MasterClass on Data-driven Support for Cyber-physical systems
DAT300, DIT668

Introduction:
Distributed Cyberphysical systems & Course Outline

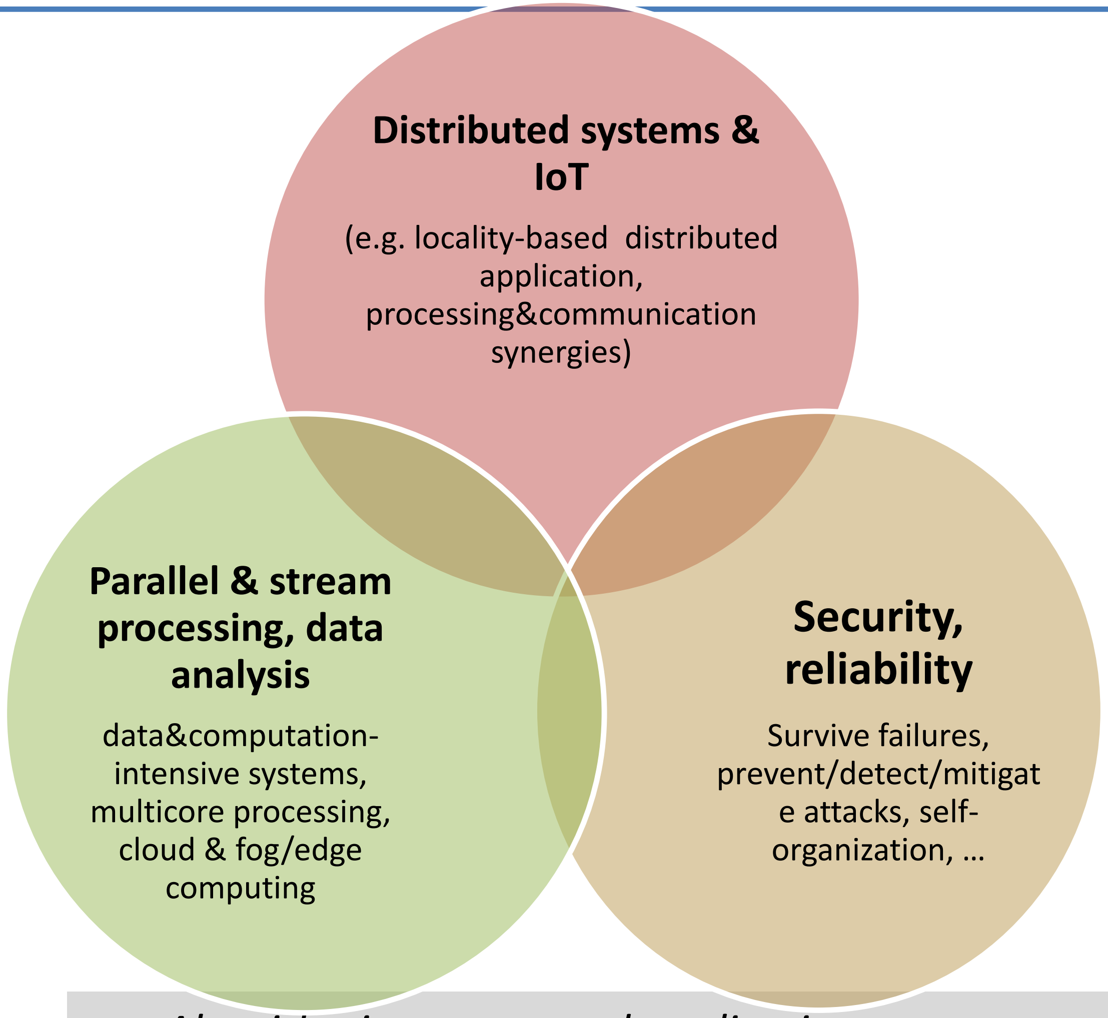
Magnus Almgren

M. Papatriantafilou

Networks and Systems Division
Computer Science and Engineering Department
Chalmers University of Technology & Gothenburg University

Briefly on research + education area of the supporting team

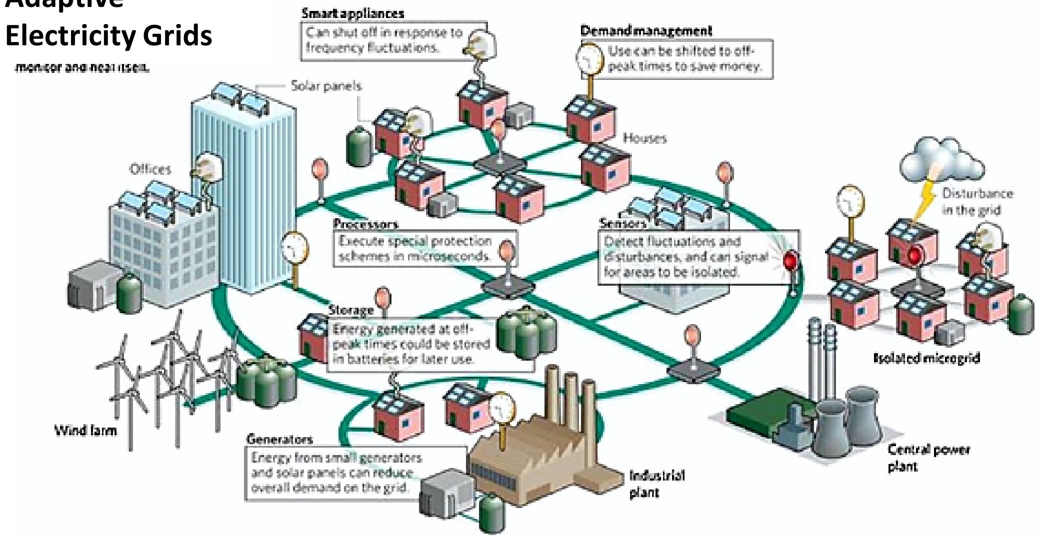
Also in the course-support team :
- Wissam Aoudi
- Karl Bäckström
- Romaric Duvignau
- Bastian Havers
- Amir Keramatian
- Joris van Rooij
- Babis (Charalampos) Stylianopoulos
- (TBC)



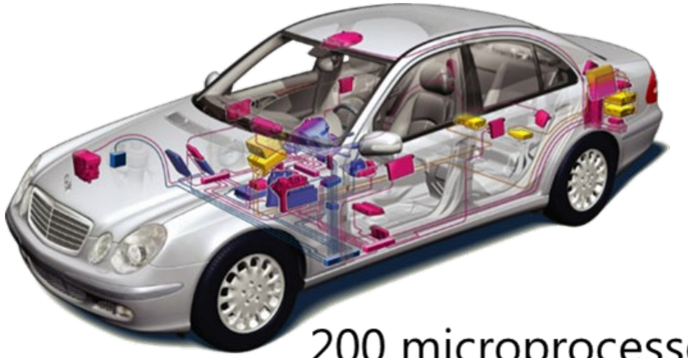
- *Algorithmic aspects and applications*
- *Domains:* energy- production- vehicular-systems, communication networks (IoT, 5G)

Examples Cyber-Physical Systems (CPS)

