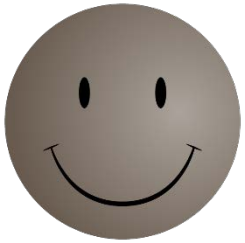
MasterClass on Data-driven Support for Cyber-physical systems
DAT300, DIT615

Introduction:
Distributed Cyberphysical systems with Electricilty Networks as example (& Course Outline)

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

Briefly on research + education area of the supporting team

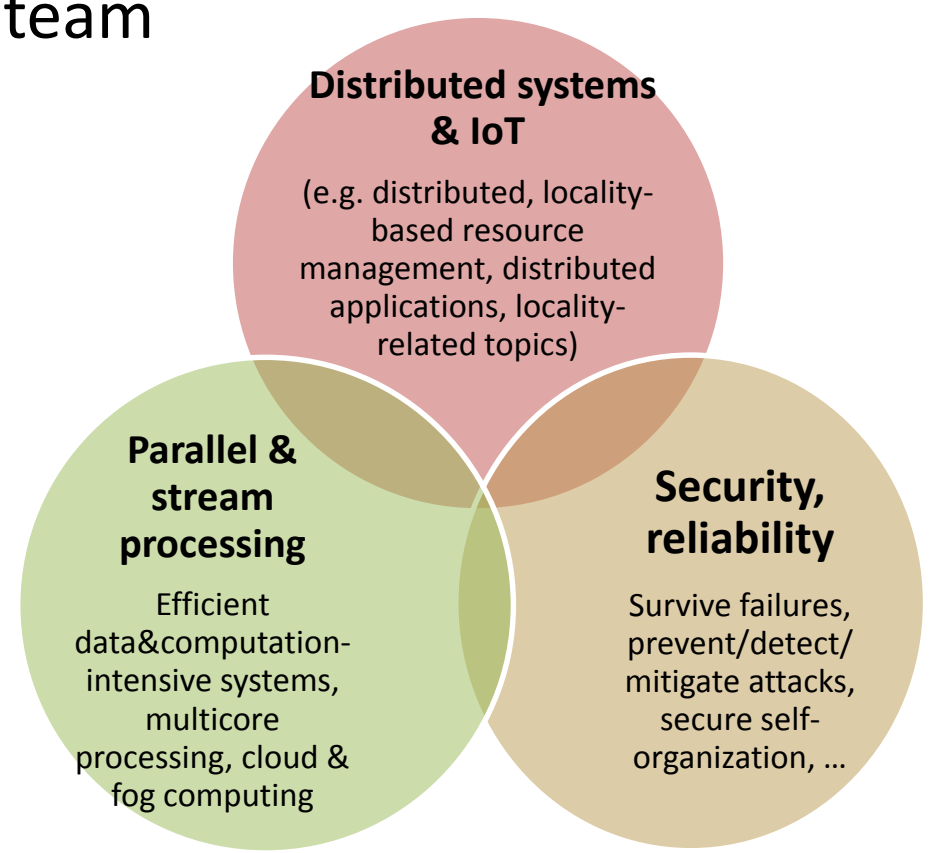


Babis (Charalampos) Stylianopoulos

Application domains: energy & other infrastructure systems, production & vehicular systems, networks

