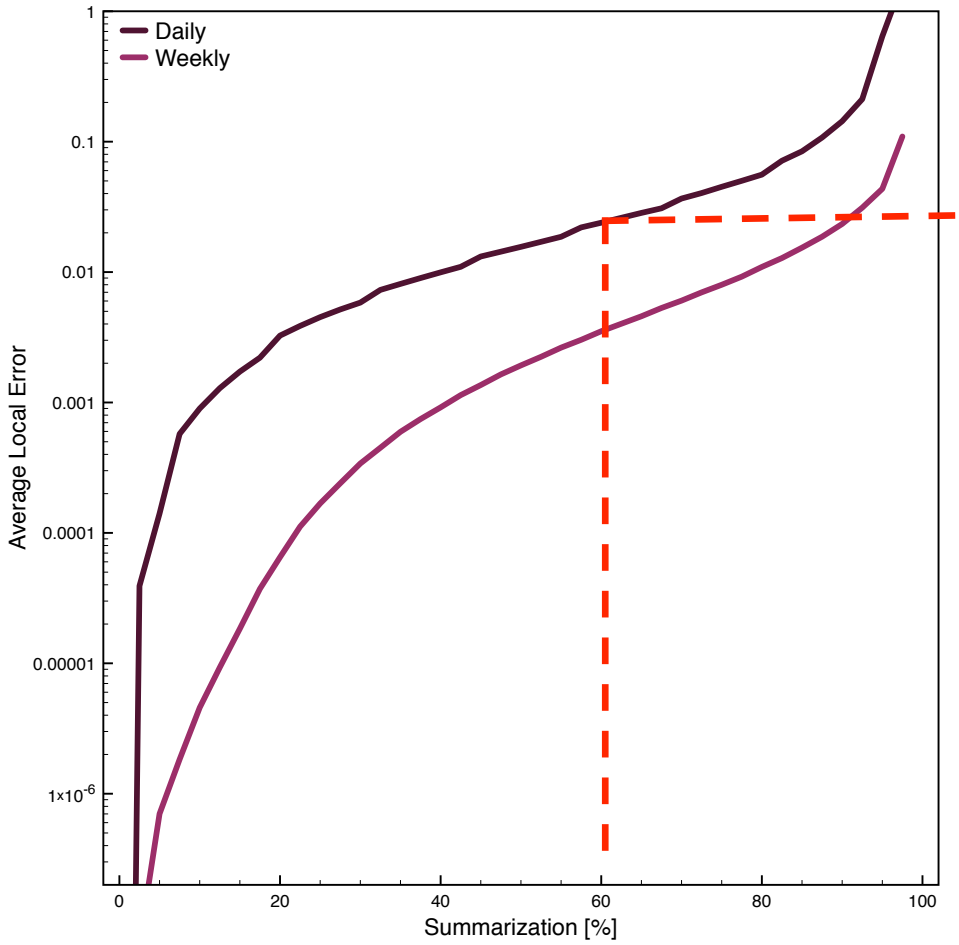
Data Sharing

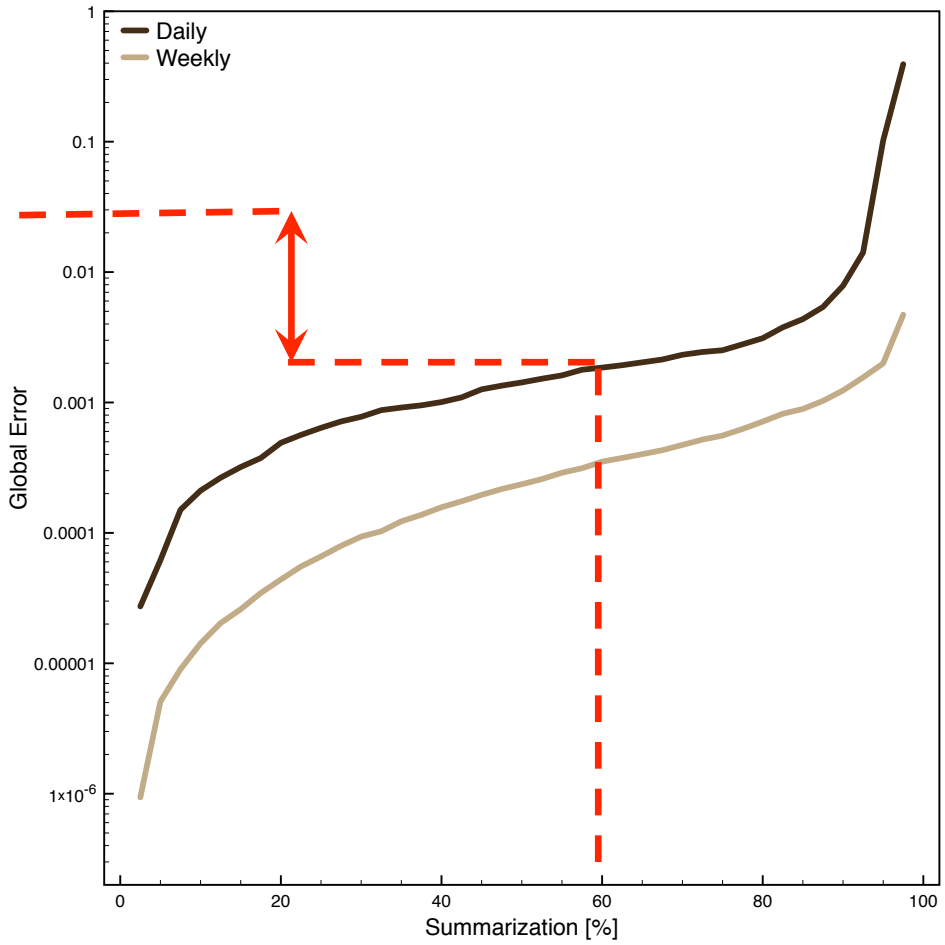
Data Sharing

Data Sharing Vision



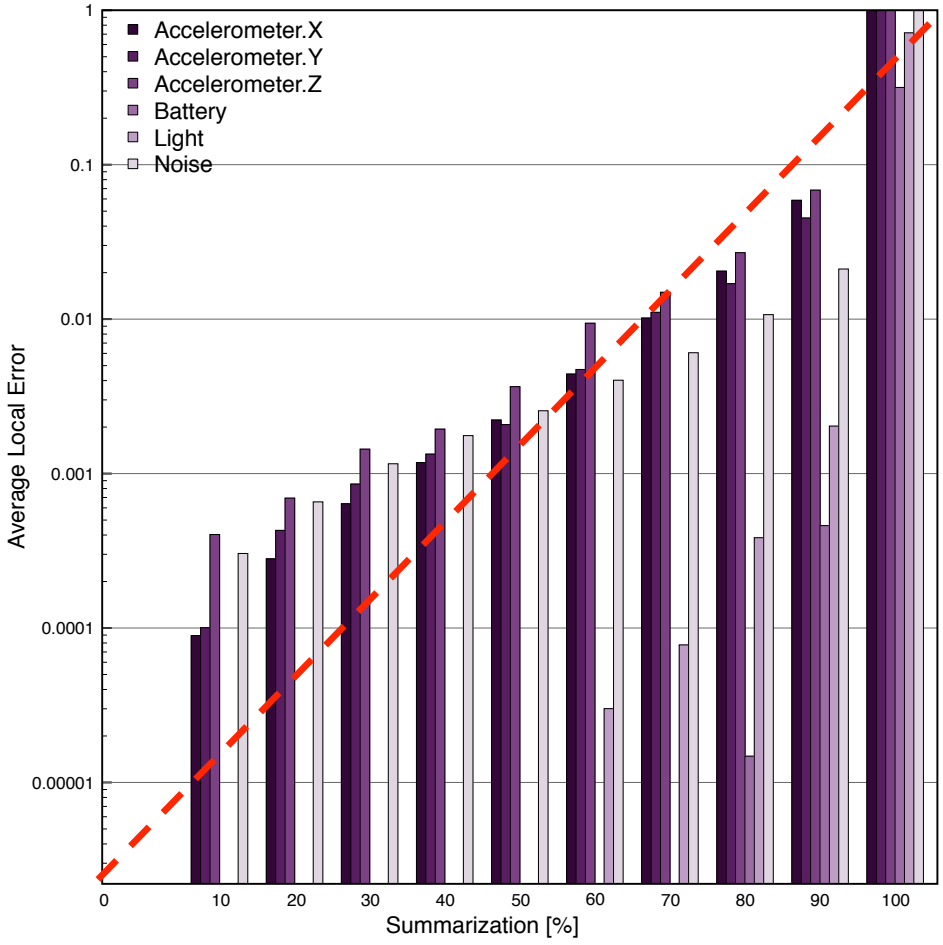
Privacy vs. Accuracy – Smart Grid

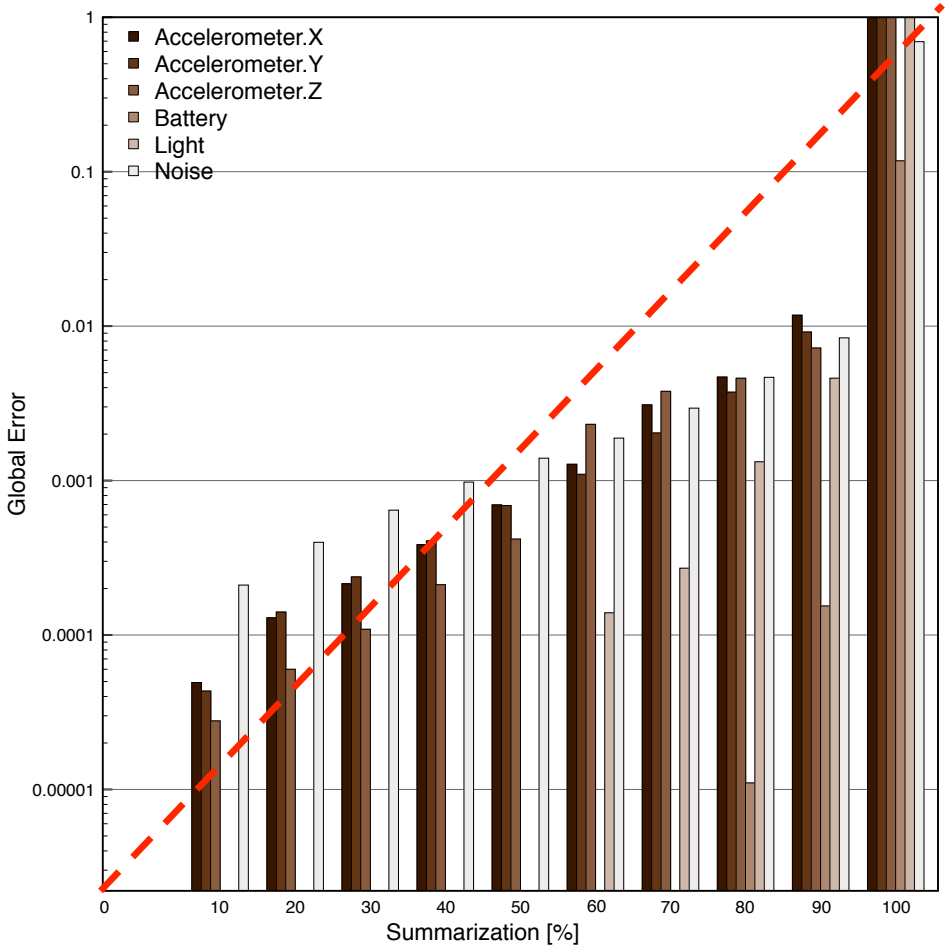




Summarization: k-means

Privacy vs. Accuracy – Nervousnet



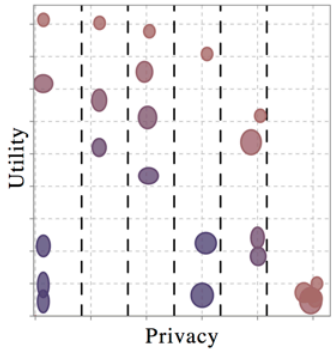


Summarization: k-means

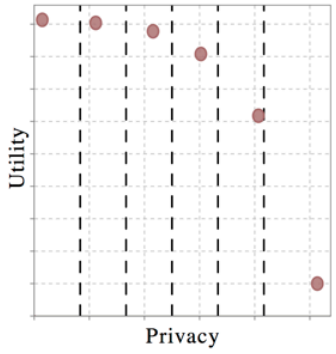
Mining Privacy-Utility Tradeoffs

(a) Privacy-utility trajectory

(b) Binning of the privac range



(c) Evaluation via objective function



(d) Bin optimization

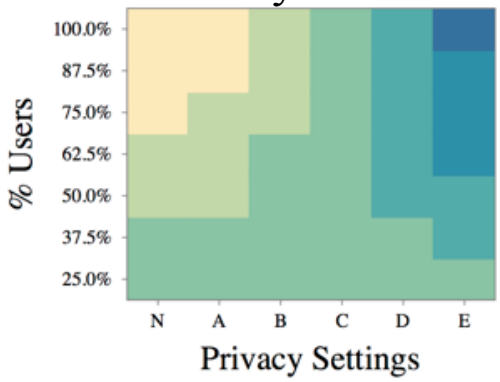
>20000 differential privacy settings

Real-world data – Smart Grids, smart phone sensing

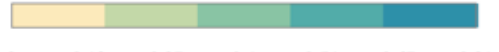
Varying # of users with varying privacy requirements