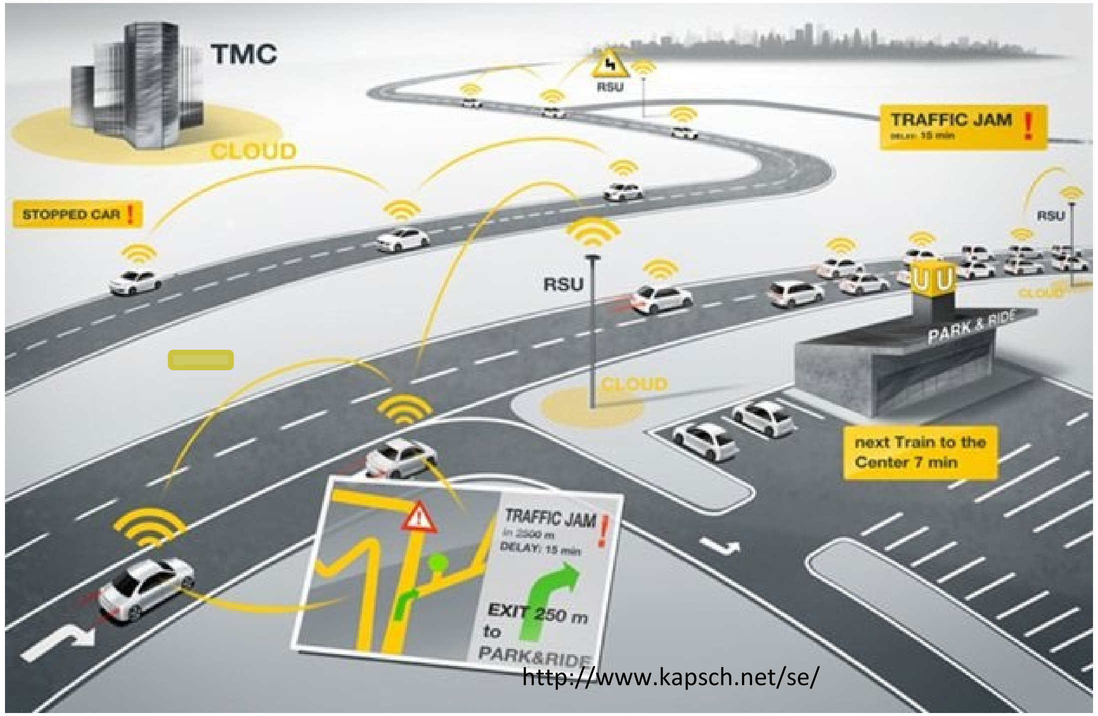
Adaptive Electricity Grids



www.energy-daily.com/images/

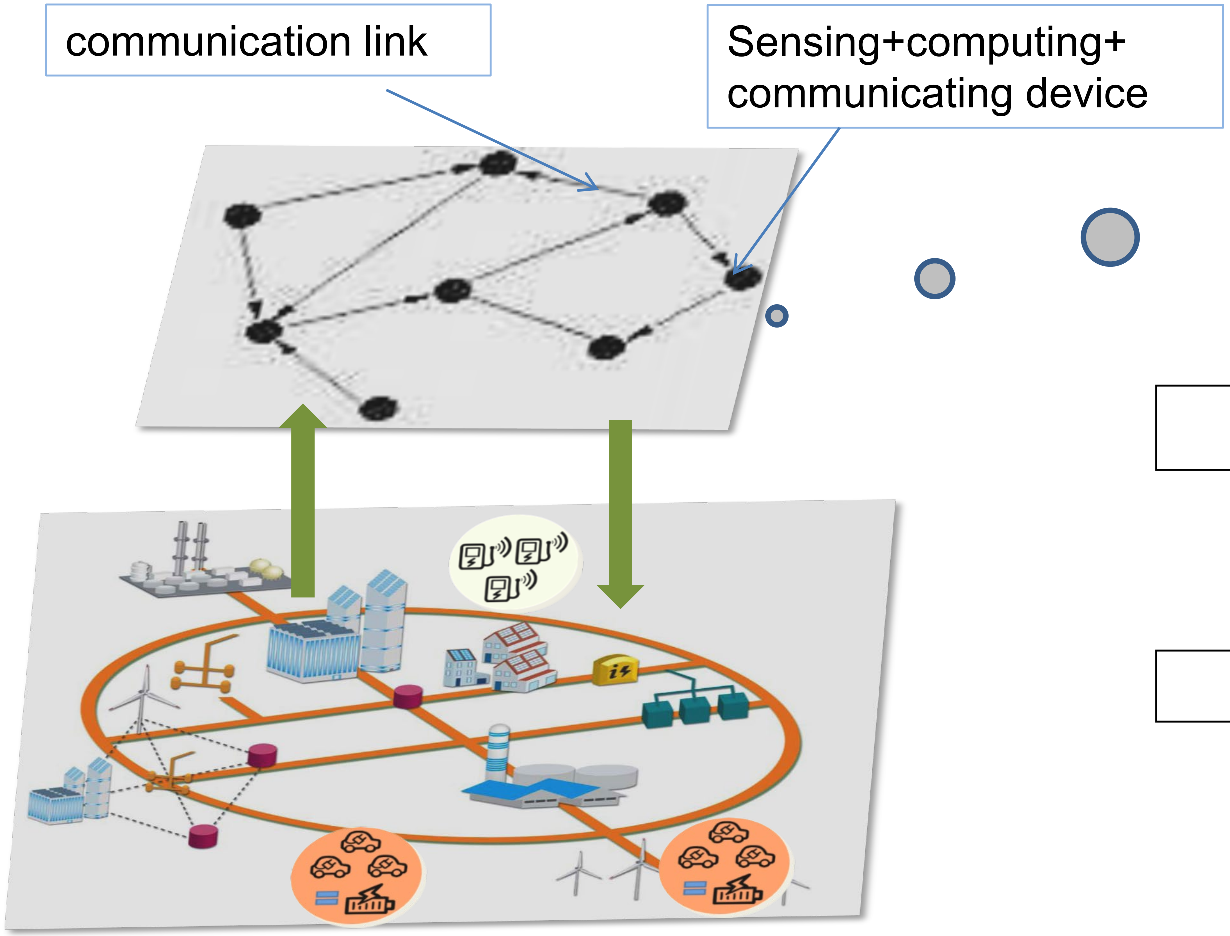


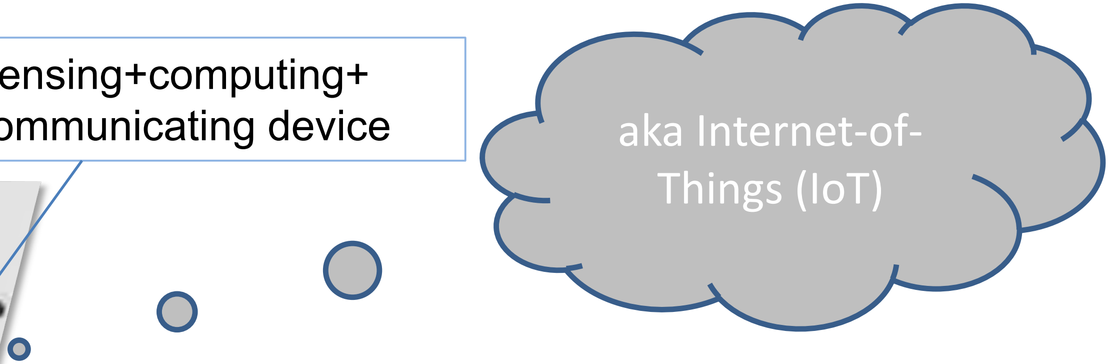
200 microprocessors
65 million lines of code

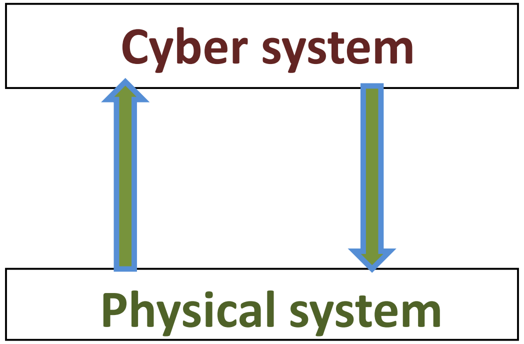


http://www.kapsch.net/se/

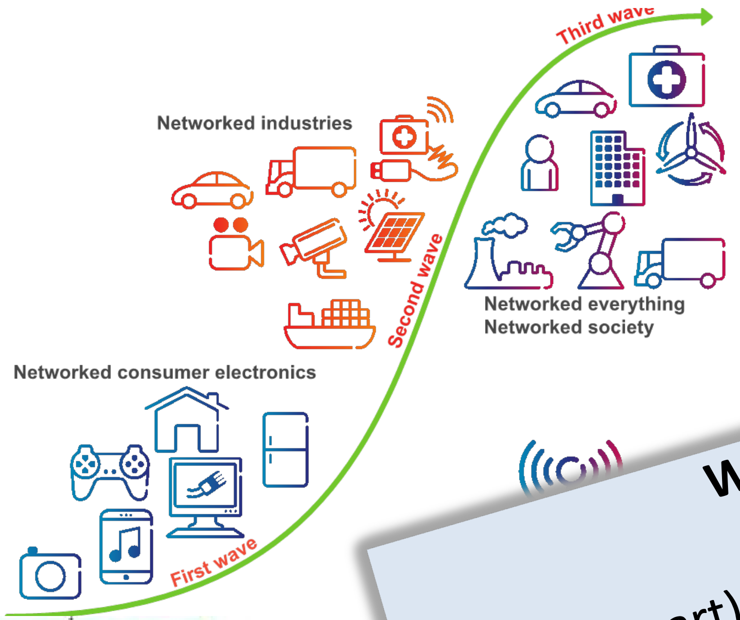
Cyberphysical systems as layered systems







CPS/IoT => big #devices, high big data rates => big volumes of events/data!

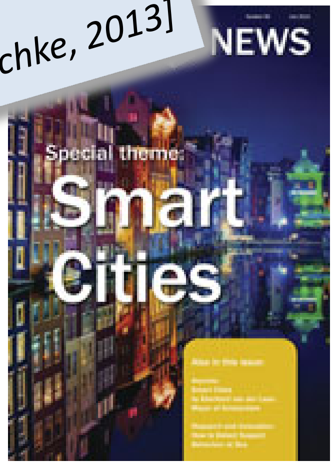


Why this complexity?

(smart) **adaptive** use of resources ….