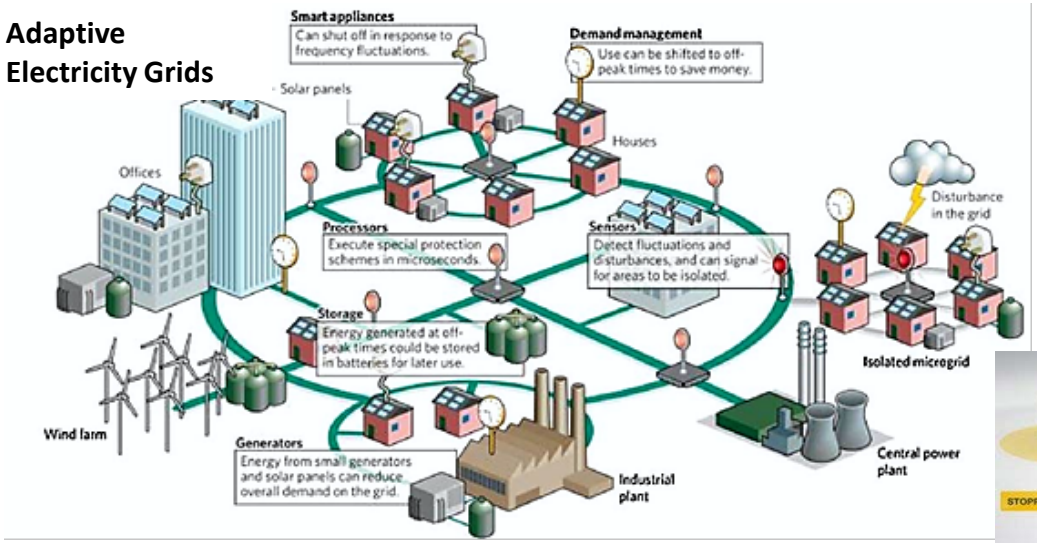
Magnus Almgren

M. Papatriantafilou

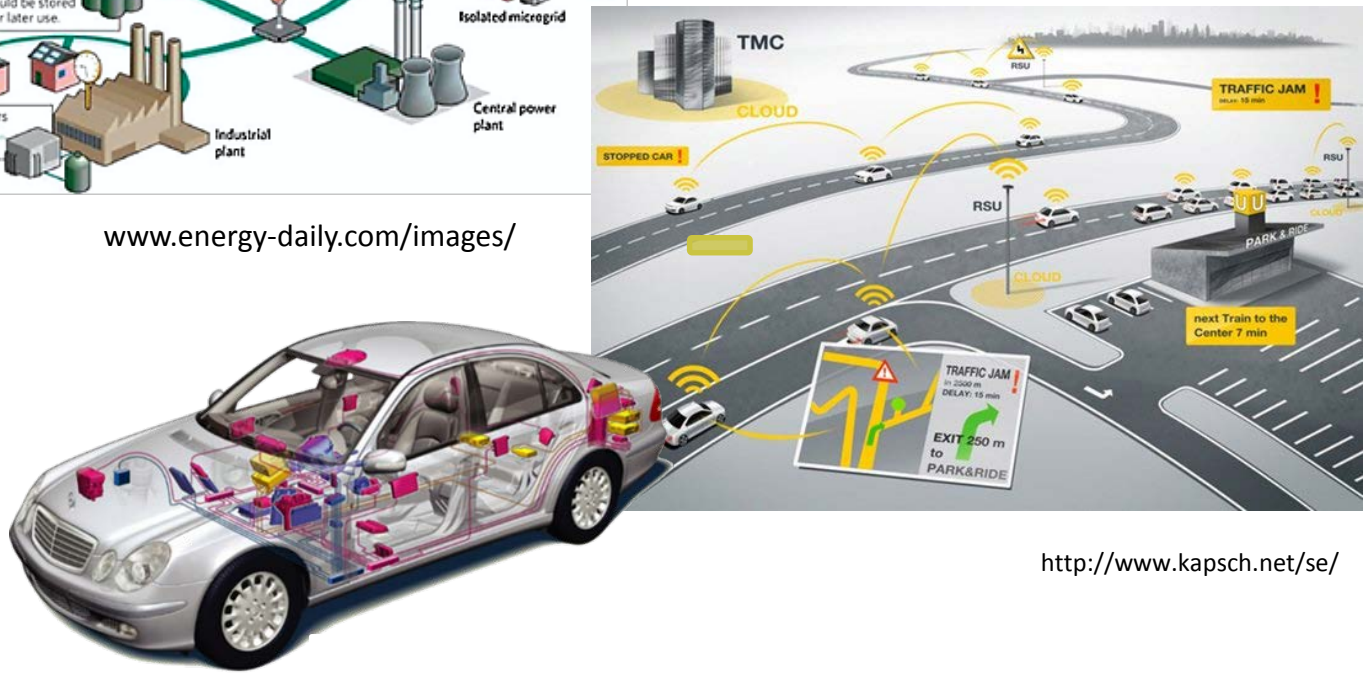


Examples Cyber-Physical Systems (CPS)