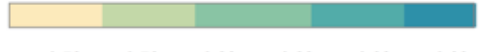
ID	Masking	Parameters	Privacy	Utility
A	cosine	0.0-0.0-0.0-0.18-0.0	0.01	0.99
B	laplace	0.005	0.20	0.98
C	cosine	0.6-0.6-0.0-0.9-0.3	0.40	0.84
D	cosine	1.2-0.3-0.6-1.2-0.9	0.60	0.76
E	cosine	1.5-1.5-1.2-0.3-1.2	0.80	0.68
N	none	-	0.00	1.00

Privacy Median



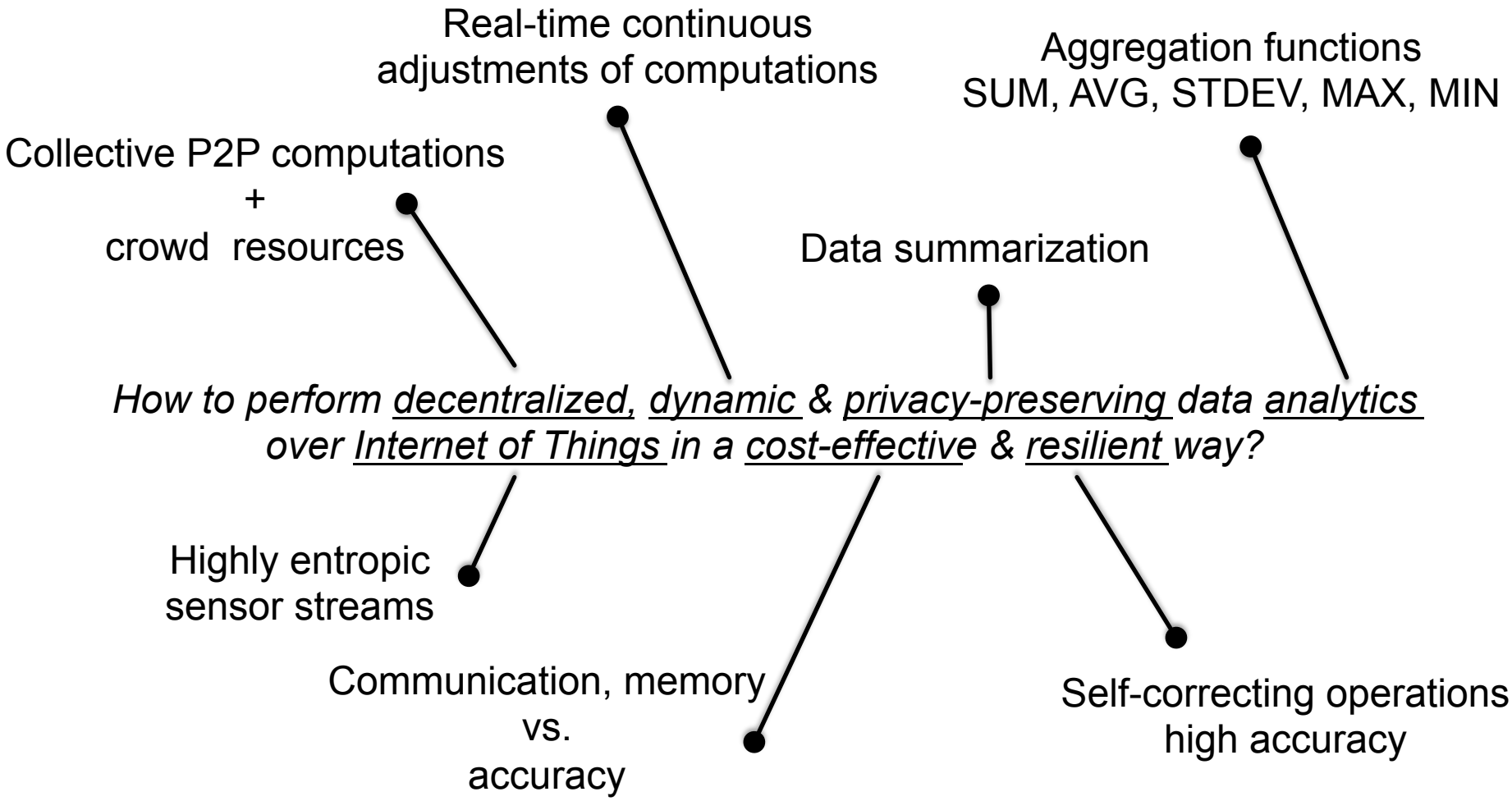
Utility Median





Data Analytics

Research Question

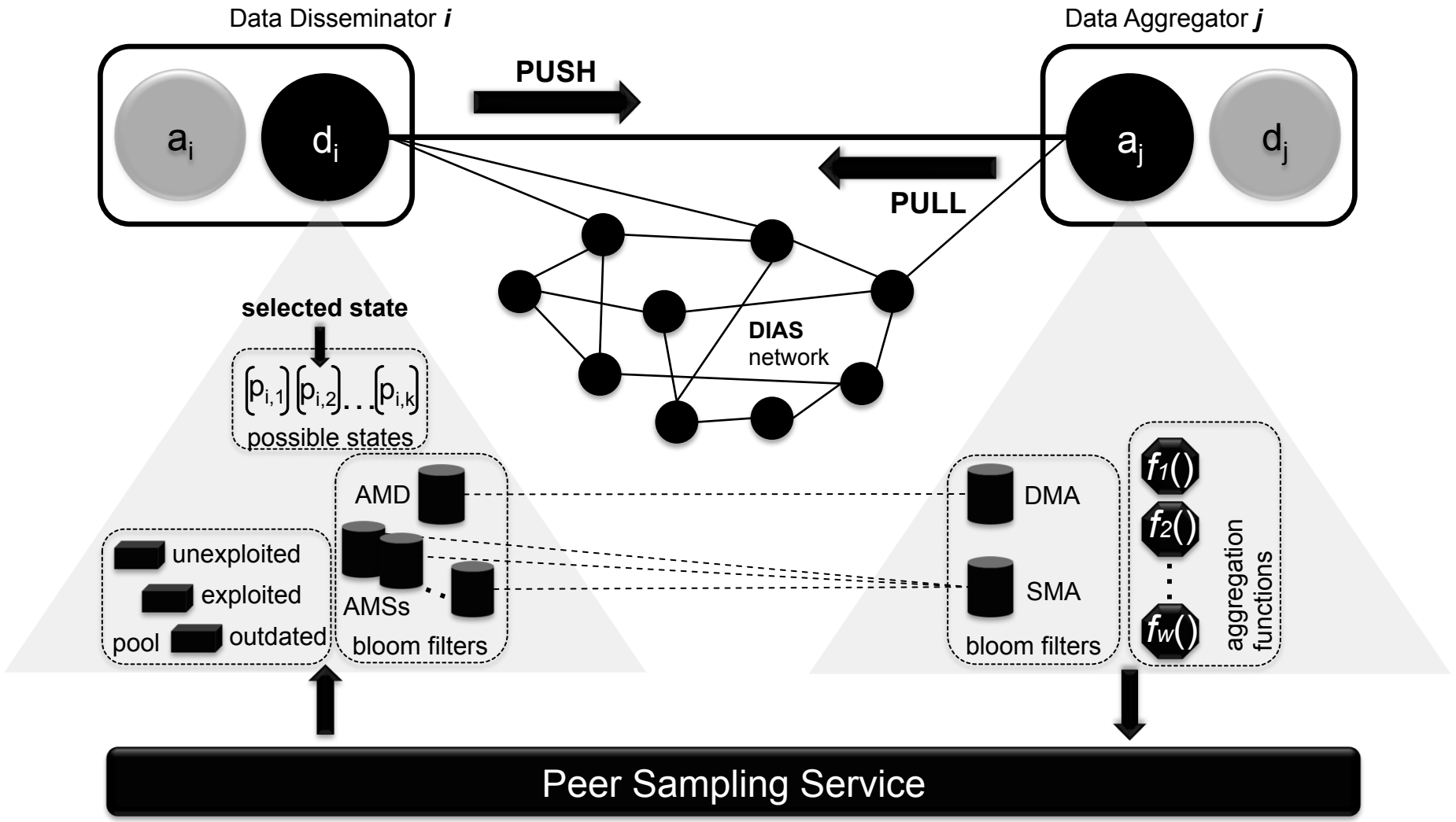


DEMOCRATIZATION OF DATA ANALYTICS

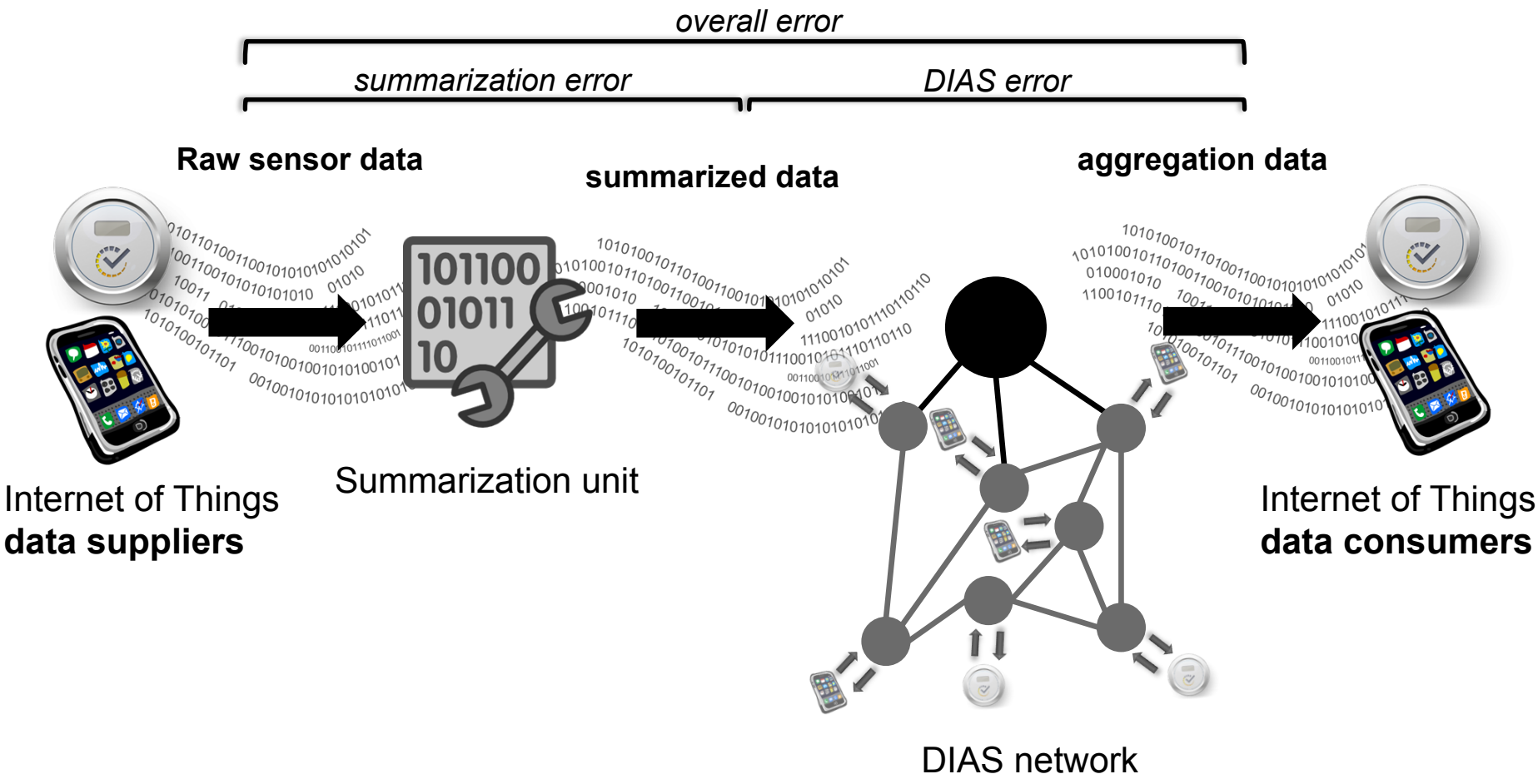
Dynamic Intelligent Aggregation Service

dias-net.org

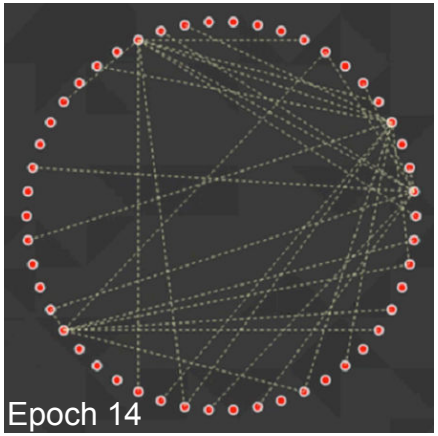
DIAS – How it works!