… possibilities of improvements: e.g. energy utilizatition, traffic bandwidth, early-warnings, … *improving systems quality&safety, …"*

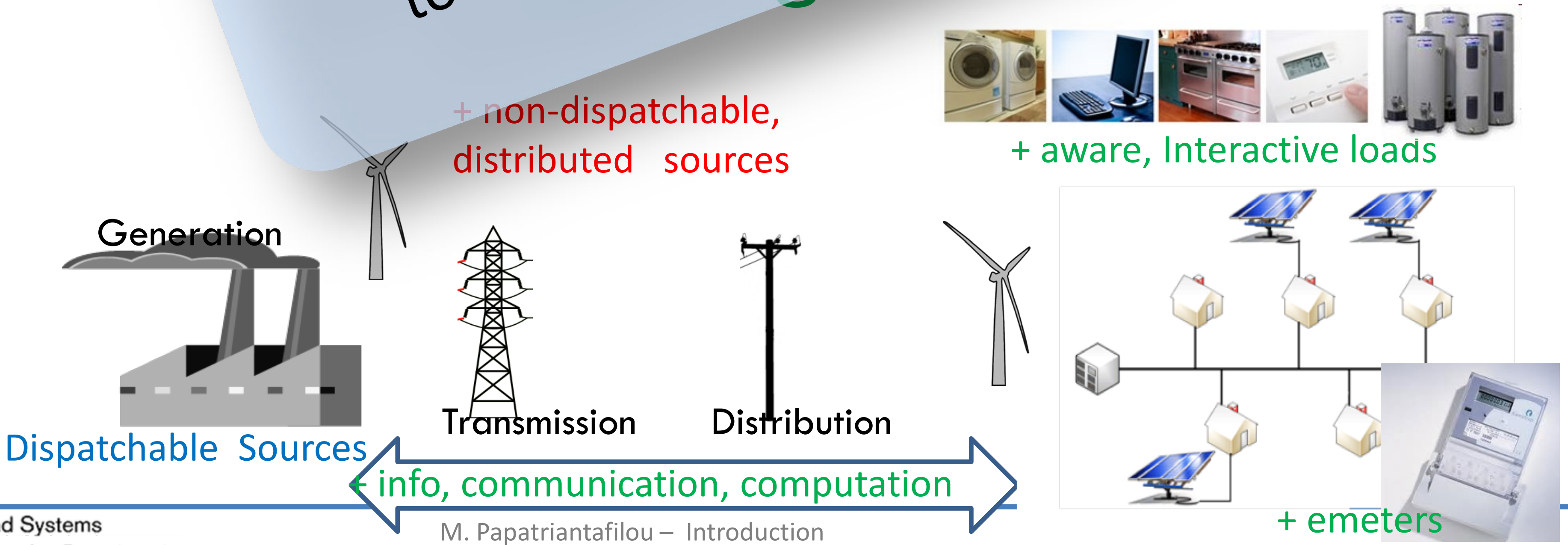
[the 4th industrial (r)evolution, presentation S. Jeschke, 2013]



e.g., in the traditional El Grid…

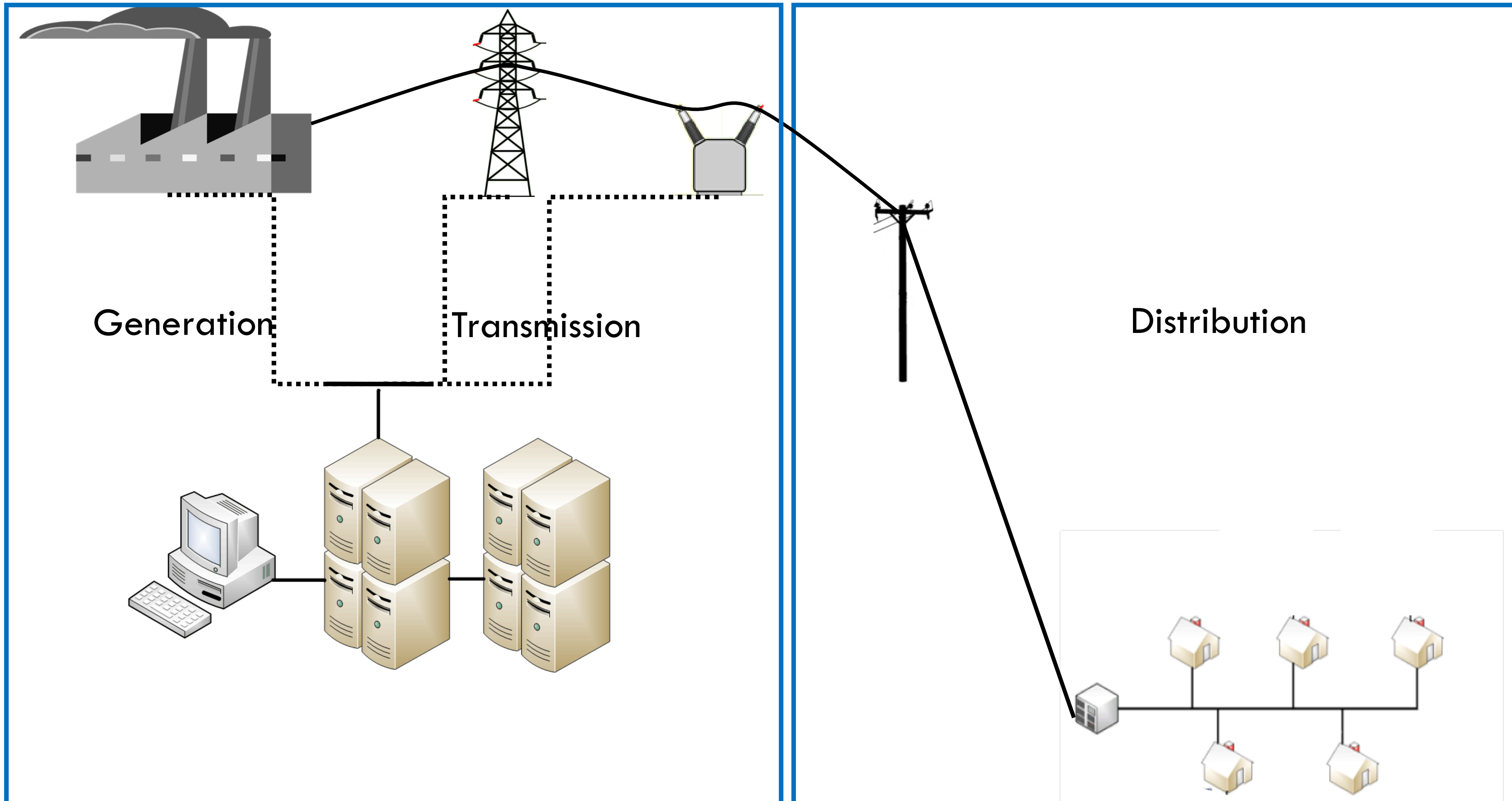
paradigm shift:
from pre-planned "broadcasting"
to adaptive scheduling

…while in the greener El Grid



Zooming into an el-network

The traditional Electrical Grid

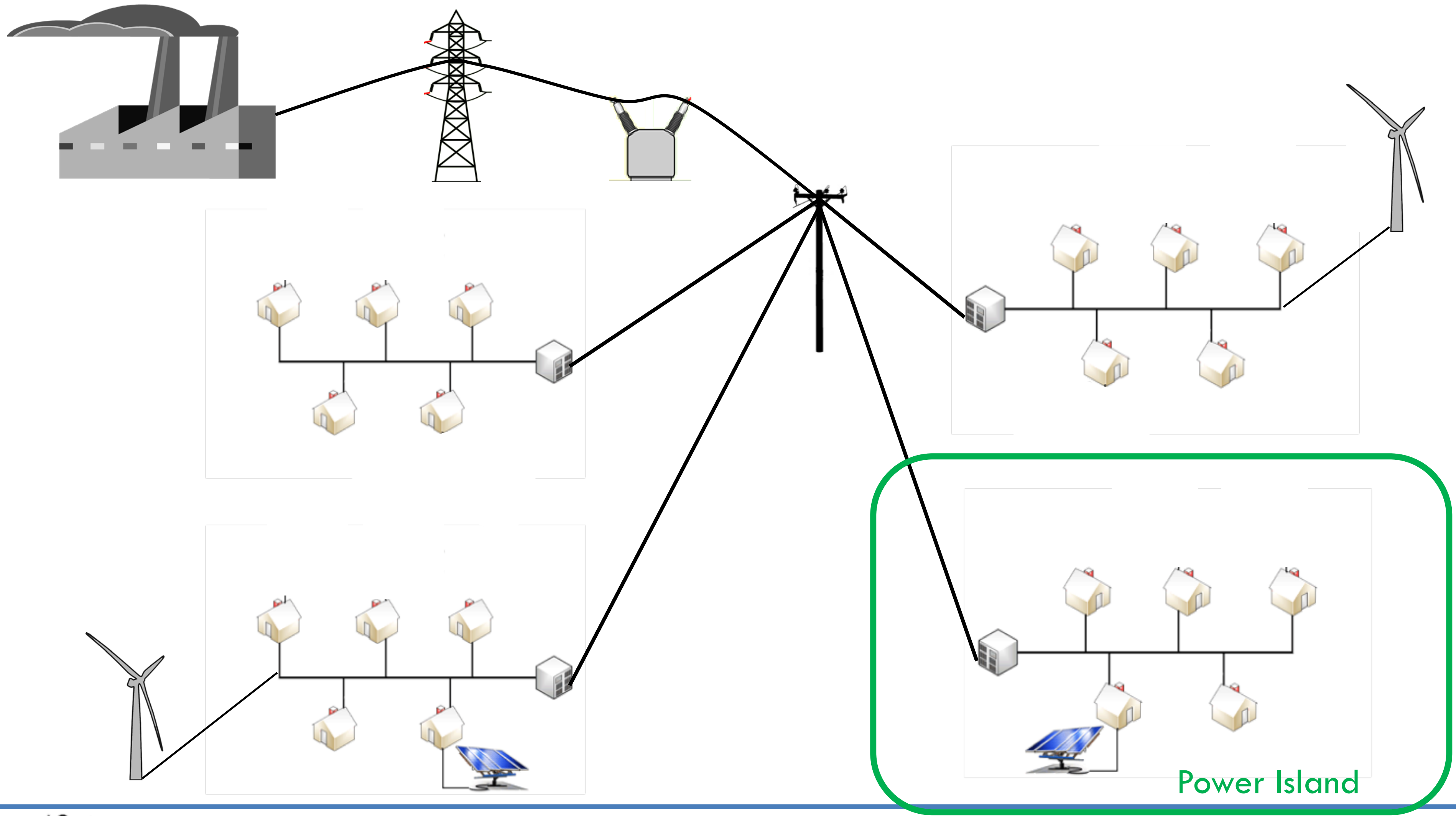


Managed and monitored by the SCADA system.