Adaptive Electricity Grids



www.energy-daily.com/images/



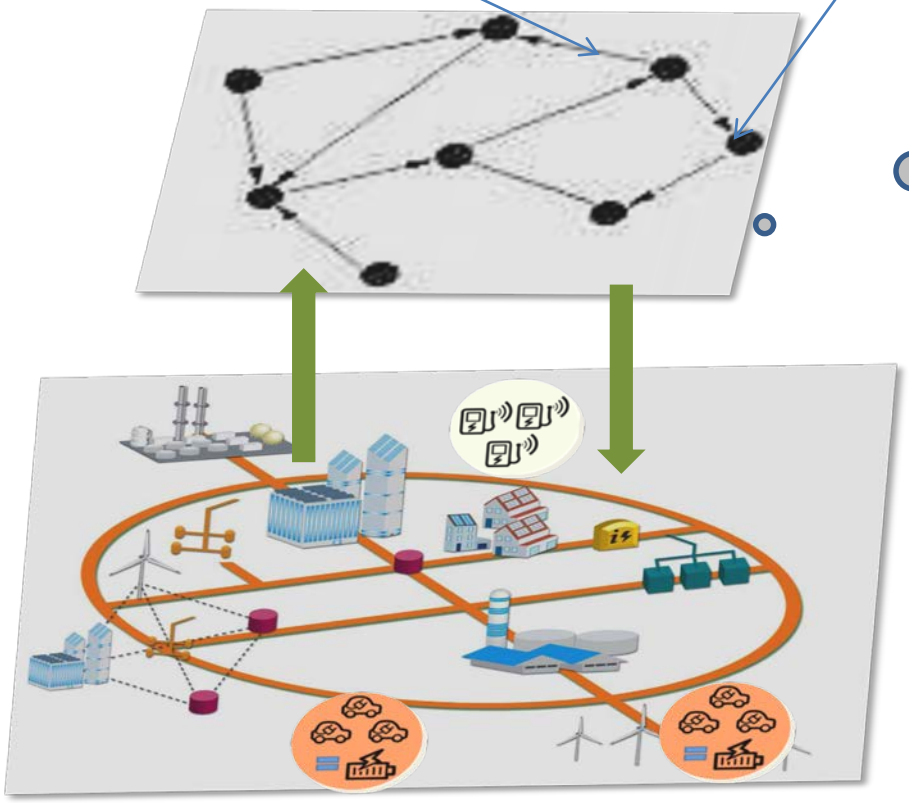
http://www.kapsch.net/se/

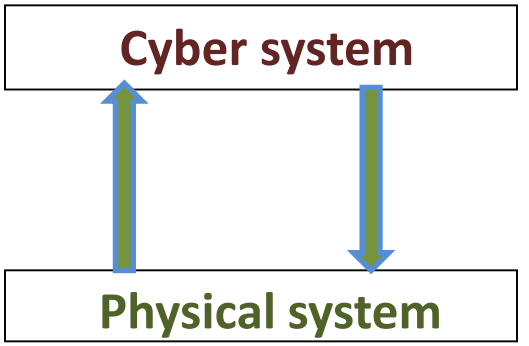
Cyberphysical systems as layered systems

communication link

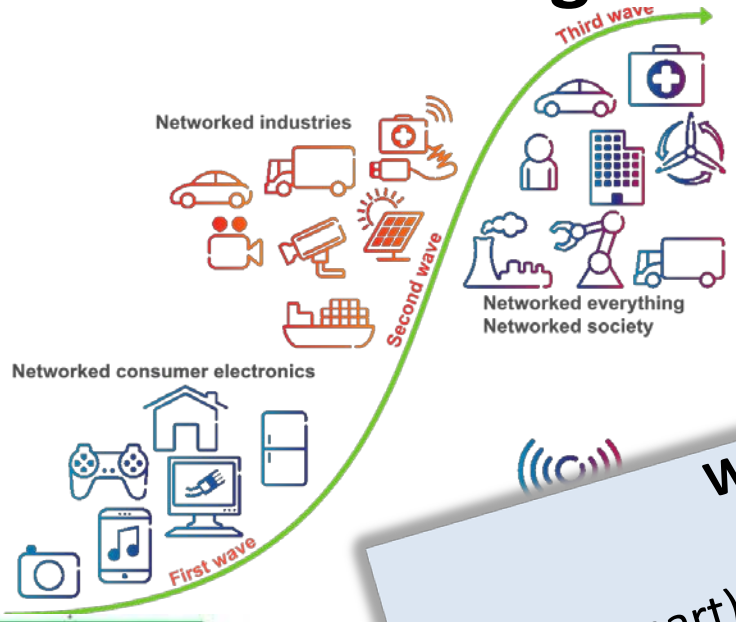
Sensing+computing+
communicating device

aka Internet-of-Things (IoT)





CPS/IoT => **big** numbers of devices and/or big data rates => **big volumes of events/data**!