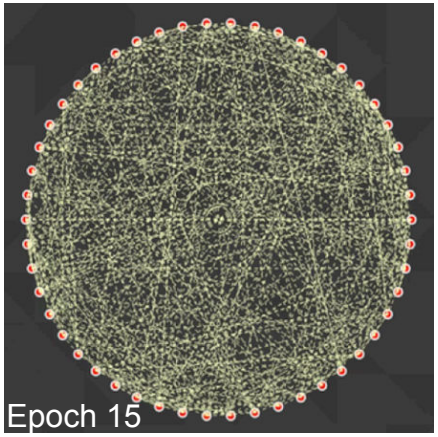


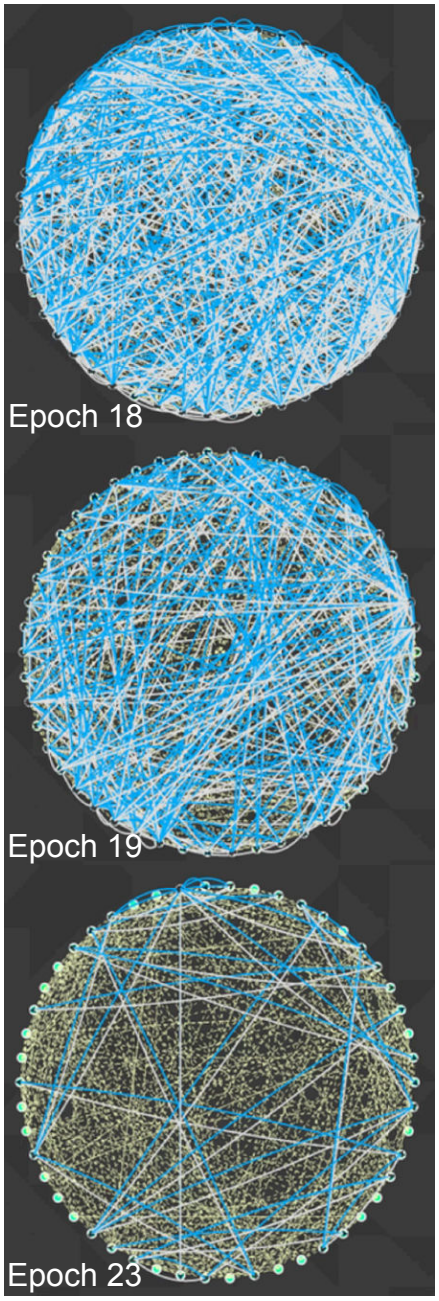
Decentralized Data Management

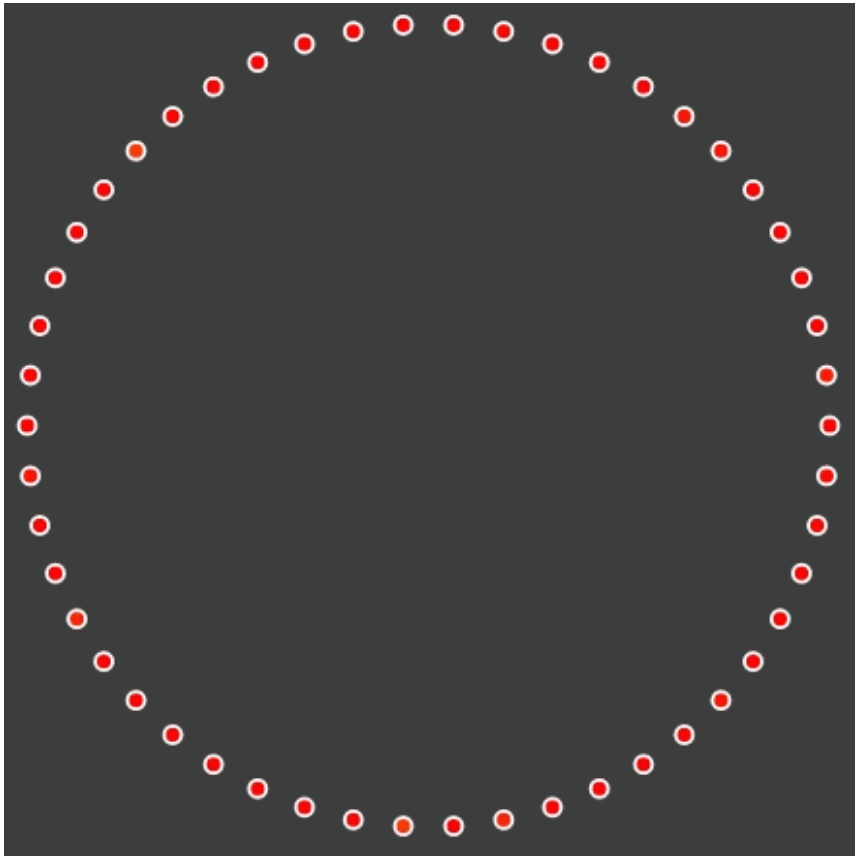


Visualization

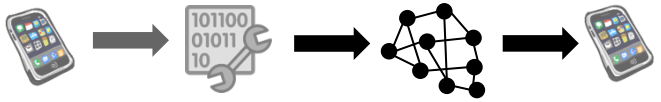


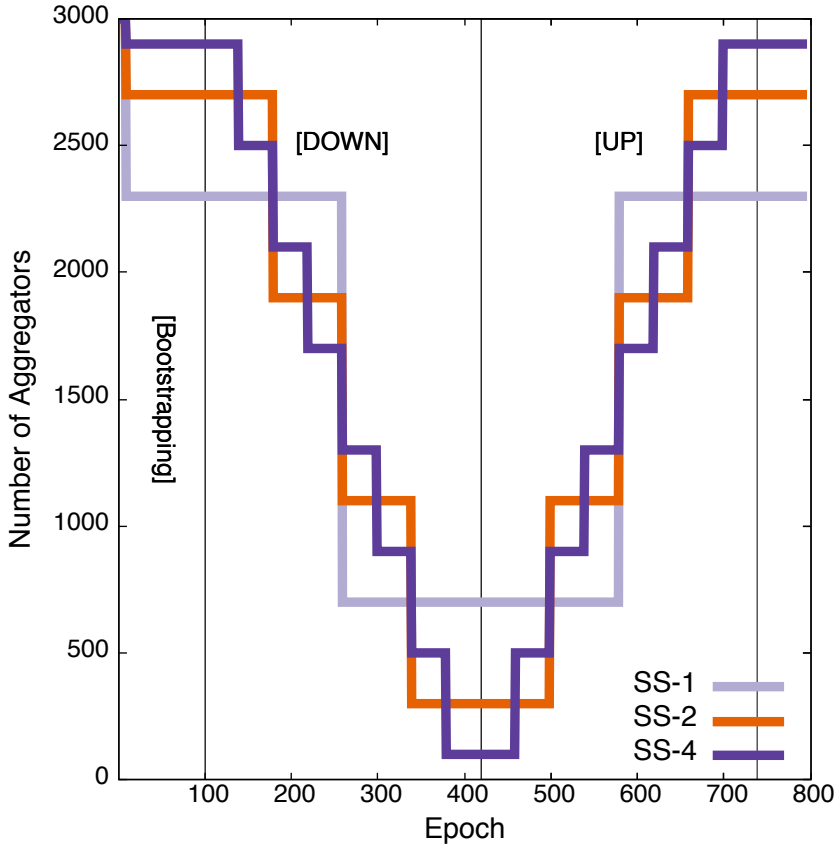


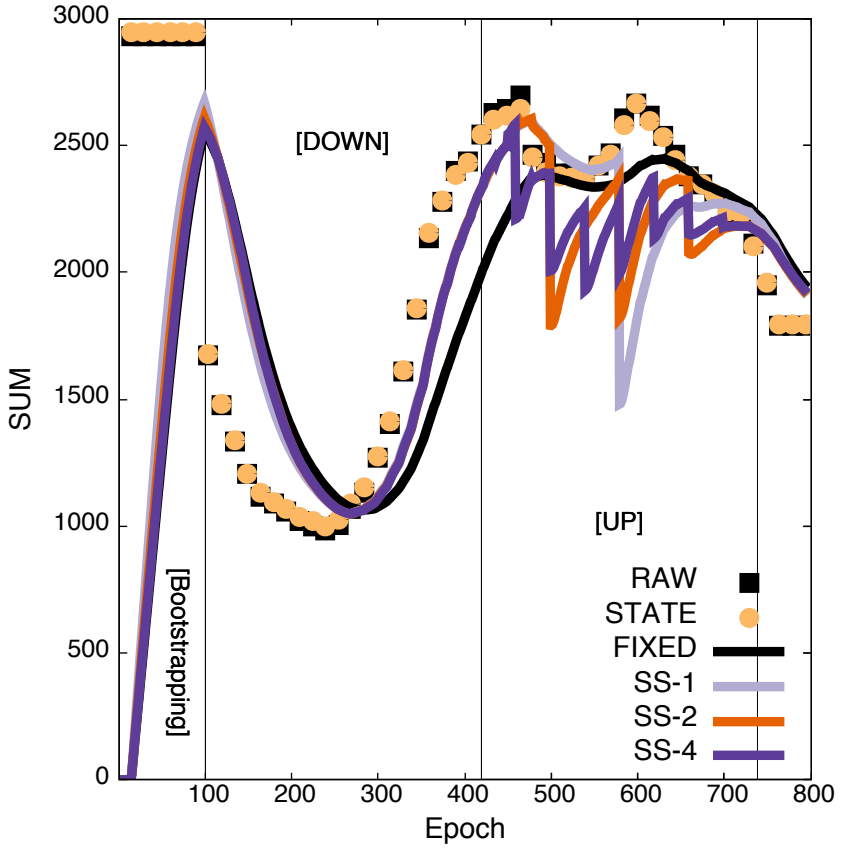




Resilience of Accuracy





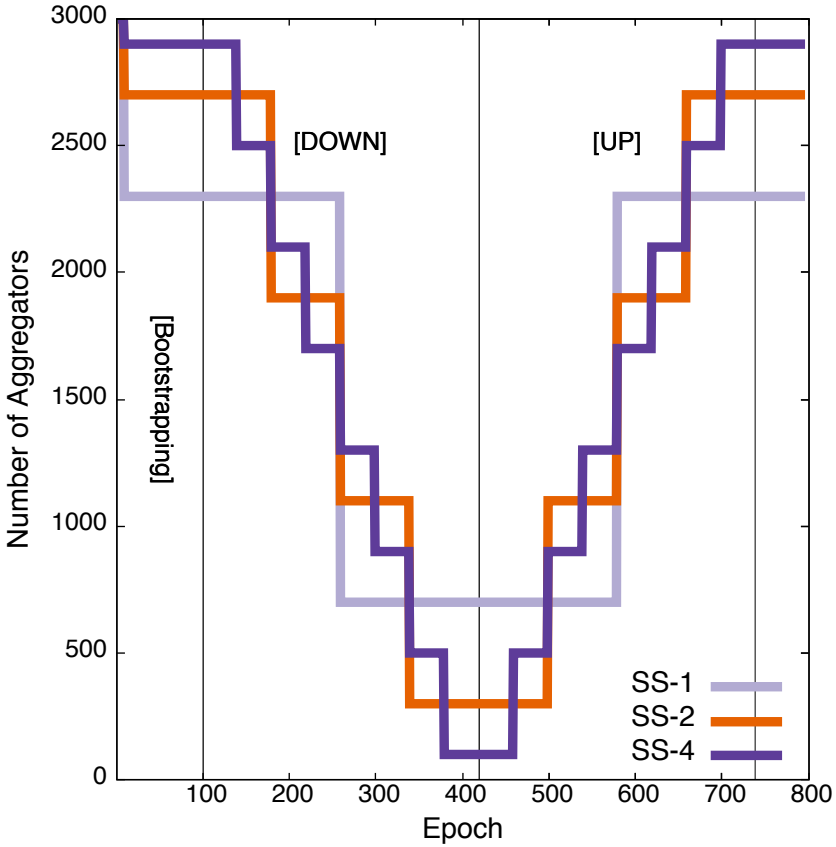


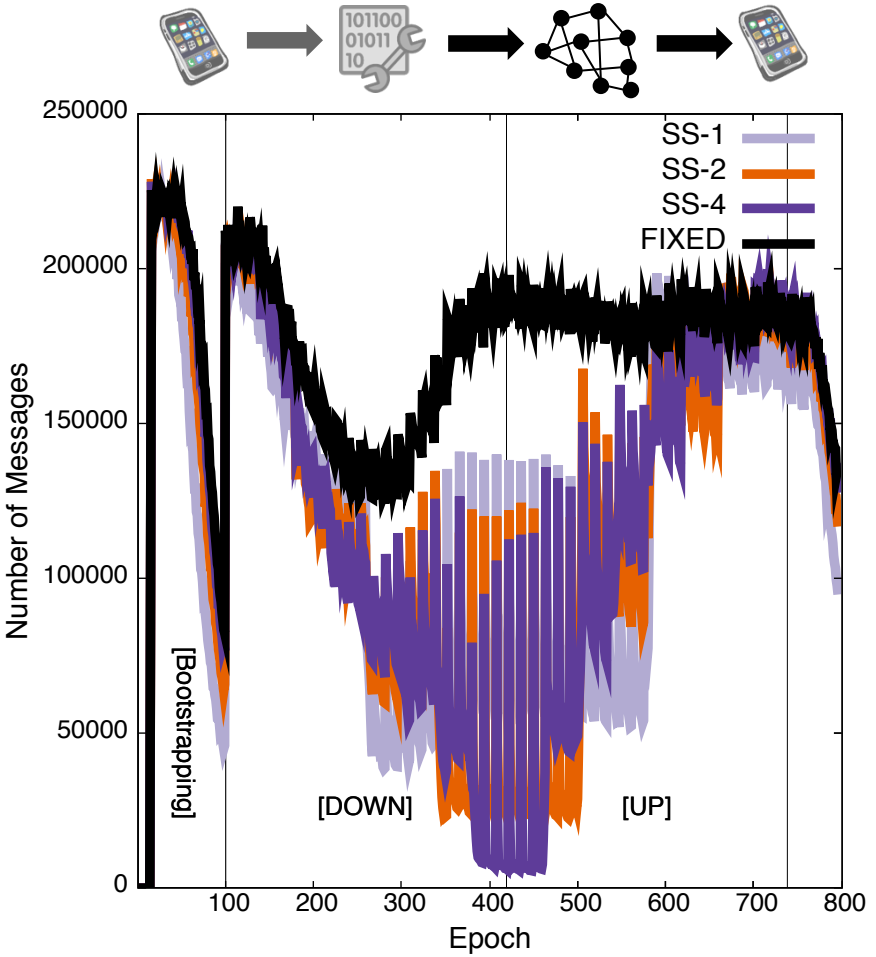
Implemented with the Protopeer distributed prototyping toolkit

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

Real-world data: Electricity Customer Behavioral Trial

Cost of Resilience





Implemented with the Protopeer distributed prototyping toolkit

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

Real-world data: Electricity Customer Behavioral Trial

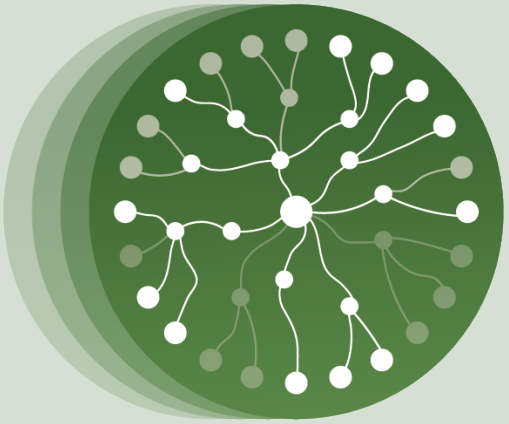
Optimization & Learning

Smart City Sharing Economies

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

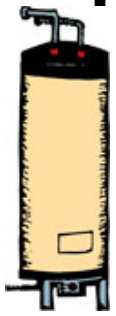