No dedicated real time monitoring system (yet).

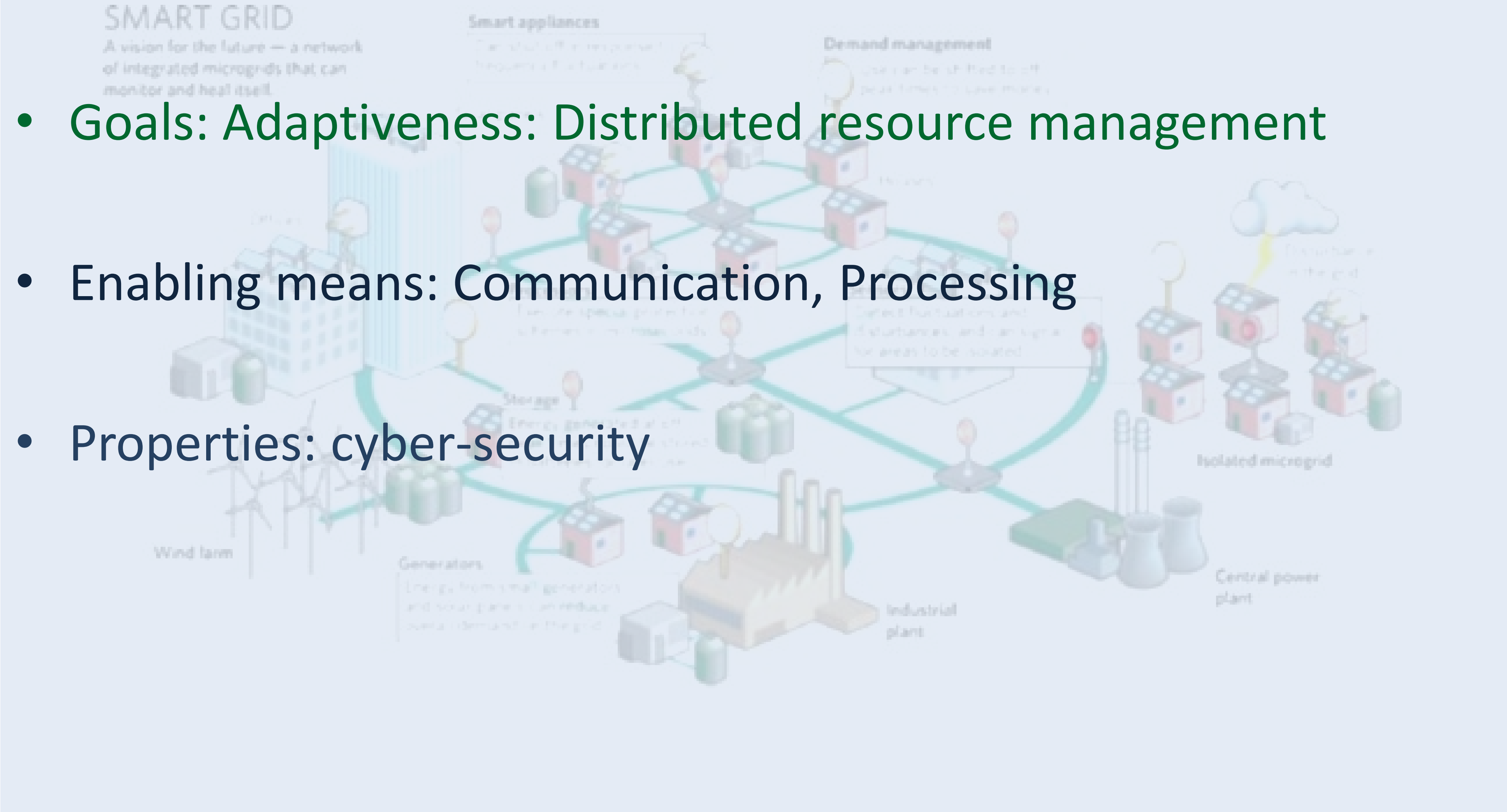
Fig. V. Tudor

From centralized to distributed generation



Pic. V. Tudor

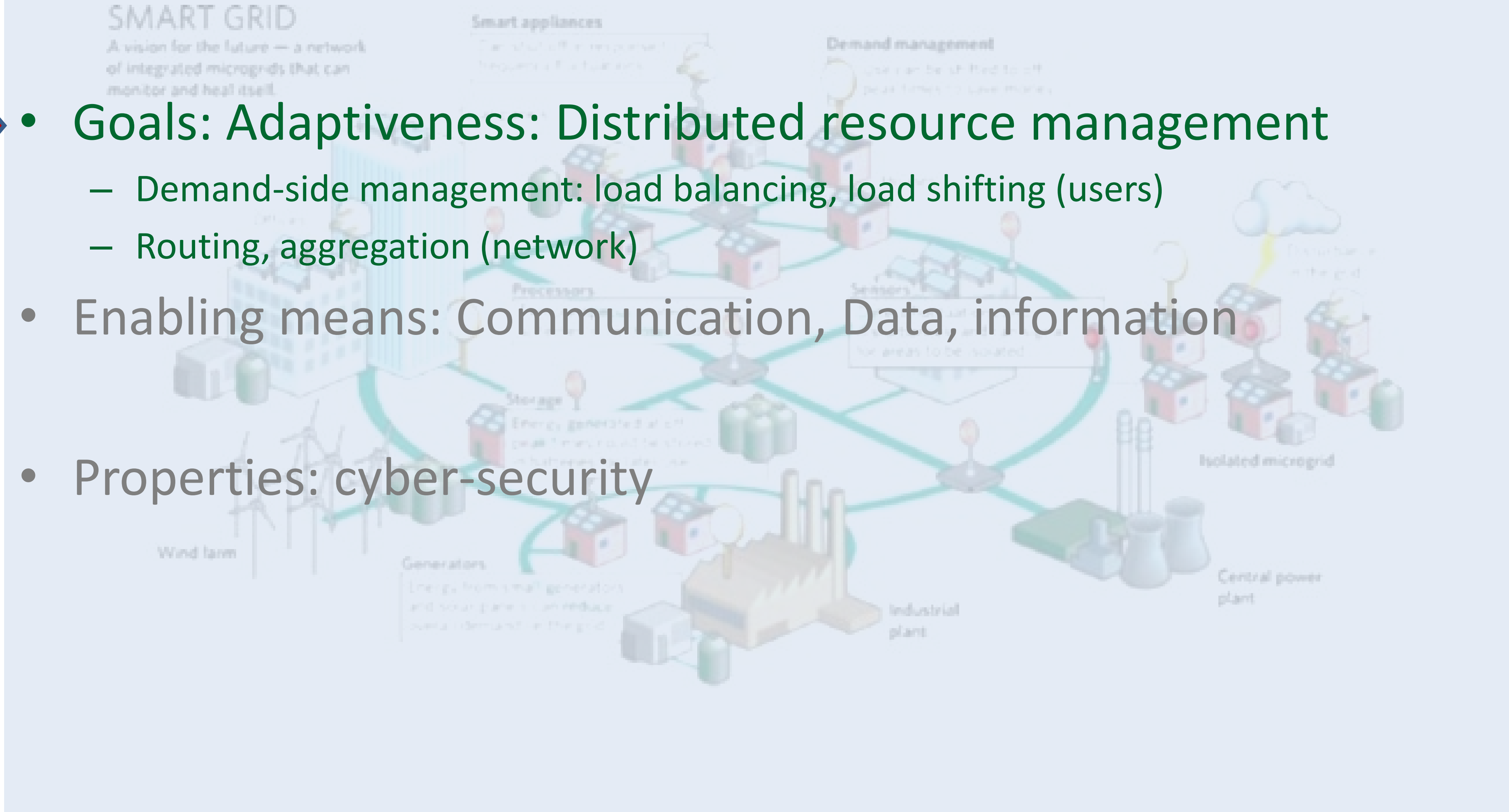
In the ElGrid CPS cyber-layer



- Goals: Adaptiveness: Distributed resource management
- Enabling means: Communication, Processing
- Properties: cyber-security