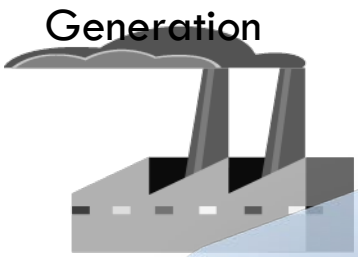


2020: Billions of connected devices
[Ericsson, Cisco]

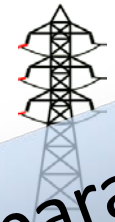
Why this complexity?

(smart) **adaptive** use of resources ....
... possibilities of improvements: e.g. energy consumption, traffic bandwidth, early-warnings, ...
improving systems quality"
[the 4th industrial (r)evolution, presentation S. Jeschke, 2013]

e.g., in the traditional El Grid…

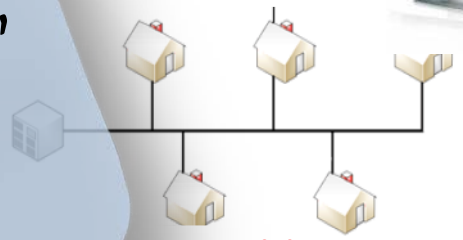


Dispatchable Sources



Transmission

Distribution



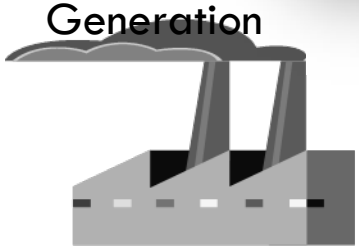
Oblivious Loads

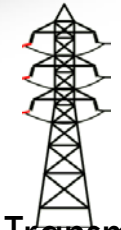
paradigm shift:
…from pre-planned "broadcasting"
to adaptive scheduling