EPOS

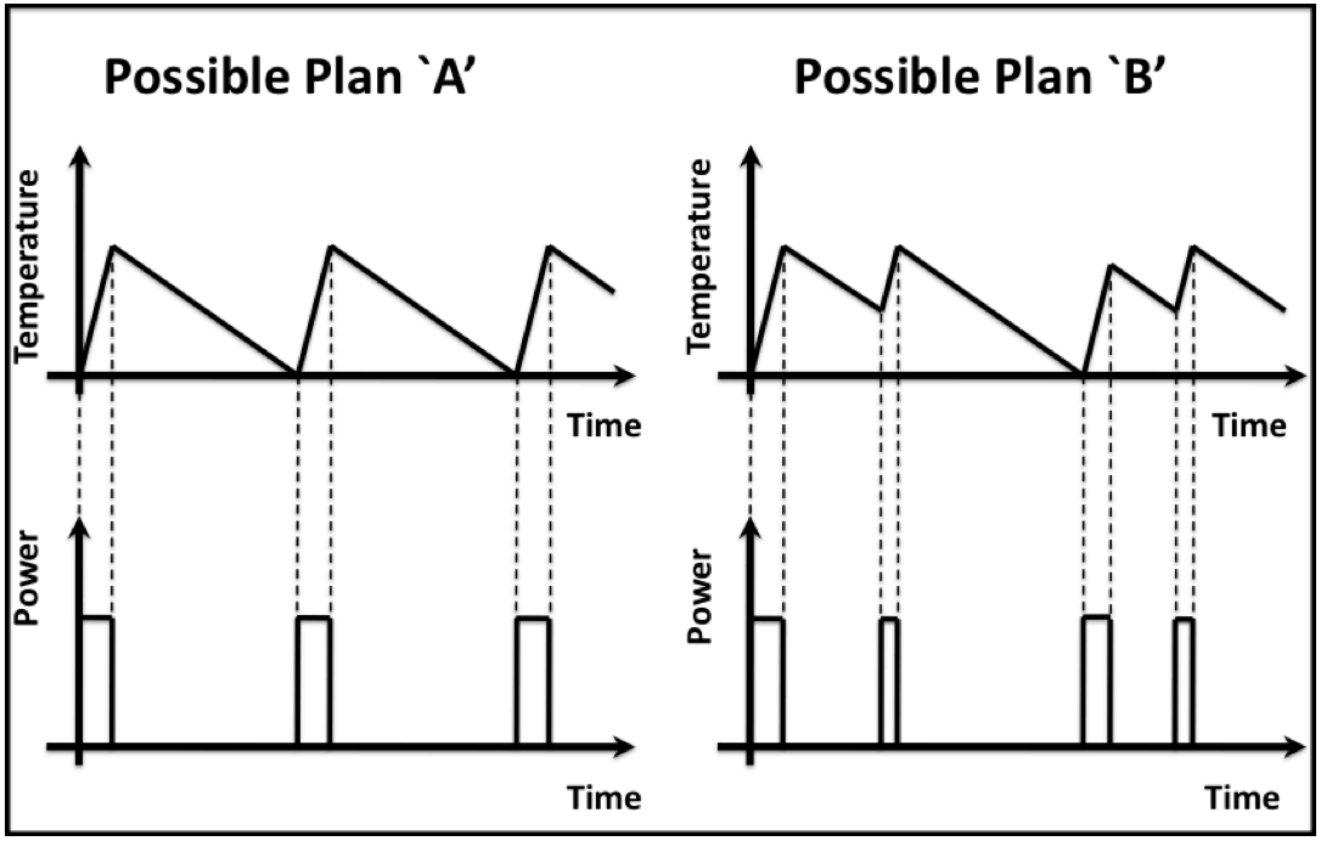
Economic Planning & Optimized Selections

epos-net.org

Participation Model – Crowd-sourced Flexibility



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. Ti of daily schedules and dispenses regular weather members can turn the fridge's LCD screen into a

Via LGE

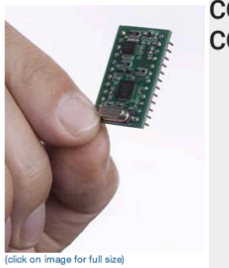
Available Technologies

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.



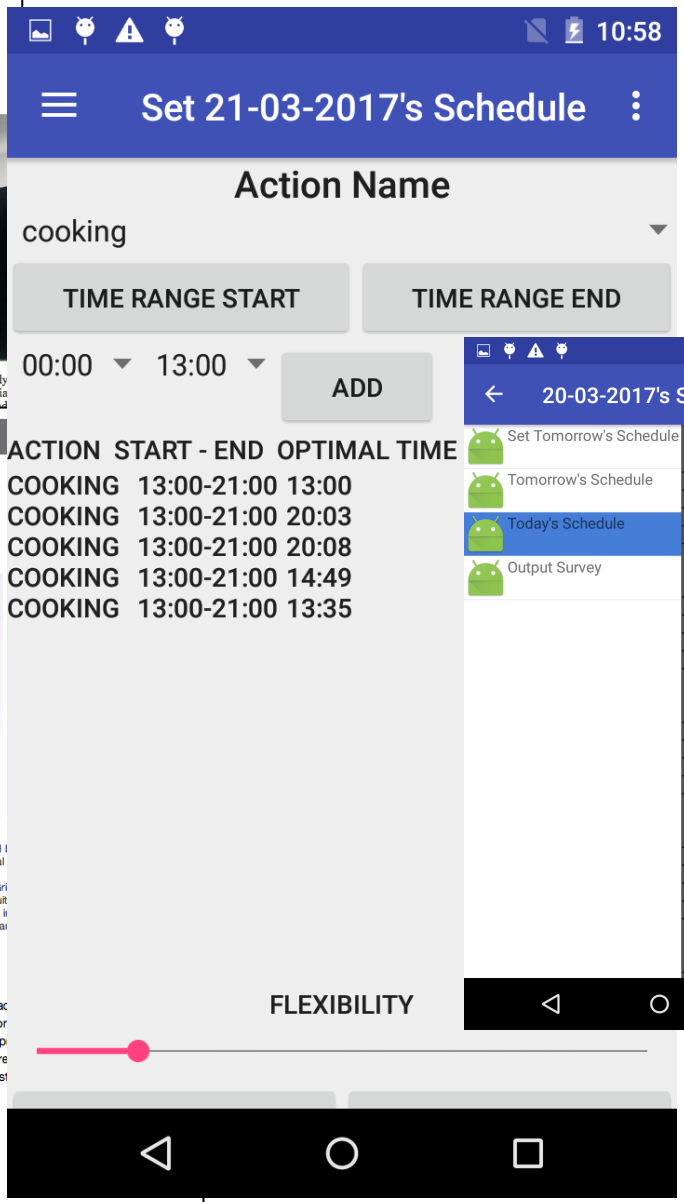
(click on image for full size)

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.

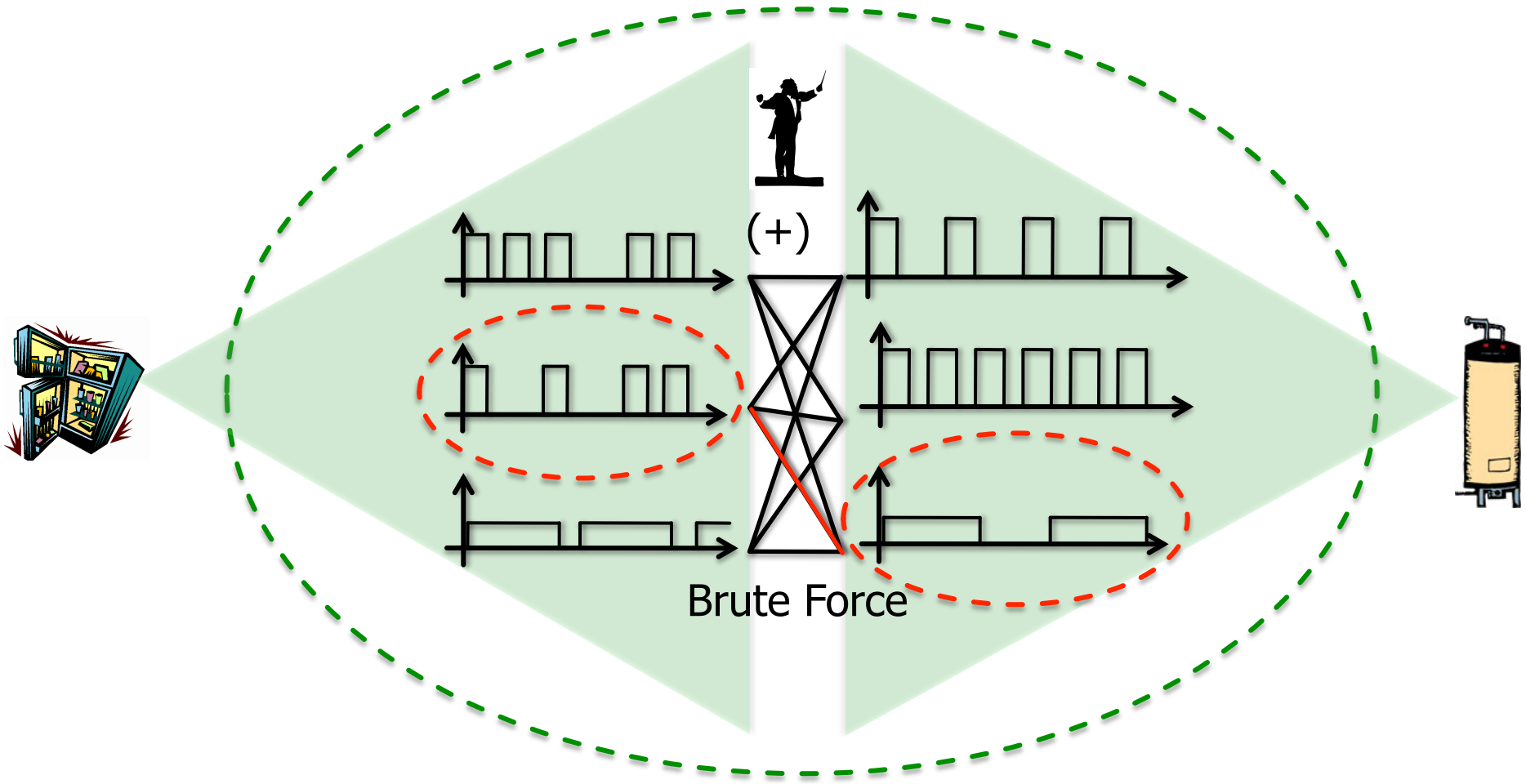
Within the North American power grid a disturbance of 60-Hz frequency is an indicator of serious imbalance between supply and demand that, if unarrested, leads to a blac can be installed in household appliances and turn them off for seconds to allow the grid to stabilize. The controllers can be p in 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