In the CPS cyber-layer

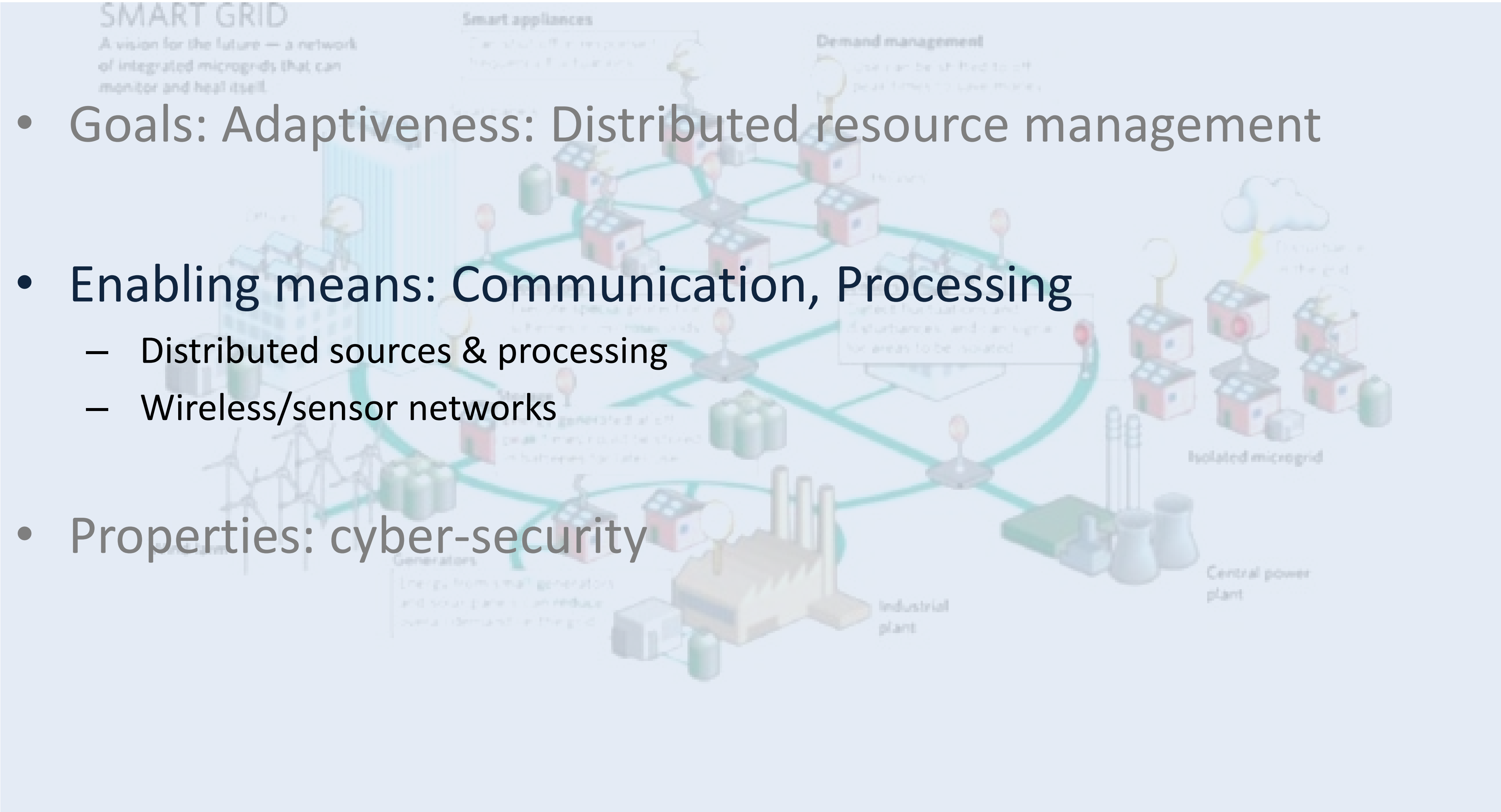
- Goals: Adaptiveness: Distributed resource management
  - Demand-side management: load balancing, load shifting (users)
  - Routing, aggregation (network)
- Enabling means: Communication, Data, information
- Properties: cyber-security



Adaptiveness: eg Demand-side management
household/neighborhood-scale and more

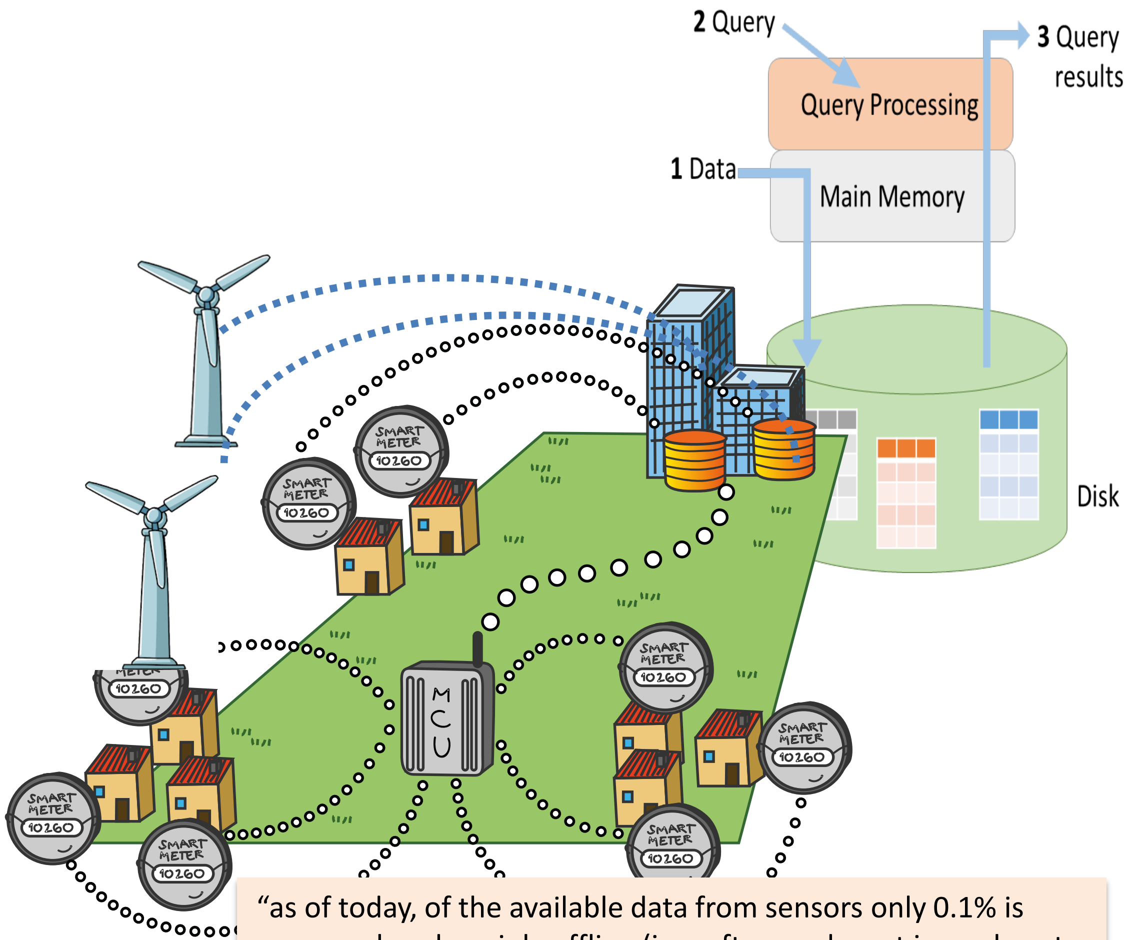
Problem: align supply & consumption; continuous decisions based on info on load, constraints, possibilities ((non)shiftable load, thermal or other storage…)
(recall power island, aka microgrid)

In the CPS cyber-layer



- Goals: Adaptiveness: Distributed resource management
- Enabling means: Communication, Processing
  - Distributed sources & processing
  - Wireless/sensor networks
- Properties: cyber-security

Communication&processing: Info needed in near-real-time

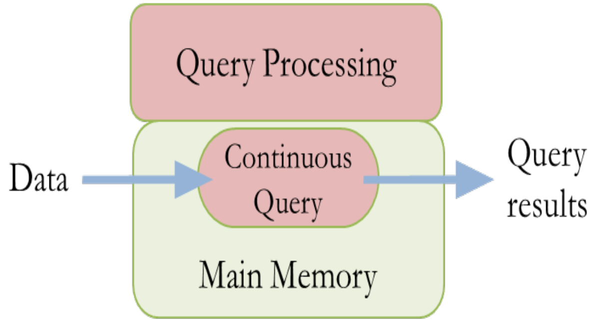


> “as of today, of the available data from sensors only 0.1% is analyzed, mainly offline (i.e., afterwards, not in or close to real-time)”
> *[Jonathan Ballon, Chief Strategy Officer, General Electric]*

fig: V. Gulisano, R. Rodriguea

Is store&process (DB) a feasible option?