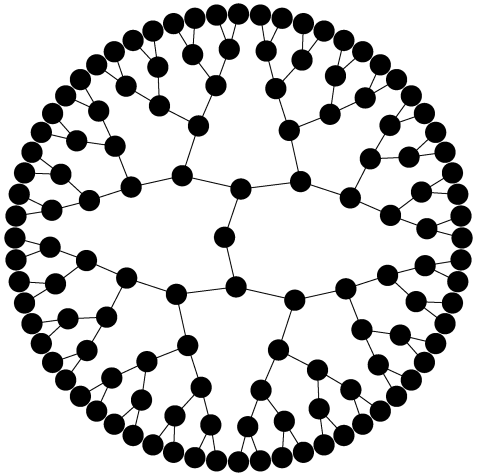
Complexity = # of possible plans$^{\#\ \text{of devices}}$

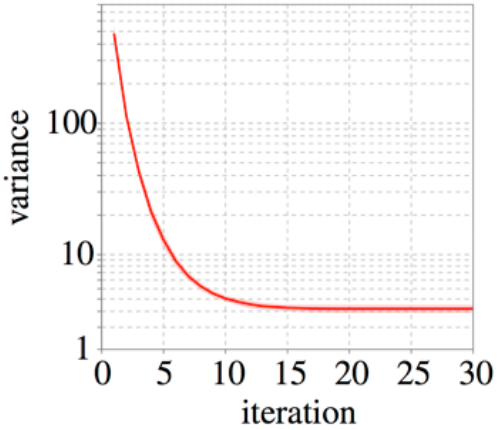
Decentralized Learning Algorithm

(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



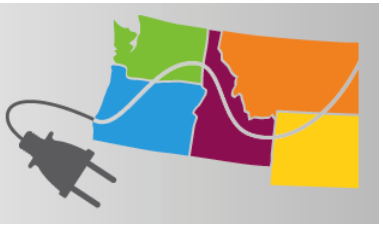


Monotonously improving/learning solutions

Local information
+
aggregate information (branch/tree)

Experimental Evaluation

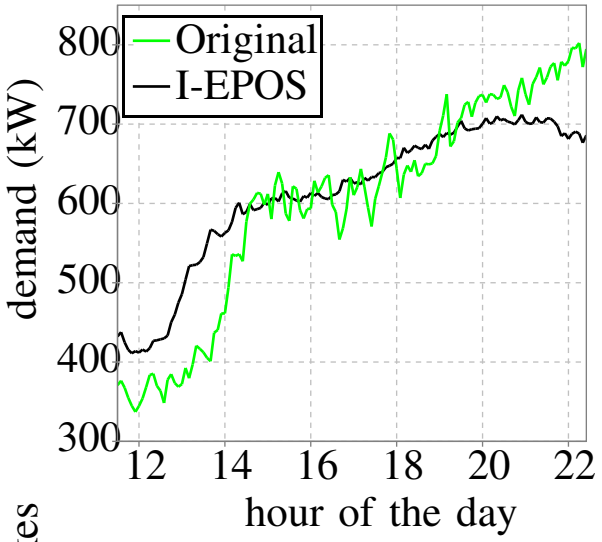
Pacific Northwest SMART GRID DEMONSTRATION PROJECT



1000 households

Time: 11:00-23:00

13 plans, generated by load-shifting

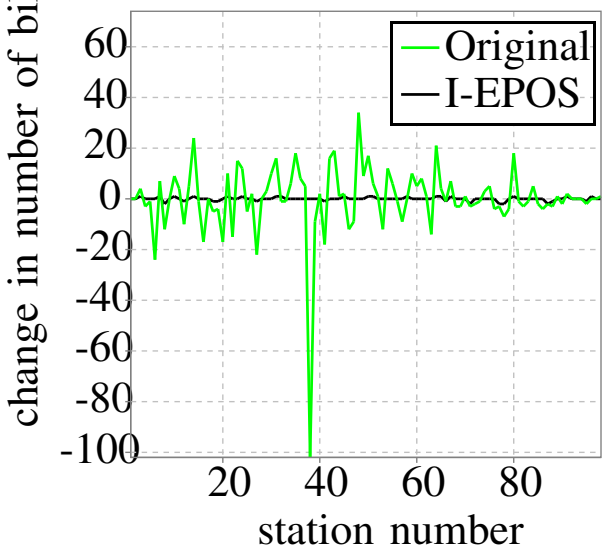


Hubway Data Visualization Challenge

1000 users

Plan generation using historic trips

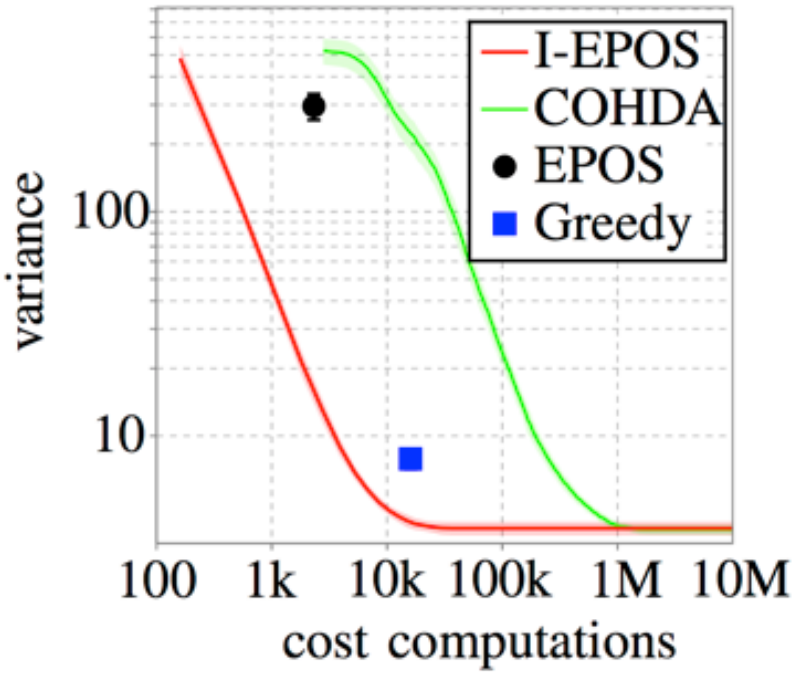
Time: 08:00-10:00



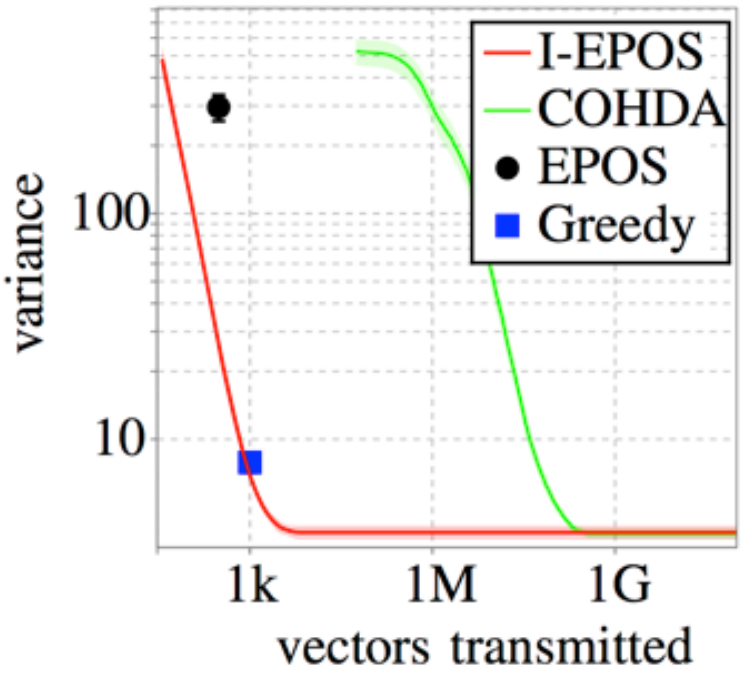
Comparison with Related Work

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

Computational cost



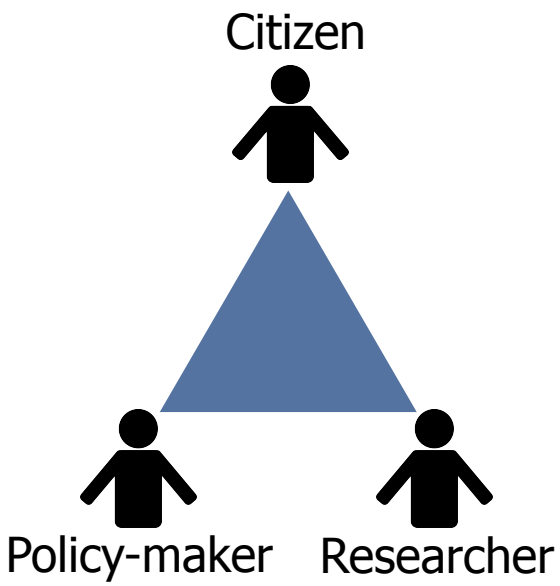
Communication cost



Connecting the dots…

Connecting the dots

Moving solutions
techno-socio-economic systems



Optimization & Learning

Data Analytics

Data Sharing

Scientific methods for evaluating regulatory practicies & policies?

Scientific Methods

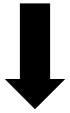
Low modularity & reconfigurability

Fragmentation & discrepancies between simulation communities

Models, data formats & tools

Modeling & simulation of techno-socio-economic systems

Understanding system complexity



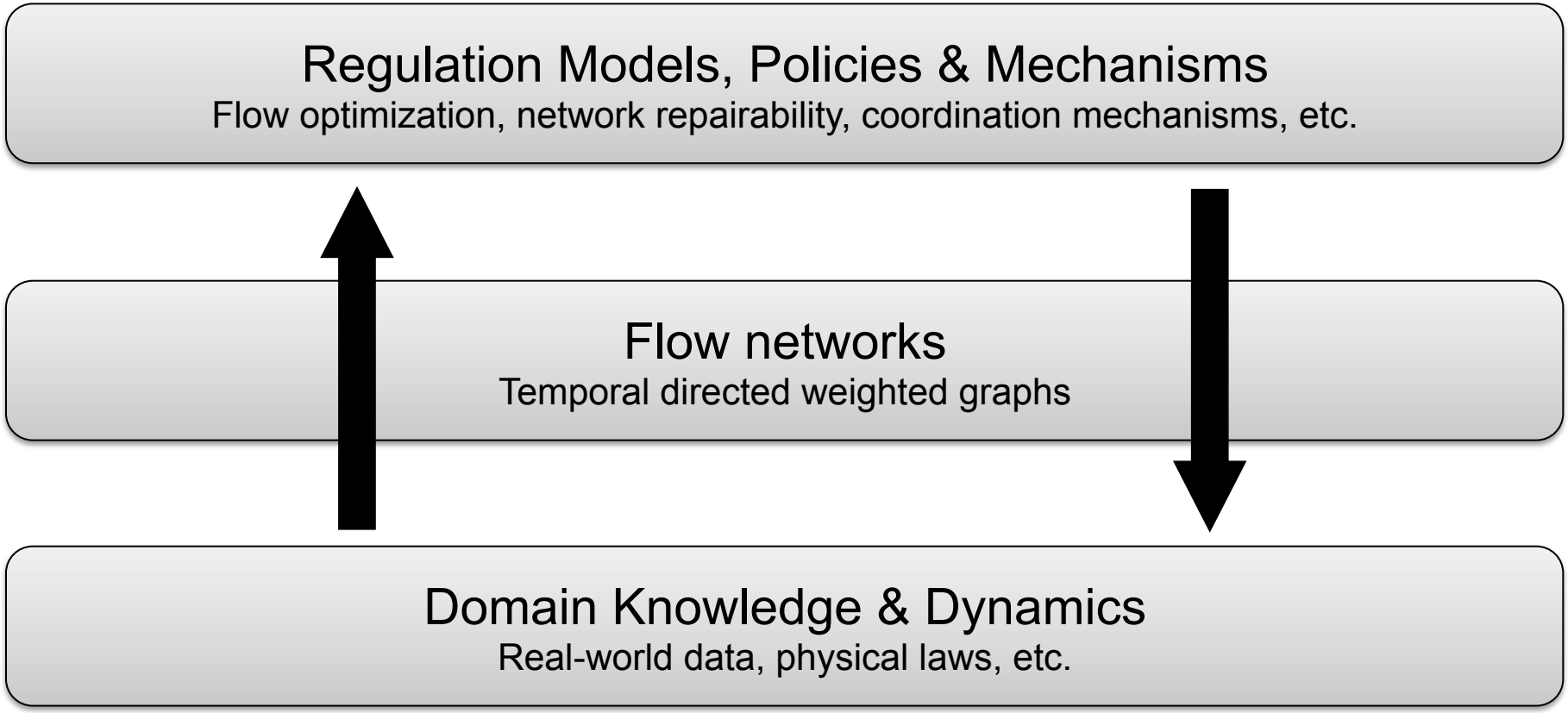
Prototyping online & distributed regulatory mechanisms to support system operations.

SFINA

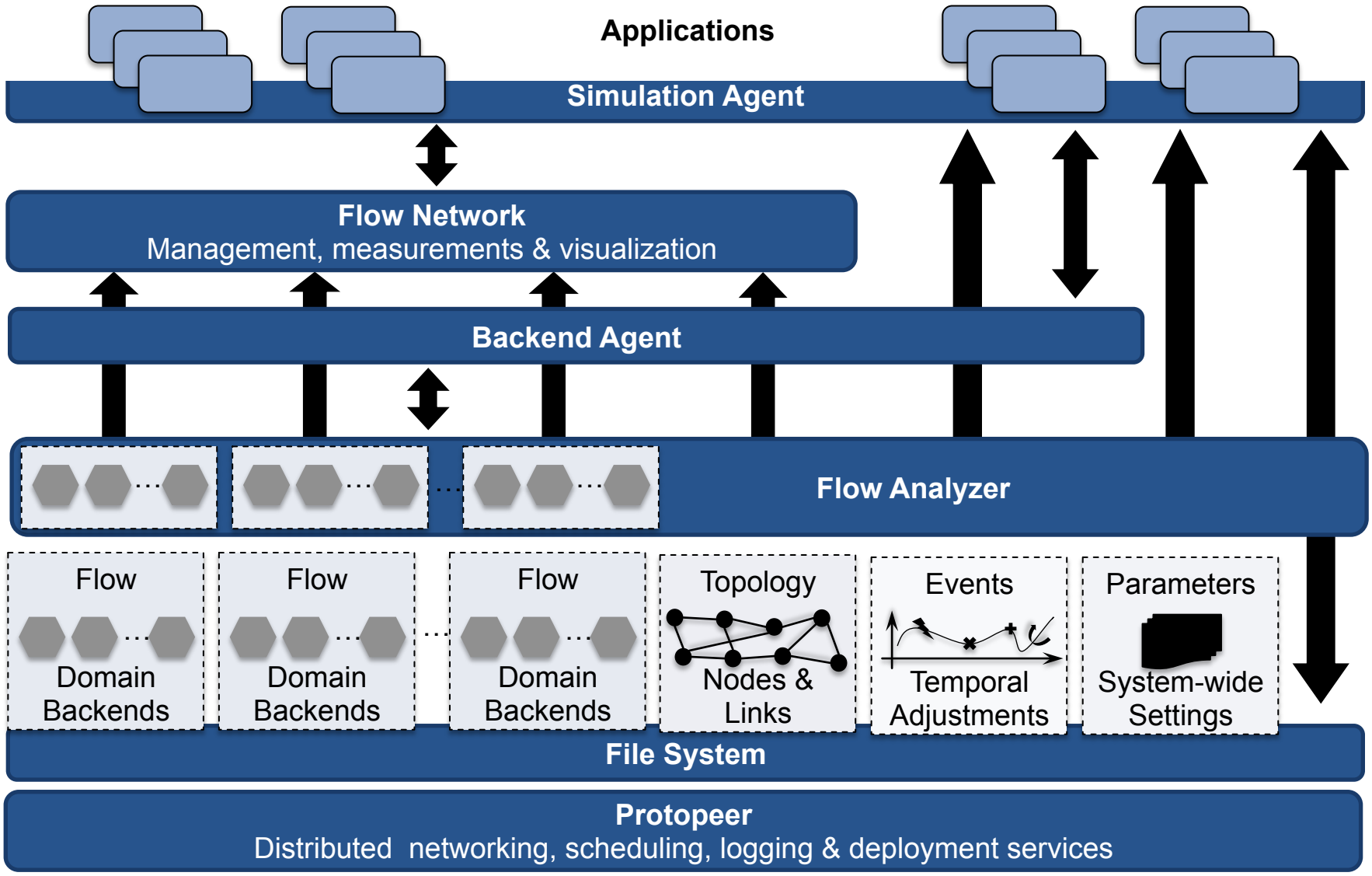
Simulation Framework for Intelligent Network Adaptations

sfina-net.org

SFINA Modeling Approach



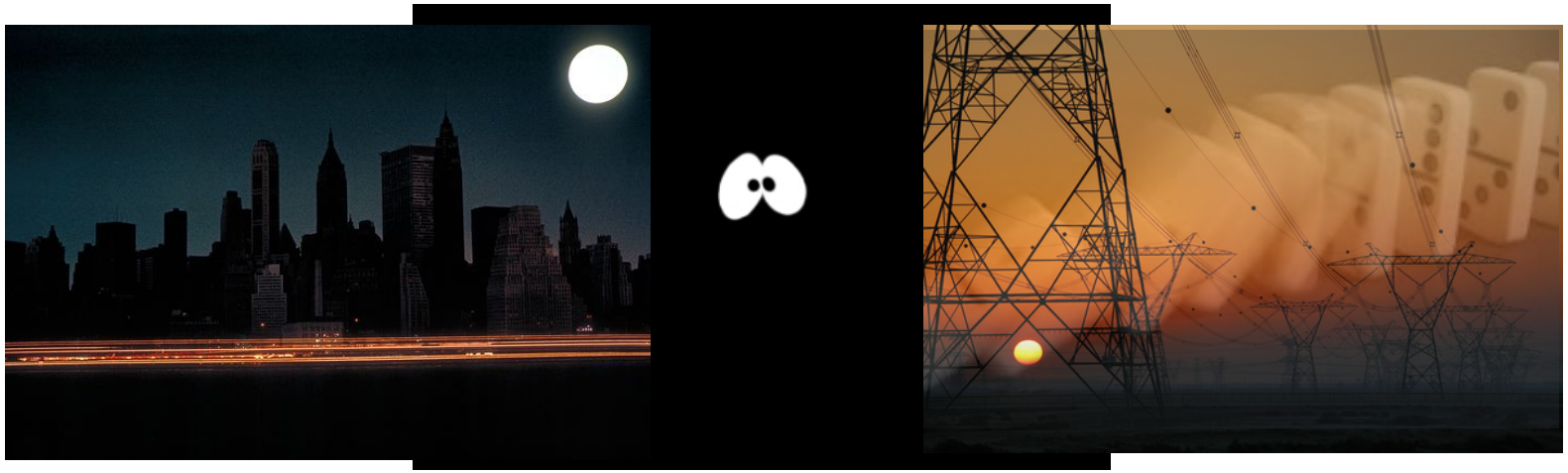
SFINA Architecture



Application Scenario

Self-repairable Smart Grids against cascading failures

using smart transformers!



Smart Transformers

Control of phase angle
in power lines
+
Intelligence & communication

⬇

Control of power redistribution
over parallel lines

⬇

Control over cascading failures:
prevention & mitigation

MIT Technology Review

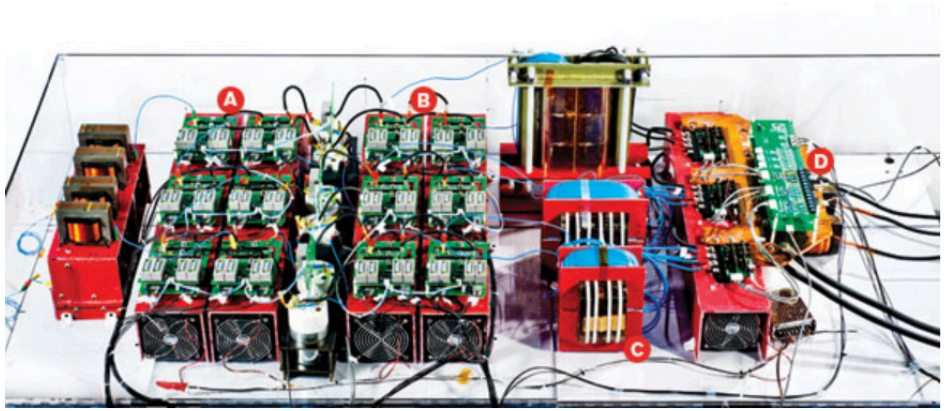
10 BREAKTHROUGH TECHNOLOGIES 2011

NEWS // ENERGY

Smart Transformers

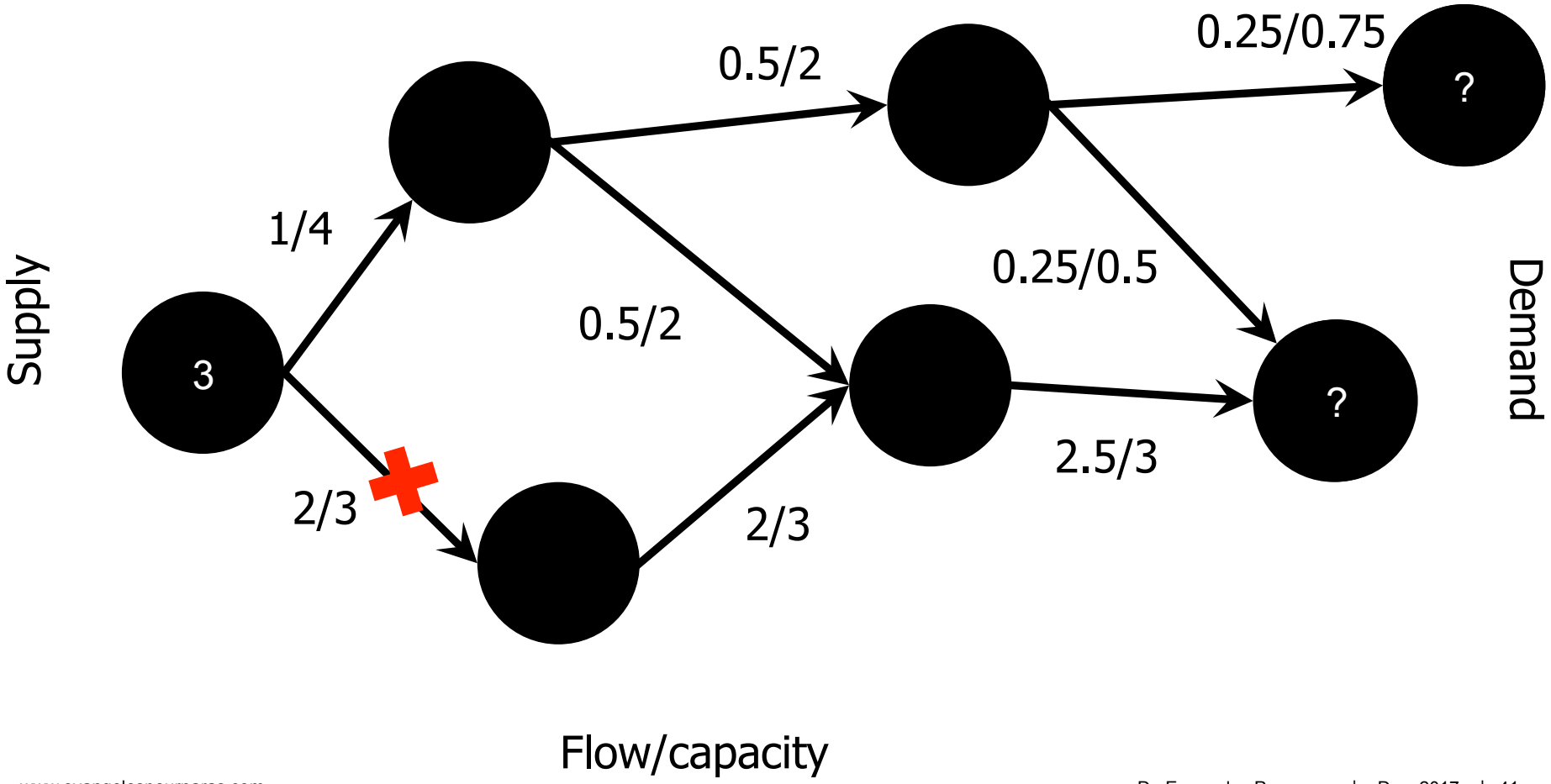
Controlling the flow of electricity to stabilize the grid