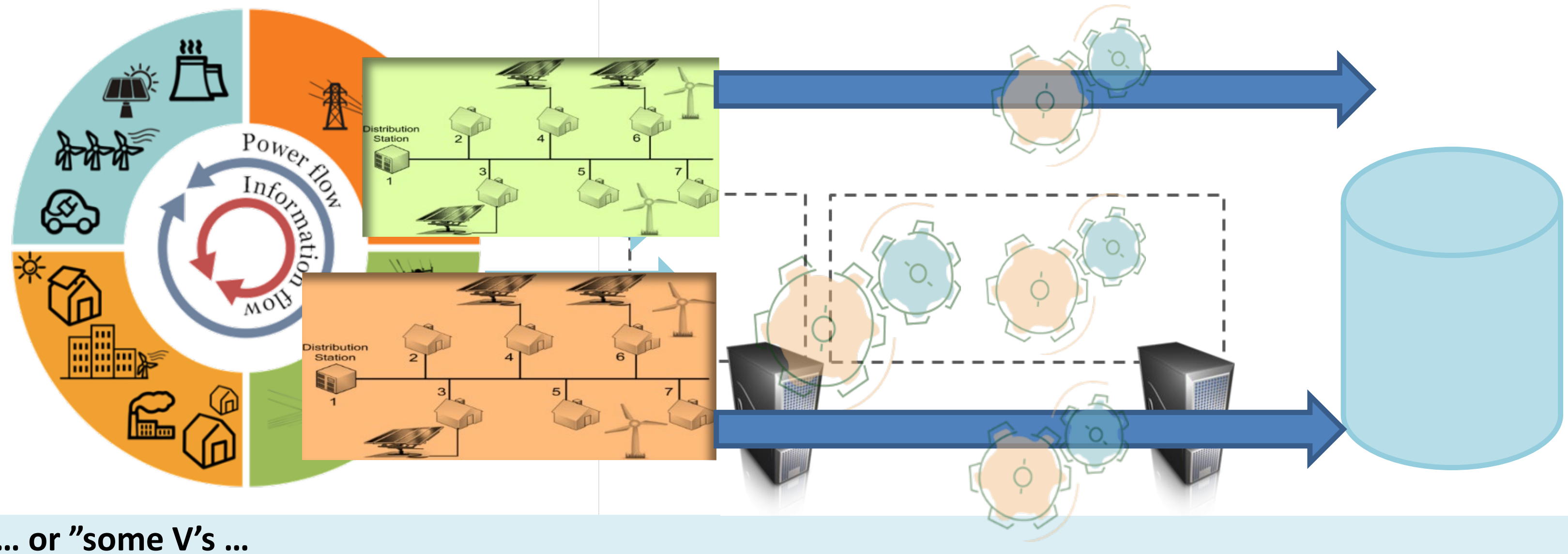
– high-rate sensors, high-speed networks, soc. media, financial records: up to Mmsg/sec; sometimes decisions must be taken **really fast** e.g., fractions of msec, even μsecs.



Data Stream Processing:

– **In memory, in-network, distributed**
– **Locality**, use of available resources
– Efficient **one-pass analysis & filter**

… system: Big!   … data: Big! but: locality!



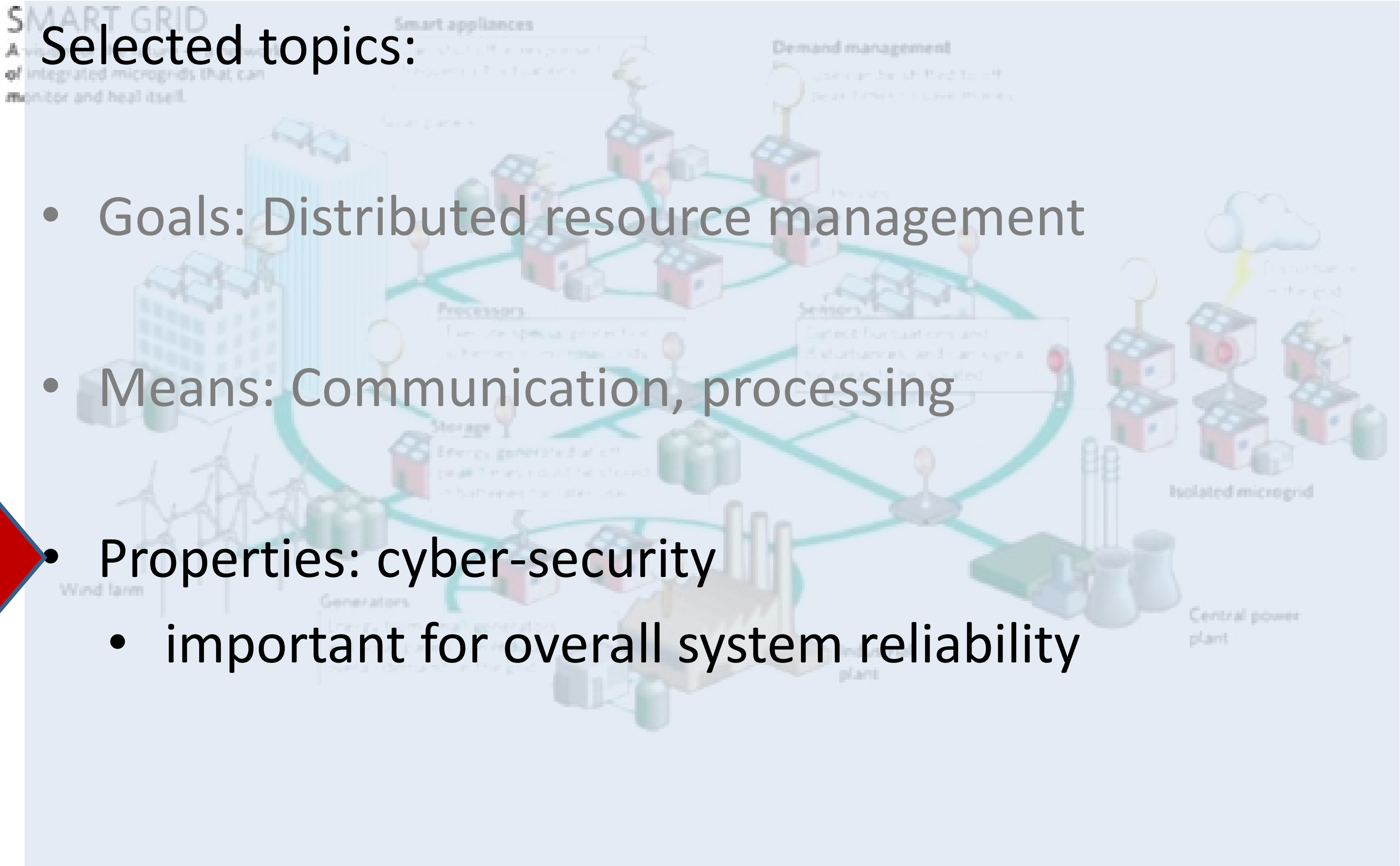
… or ”some V’s …

- Volume: terabytes – peta/exa/zetabytes — *i.e. BIG!*
- Velocity: streams — *Good! Process on-the fly can eg filter peta+bytes to megabytes*
- Variety: various types of data … — *with various relevance domains; locality: good!*

… and one D”: Distribution

Not always necessary to centralize => allow multiple actors, data-streaming, scaling, privacy, …