4 comments
DAVID H. FREEDMAN
Tuesday, April 19, 2011

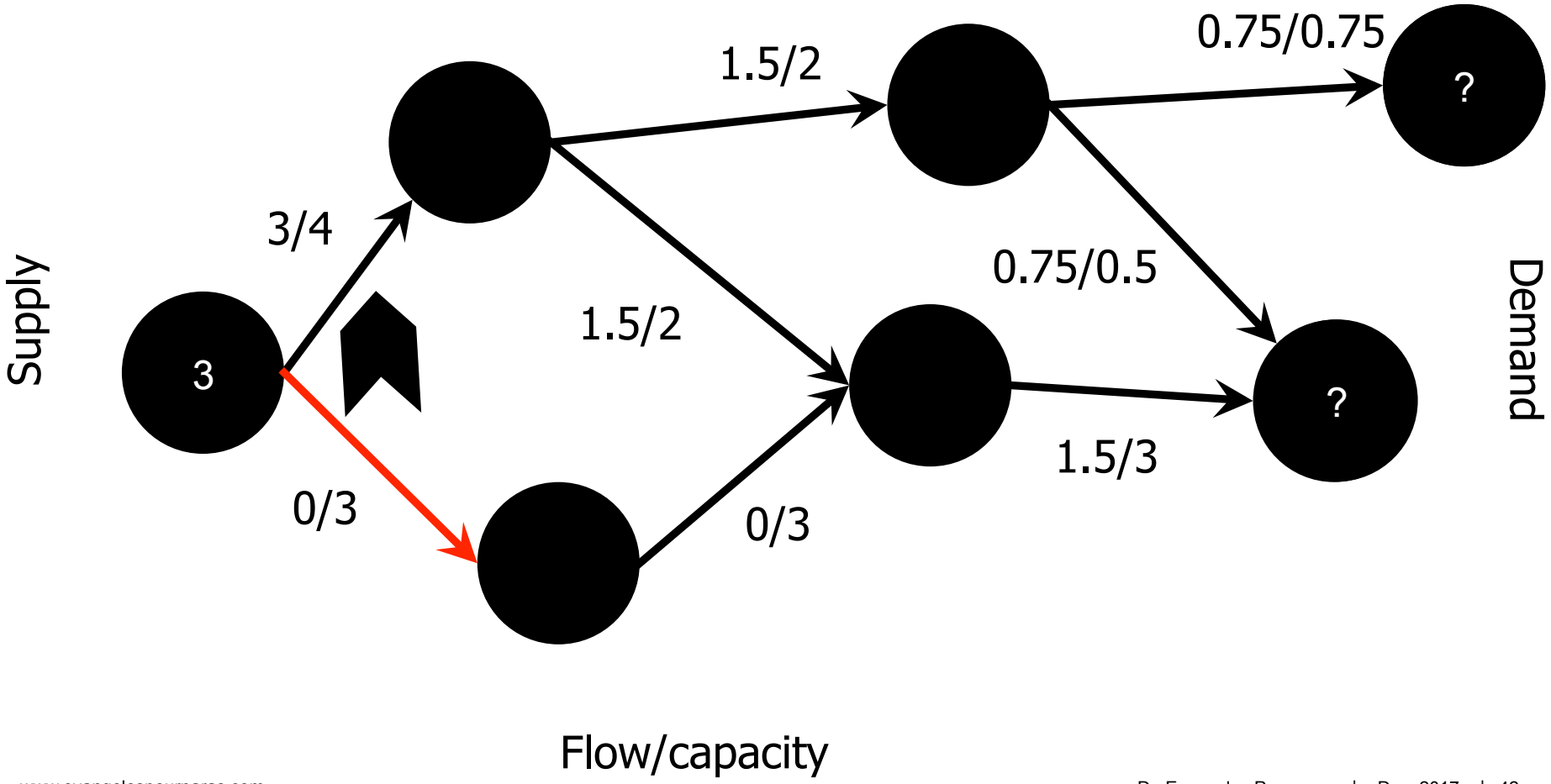


Powerful electronics: The smart transformer can handle AC and DC power and, thanks to semiconductors capable of handling high voltages, be programmed to redirect the flow of electricity in response to fluctuations in supply and demand.
A. High-voltage semiconductor-based AC rectifier.
B. High-voltage semiconductor-based DC converter.
C. High-frequency transformers.
D. Control circuitry.

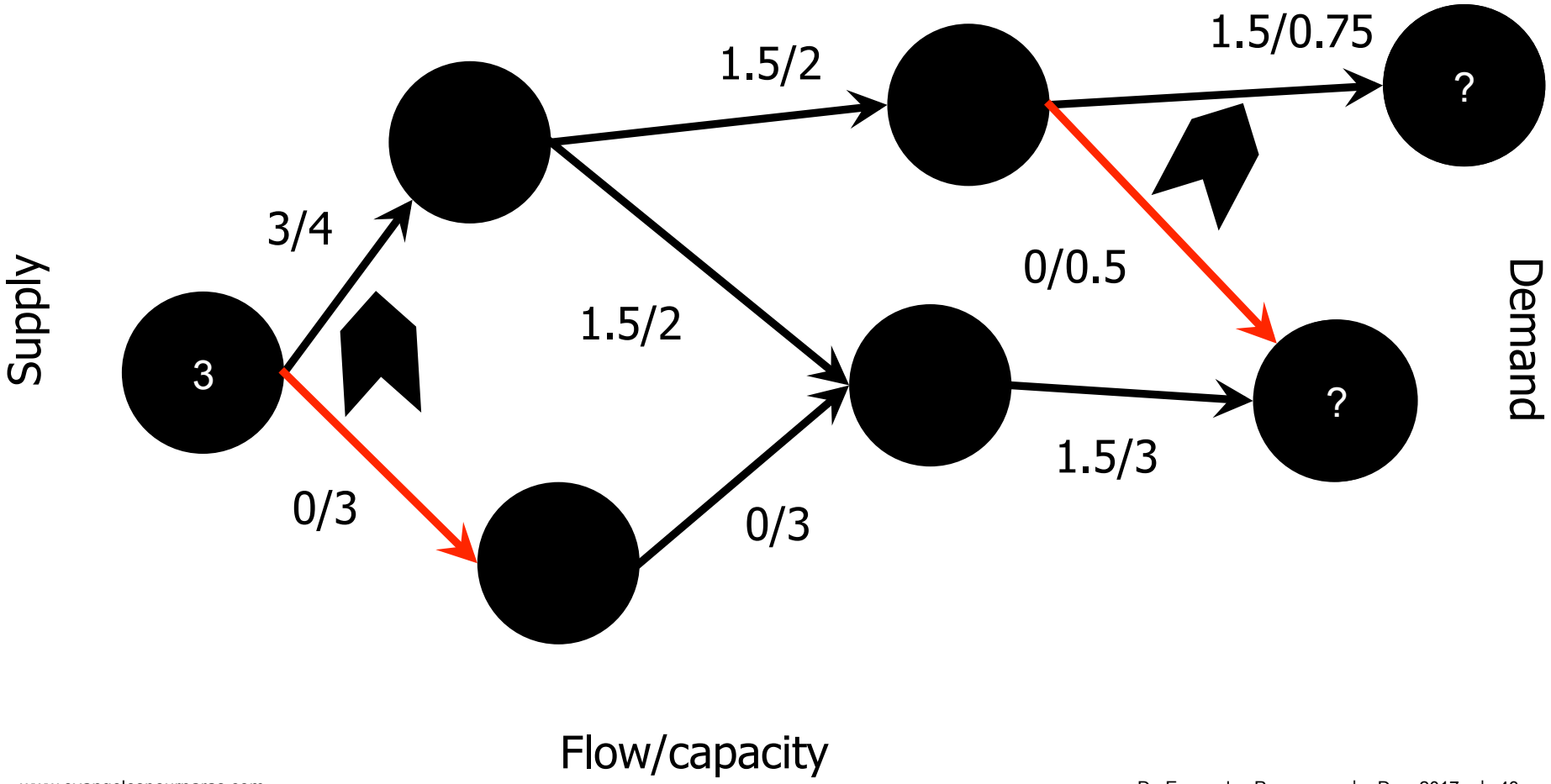
Smart Transformers against Cascading Failures



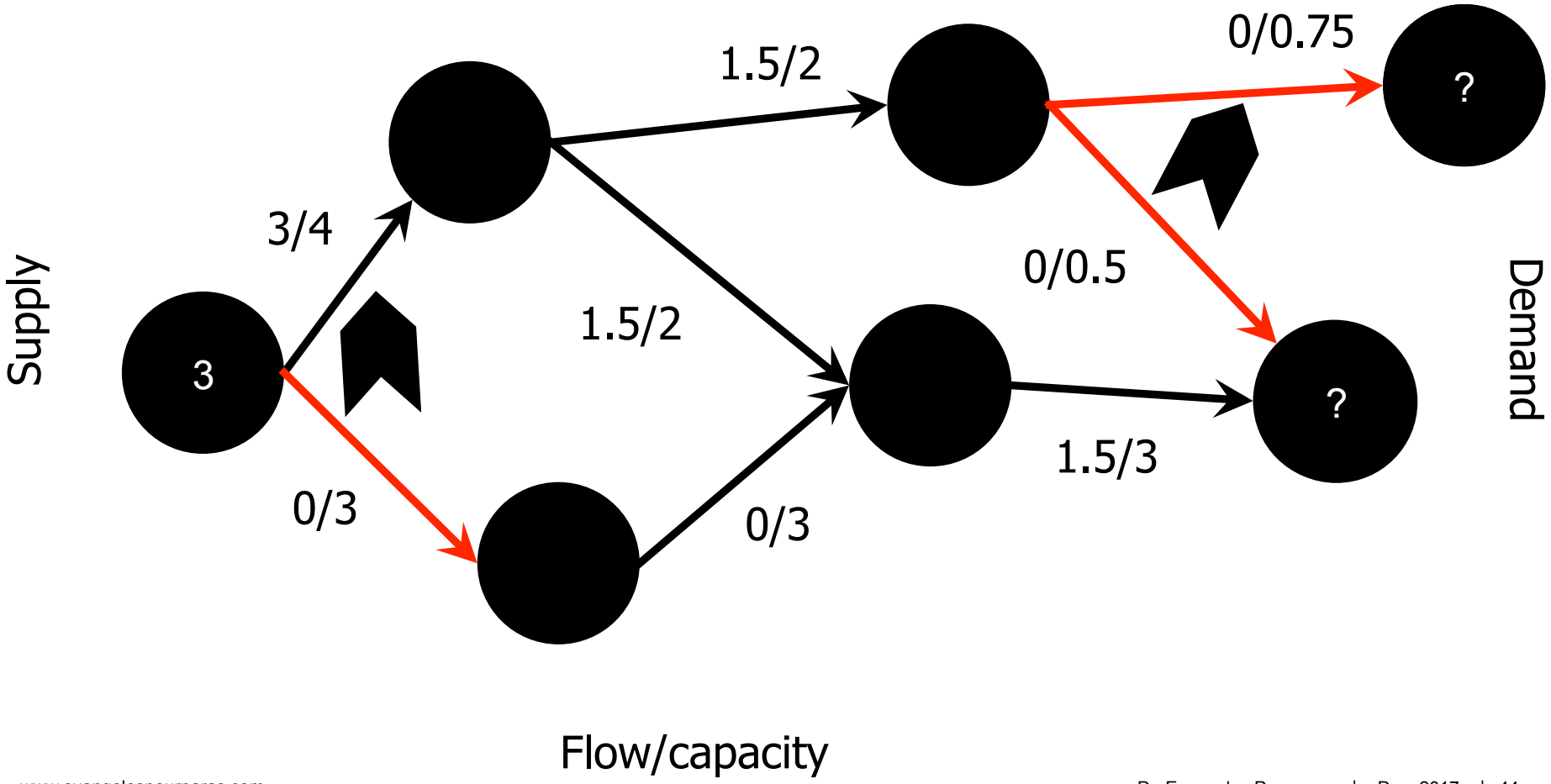
Smart Transformers against Cascading Failures



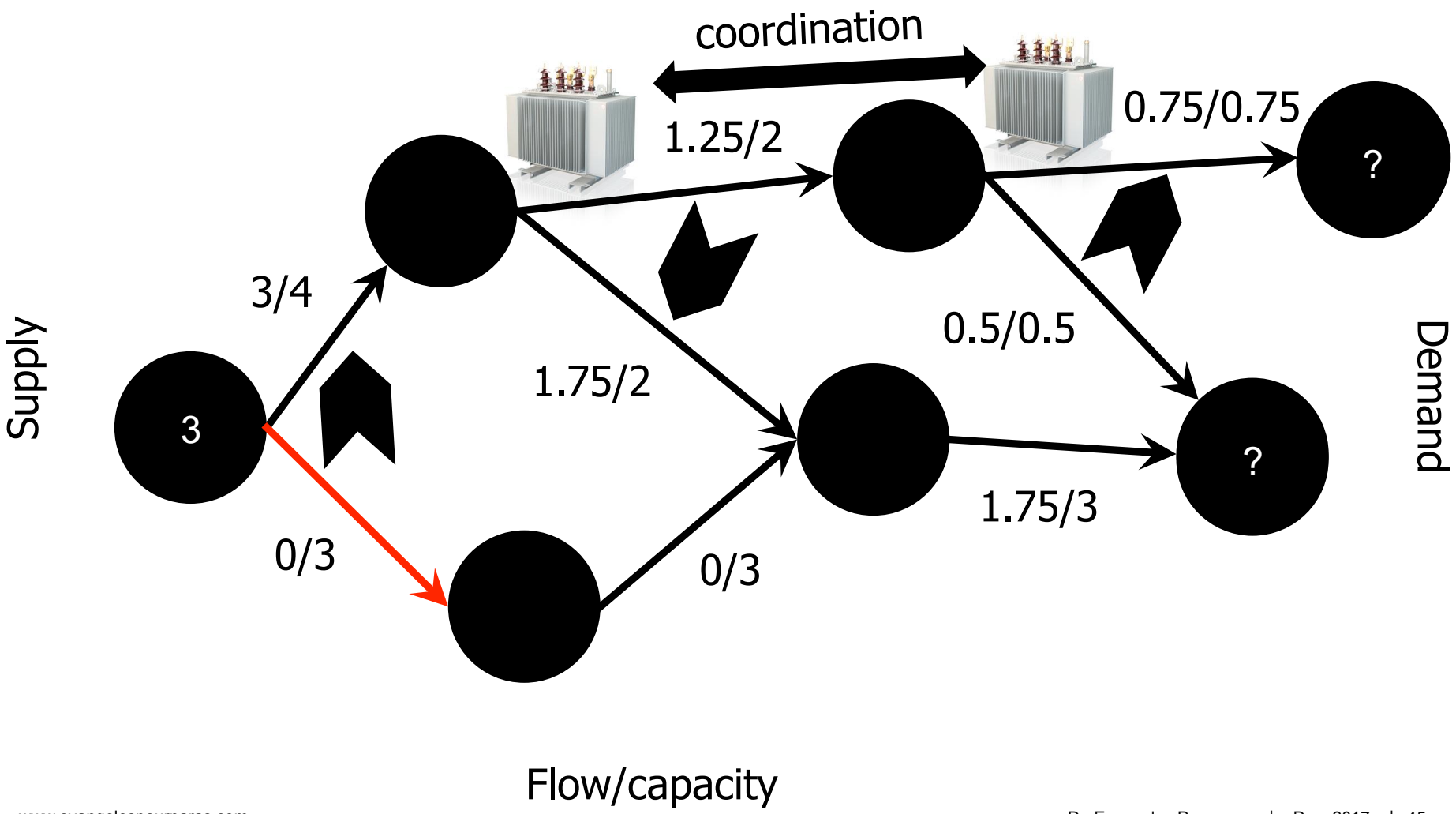
Smart Transformers against Cascading Failures



Smart Transformers against Cascading Failures



Smart Transformers against Cascading Failures



Actor Perspectives

Quality of Service

Citizens

Infrastructural costs & investments

Policy-makers

Self-repairable Smart Grids against Cascading Failures

using smart transformers!

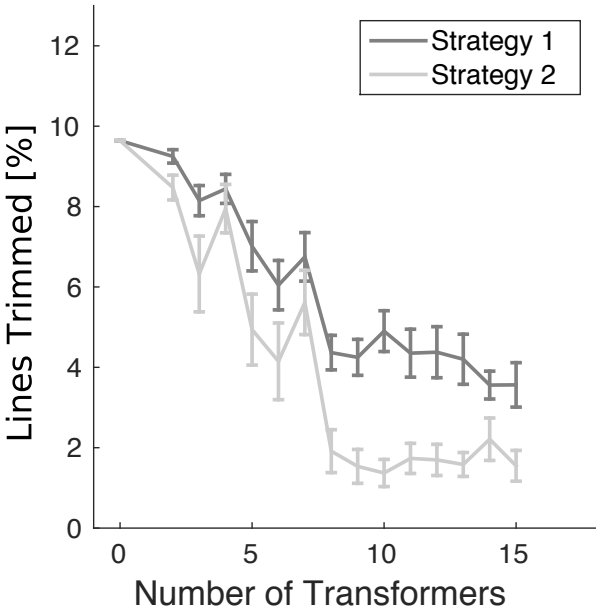
Well-established resilience actions

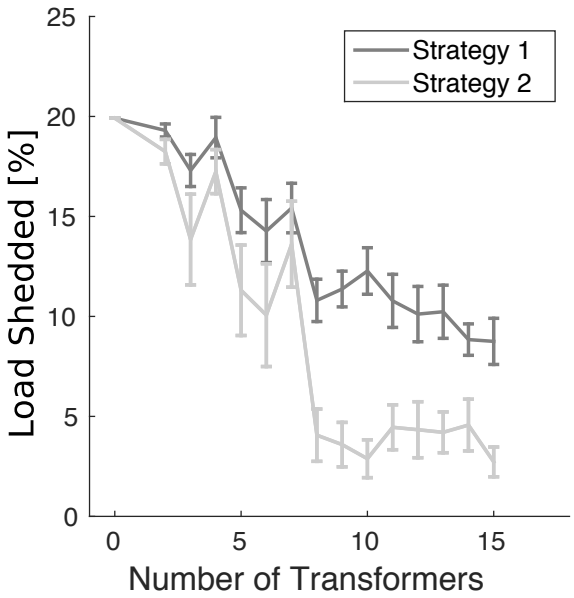
System Operators

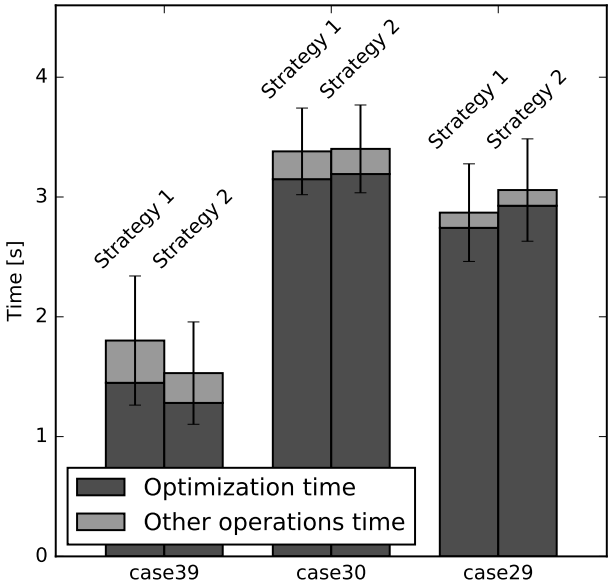
Discover new applicable solutions

Researchers

Online Coordination of Smart Transformers







IEEE case 39, AC power flows

2 optimization strategies

N-1 contingency analysis

0-15 smart transformers

Dell inspiron n5110 personal computer
6GB memory
Intel(R) Core(TM) i7- 26300QM CPU @ 2.00GHz
Ubuntu 15.10.

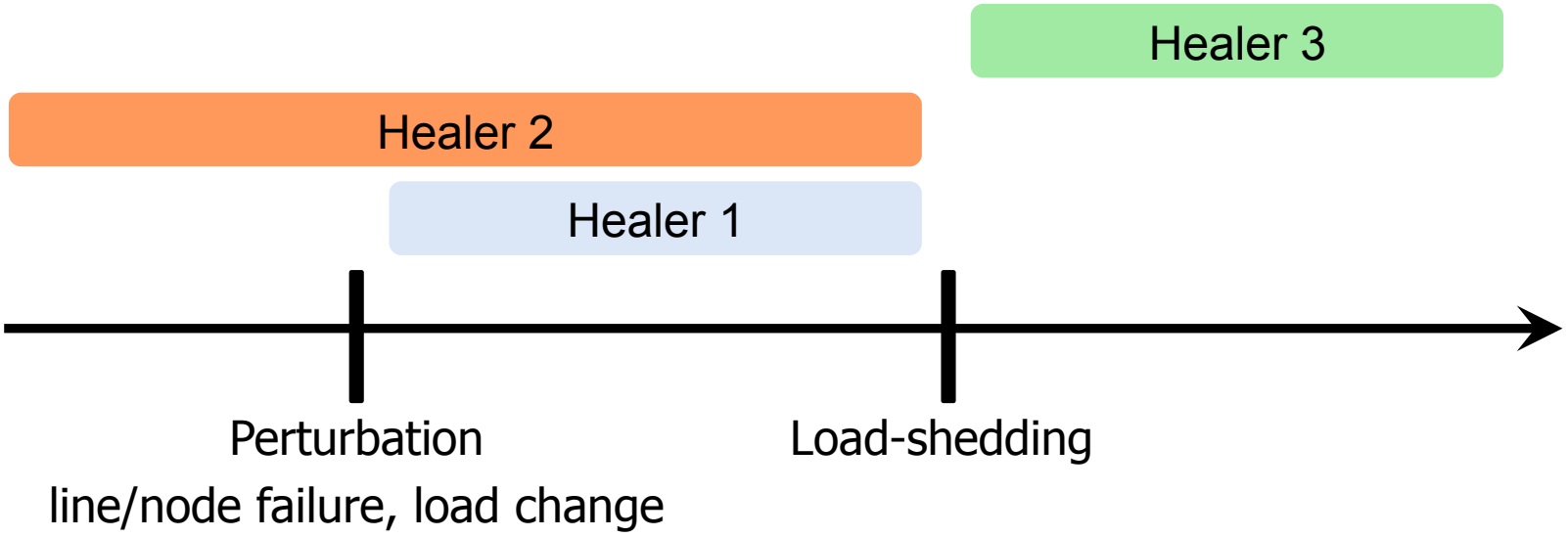
Smart Transformer Healing Modes

Healer 1: **AFTER** system perturbation **AND BEFORE** load-shedding

Healer 2: **BEFORE AND AFTER** system perturbation **AND BEFORE** load-shedding

Healer 3: **AFTER** system perturbation **AND AFTER** load-shedding

Events Sequence



Smart Transformer Healing Modes

	Position	STRATEGY 1			STRATEGY 2		
BASE CASE	-	50.5			50.5		
1	34 37 5 35 24	47.3	54.9	49.2	46.2	45.6	46.1
2	4 12 22 37 36	48.6	47.7	46.3	43.1	48.4	43.1
3	7 39 38 19 30	47.3	68.8	51.8	59.8	47.1	59.8
4	6 17 36 31 39	47.7	47.7	49.2	45.7	51.2	45.7
5	27 2 34 36 26	47.8	41.5	46.3	47.2	52.1	48.2
6	32 30 16 25 7	73.3	67.5	74.4	48.3	49.1	48.3
7	29 2 11 40 4	48.0	42.8	47.8	46.3	52.4	46.3
8	34 28 13 37 2	48.5	45.6	46.1	45.4	45.3	45.4
9	18 16 30 31 7	71.9	50.4	72.1	48.2	49.1	48.2
10	21 18 26 27 28	48.5	42.5	49.4	52.4	46.8	52.4

	Healer 1	Healer 2	Healer 3
Strategy 1	52.89%	50.94%	53.26%
Strategy 2	48.26%	48.71%	48.35%

Smart Transformer Healing Modes

	Position	STRATEGY 1			STRATEGY 2		
BASE CASE	-	16.4			16.4		
1	36 40 7 38 25	16.8	16.8	17.2	13.6	13.6	14.4
2	6 12 24 40 38	12.3	9.2	13.3	8.4	1.9	8.5
3	8 44 42 21 30	15.2	15.2	16.1	7.8	6.8	8.0
4	7 19 40 31 38	14.2	14.2	14.5	12.1	12.2	11.9
5	28 3 36 38 27	12.8	12.8	12.7	9.9	8.4	10.0
6	32 31 16 26 8	10.7	8.7	10.7	5.4	0.8	5.4
7	30 3 12 44 6	12.2	12.2	12.9	0.8	0.8	0.8
8	36 29 13 40 3	13.1	10.5	13.0	3.3	5.0	3.3
9	21 16 31 43 8	11.5	9.4	11.5	6.5	0.8	6.6
10	23 21 27 28 29	15.8	15.8	15.7	15.9	16.1	18.0

Healer 1 Healer 2 Healer 3

Strategy 1	13.46%	12.48%	13.76%
Strategy 2	8.37%	6.64%	8.69%

Concluding Remarks – Resilient Smart Cities

Engineering socially-responsible data sharing

Economic rewarding of the measurable privacy cost

Design safeguards for a measurable social welfare

Re-inventing analytics, optimization & machine learning

Participation via crowd-sourced & self-determined operational flexibility

Collective computational intelligence as public good

System decentralization as tactical utility

Online infrastructural self-regulation

Highly complex & risky

Tremendous opportunities

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General Relevance

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- Evangelos Pournaras, Ben-Elias Brandt, Manish Thapa, Dinesh Acharya, Jose Espejo-Uribe, Mark Ballandies, Dirk Helbing, SFINA-Simulation Framework for Intelligent Network Adaptations, Simulation Modelling Practice and Theory, Vol. 72, pp. 34-50, 2017 © Elsevier

Questions?

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