In the Power Grid cyber-layer

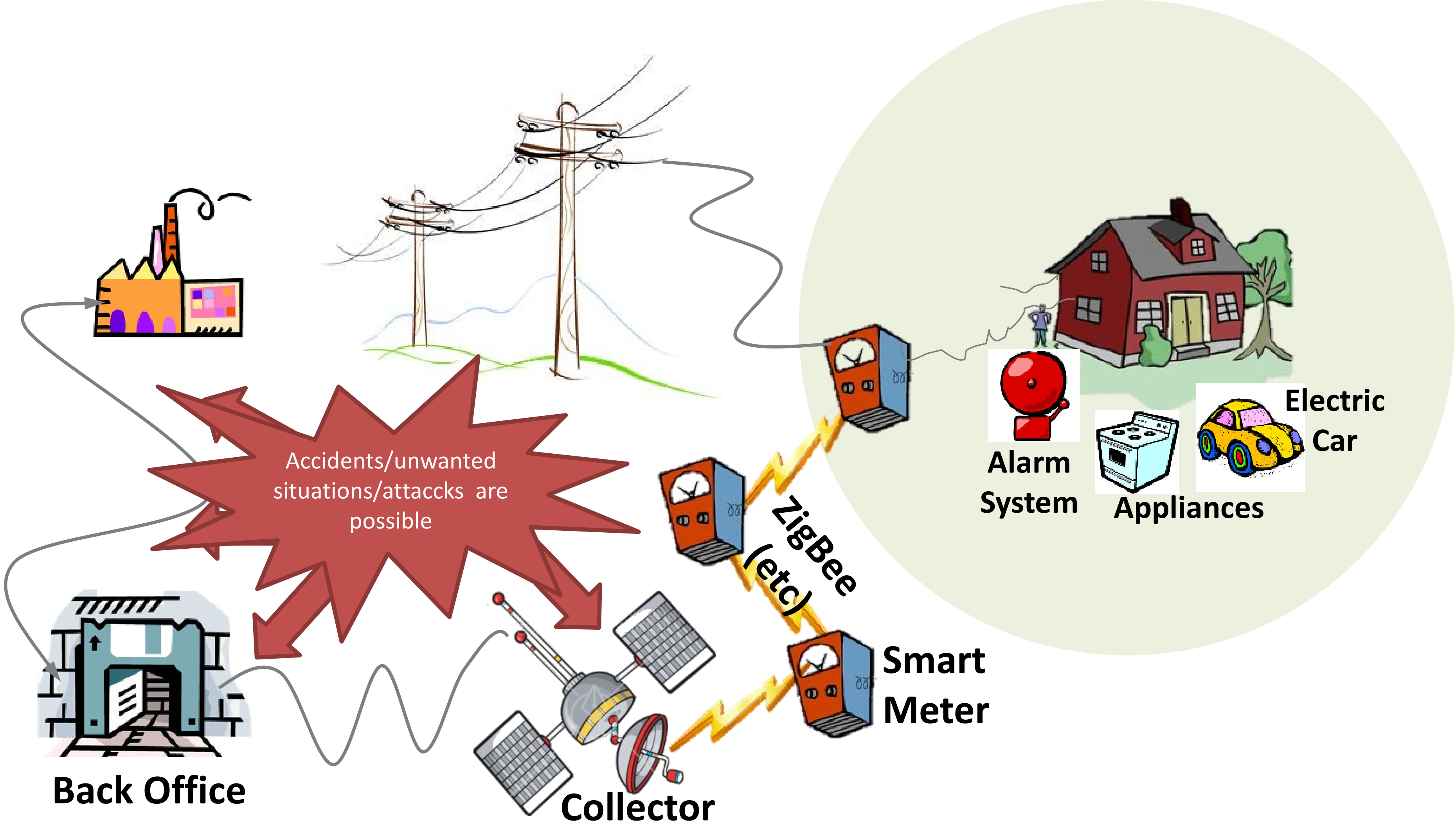


Selected topics:

- Goals: Distributed resource management
- Means: Communication, processing
- Properties: cyber-security
  - important for overall system reliability

Imperative to address cyber security from the start

Lesson learned from Internet's evolution: don't postpone dealing with security concerns

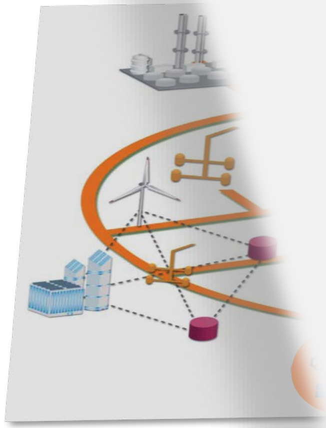


Reflecting ….

Cyberphysical systems: possibilities and challenges shake hands

Overlay network

El- link and/or communication link



Adaptive Resource Management

Data&communication: enablers

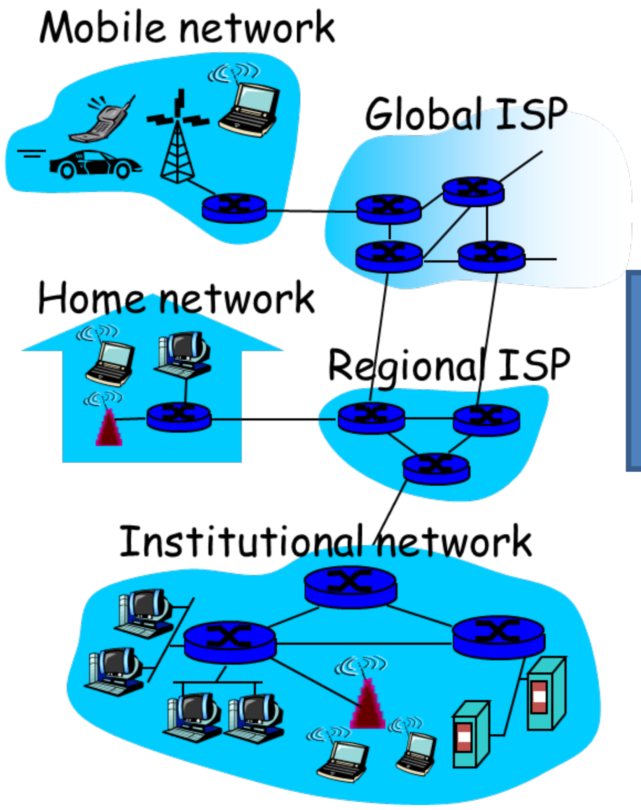
but:

- **Big networks of embedded-devices …**
- **Big data…**
- **Security, privacy …**

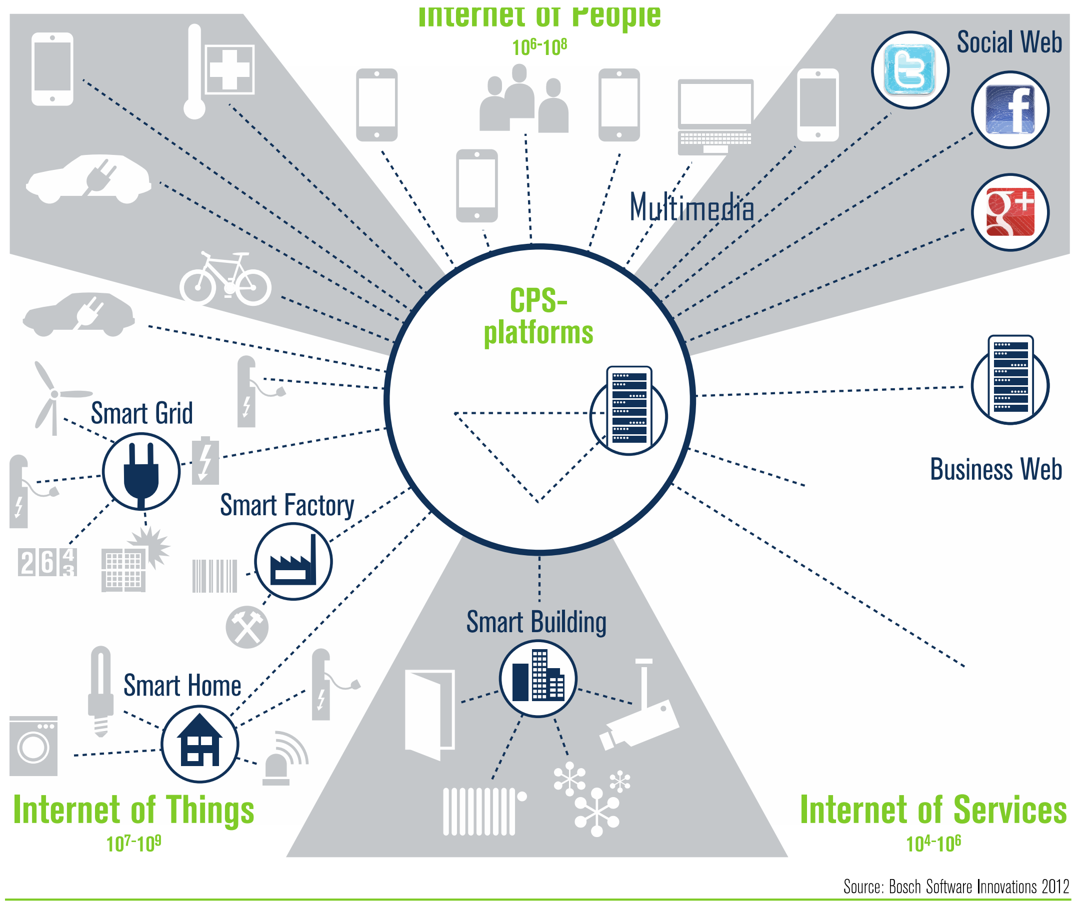
Parallel, distributed, stream processing

for solving problems locally & keeping up with scale

Reflections cont: Evolution ....



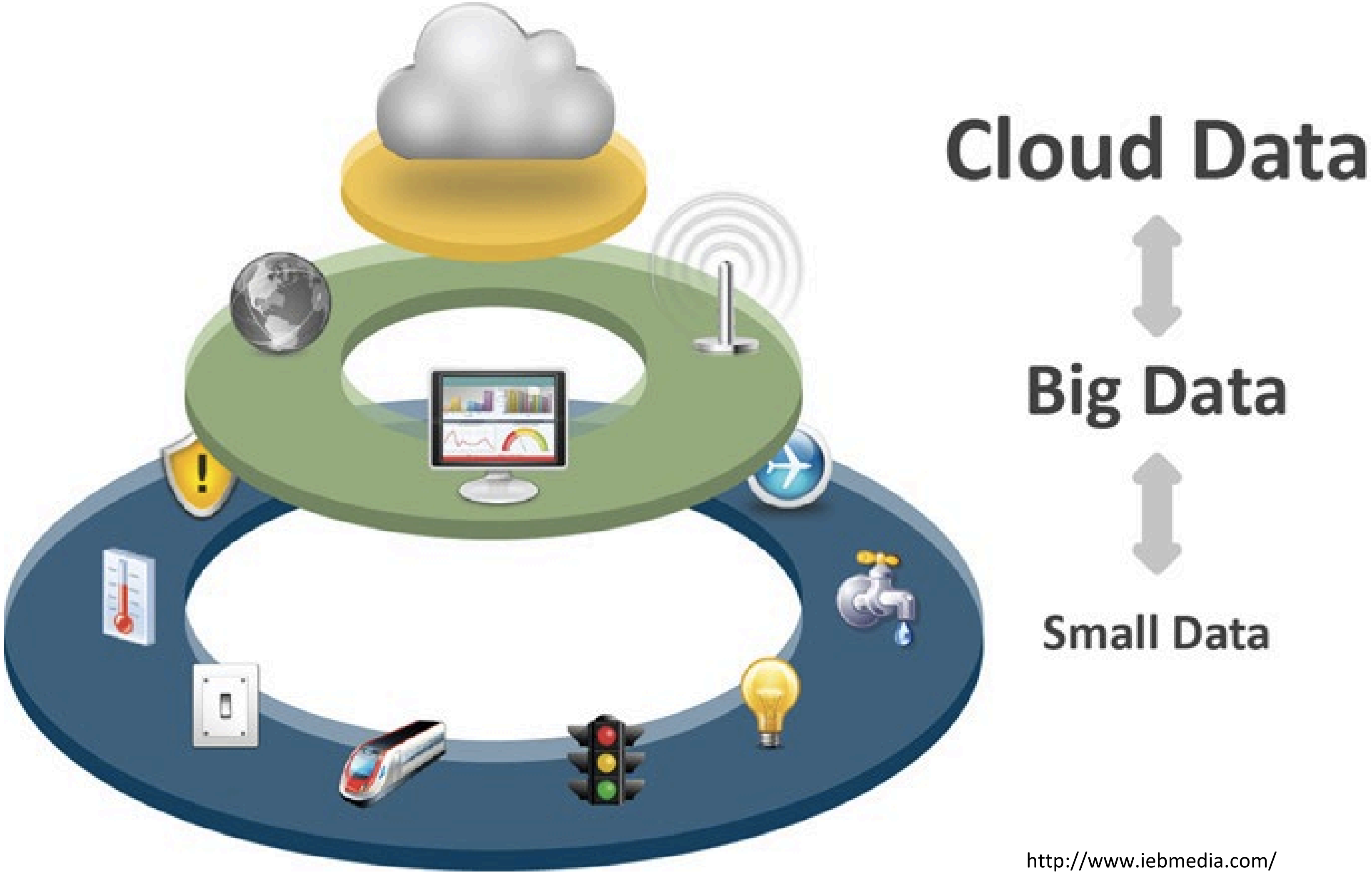
approx 10 yrs ago



continuous evolution ....

Reflection cont:
Internet, Data processing and Distributed Computing in interplay: IoT

A lot of data to be communicetd and processed



http://www.iebmedia.com/

@NS division (approx 25 pers): Cyberphysical systems research

Distributed systems, IoT

Parallel &stream computing

Security, dependability

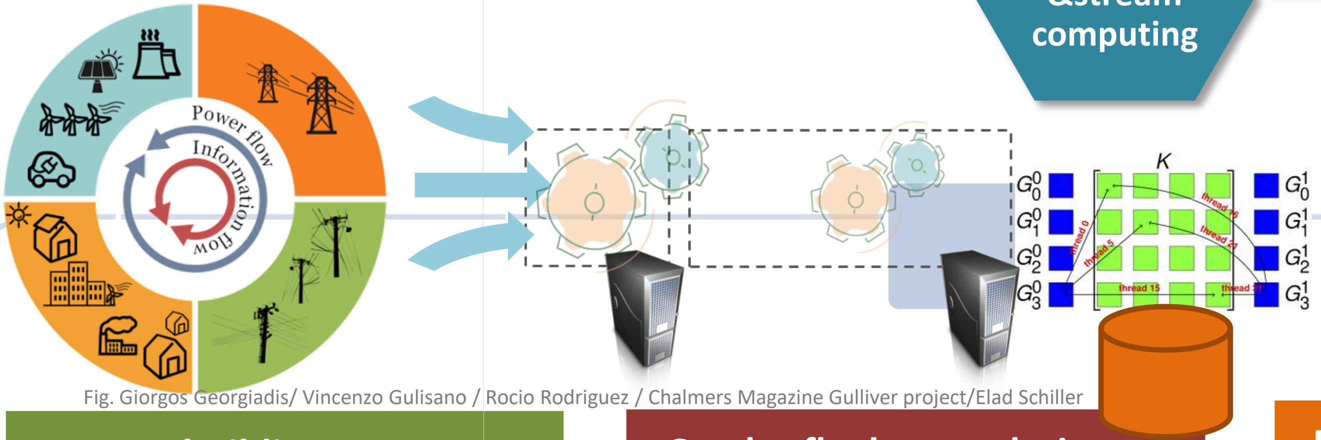


Fig. Giorgos Georgiadis/ Vincenzo Gulisano / Rocio Rodriguez / Chalmers Magazine Gulliver project/Elad Schiller

Energy, buildings, vehicular systems, production systems

- data-driven distributed monitoring,coordination, resource planning

- testbeds/usecases e.g. EoN, Ericcson 5G, GE, Gulliver, Scania, Volvo)

On-the-fly data analysis

- Aggregation, learning, validation, monitoring (ML, LiDAR) …

-Security, privacy

Processing infrastructure: efficient, energy-friendly

- streaming , parallel/multicore computing, incl. on embedded processors (ARM, Odroid systems, GPUs, ..)

Example research of the DCS group

Parallel, distributed and stream processing on variety of processing platforms, appropriate for fog & cloud:

+ 1-order of magnitude faster than SoA

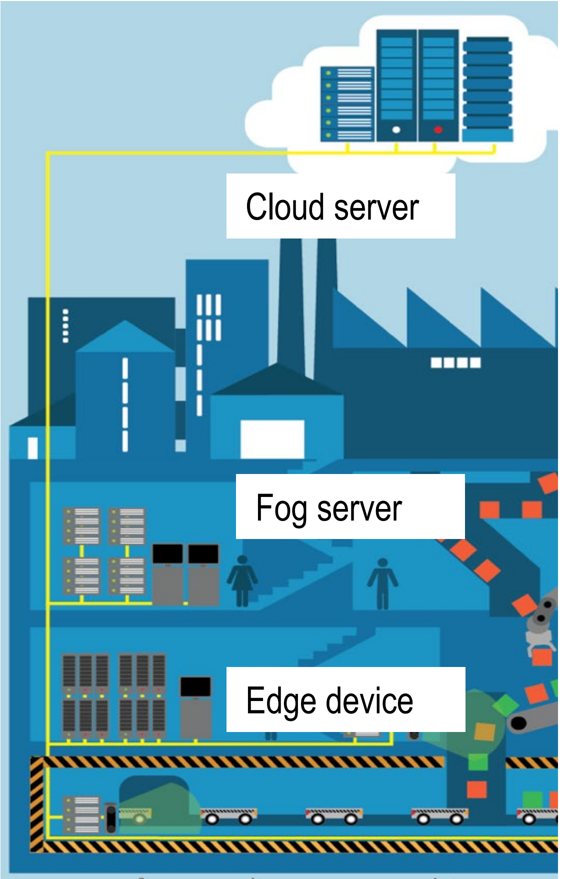


fig: V. Guliasano, R. Rodriguez, MP

min/hour/day/week/month/year

sec/min

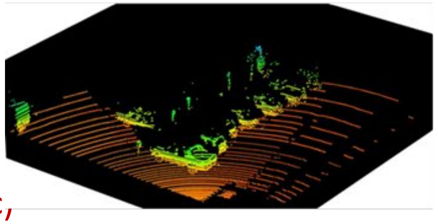
Real-time (sec/msec,

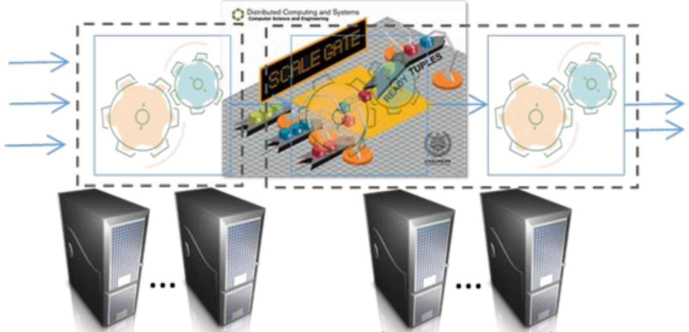
Applications/what is enabled:

- RT-compliant alerts, anomaly/event-detection, optimization & bottlenecks analysis
- LiDAR: collision risk, geo-fences, digital twins/dynamic pipelines

Fig: Micieta et-al DOI: 10.2507/daaam.scibook.2015.33

New: continuous LiDAR point cloud processing





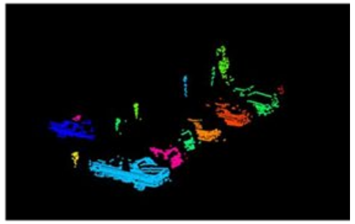


Fig: H. Najdataei, V. Gulisano, R. Rodrigues, MP

In this course:

Topics:

- Analysis for CPS needs: eg algorithmc aspects, learning, adaptiveness, distributed resource management
- Enablers: Communication, Data processinh
- Properties: Cyber-security

Structure, todo’s:

- Projects
- Lectures by the supporting team + collaborators and industry
- Self-study, projects and presentations

How?

- Cf *Administrative Details.pptx*

Recent&current related research project support @NS

AoA Building Futures, Energy, ICT, Production, Transport

Faculty researchers responsible:

Magnus Almgren

Vincenzo Gulisano

Tomas Olovsson

Marina Papatriantafilou

Elad Schiller

Philippas Tsigas