…while in the greener El Grid

+ aware, Interactive loads

+ non-dispatchable, distributed sources



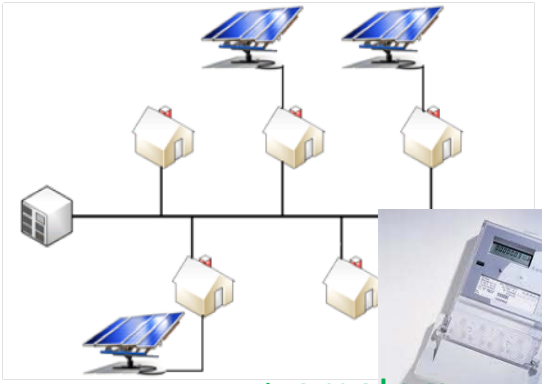


Transmission

Distribution

Dispatchable Sources

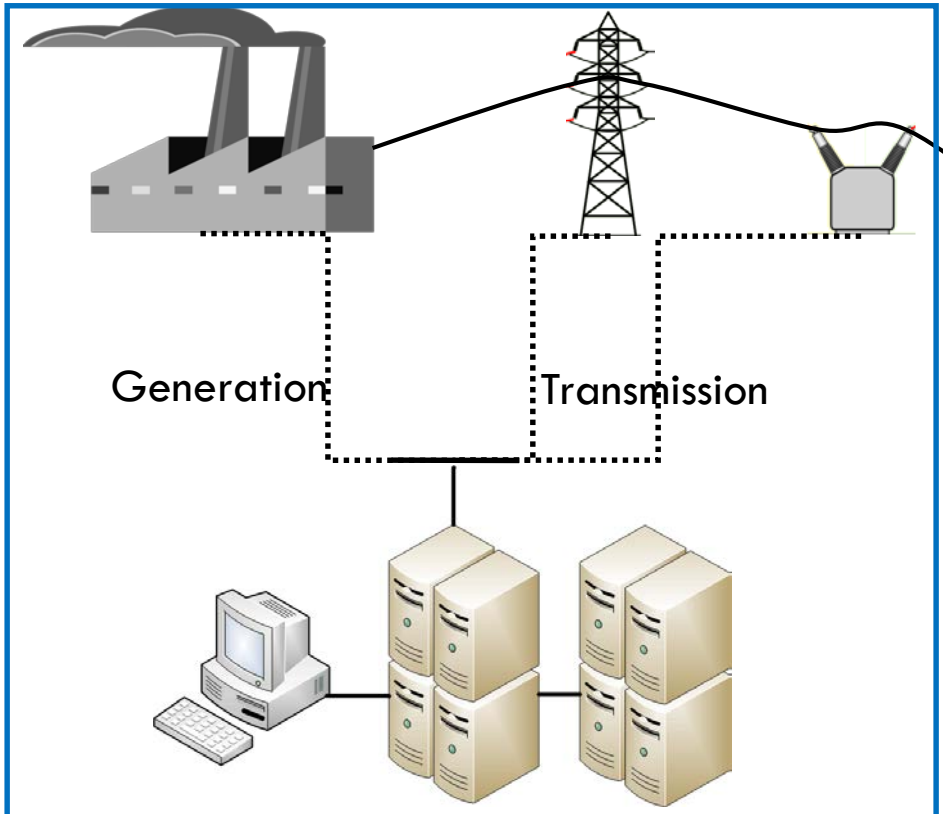
info, communication, computation



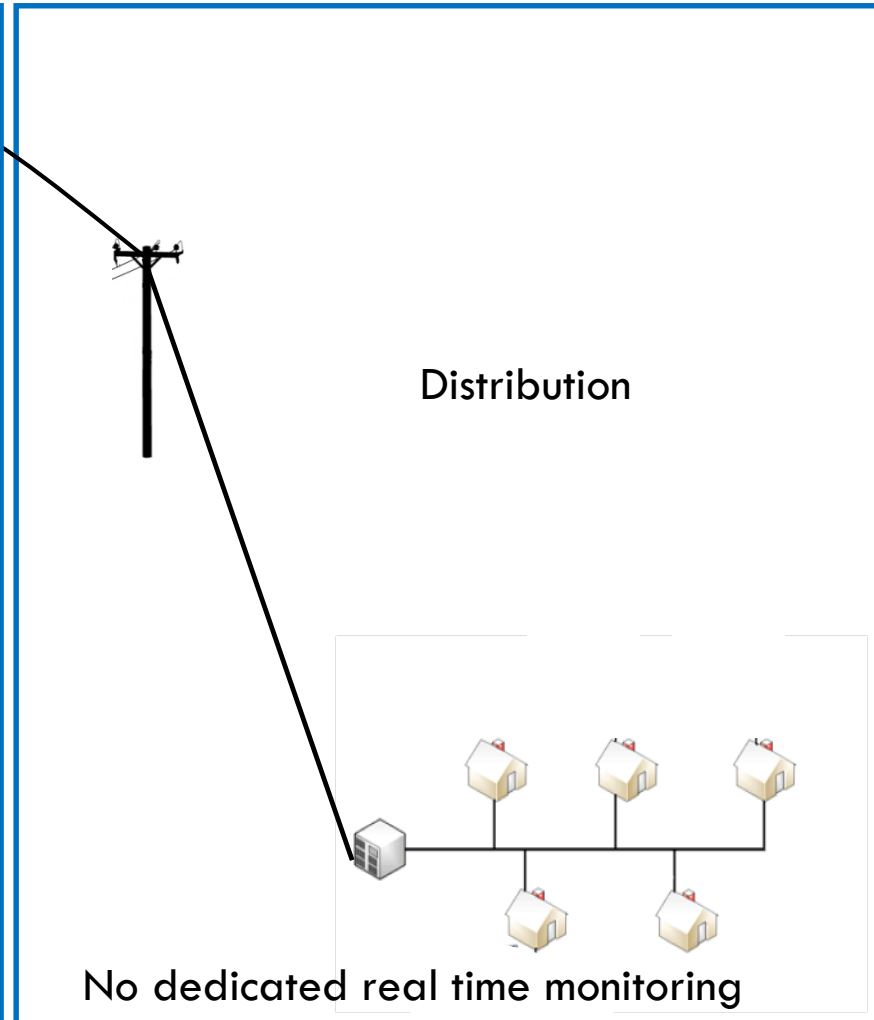
+ emeters

Zooming into an el-network

The traditional Electrical Grid



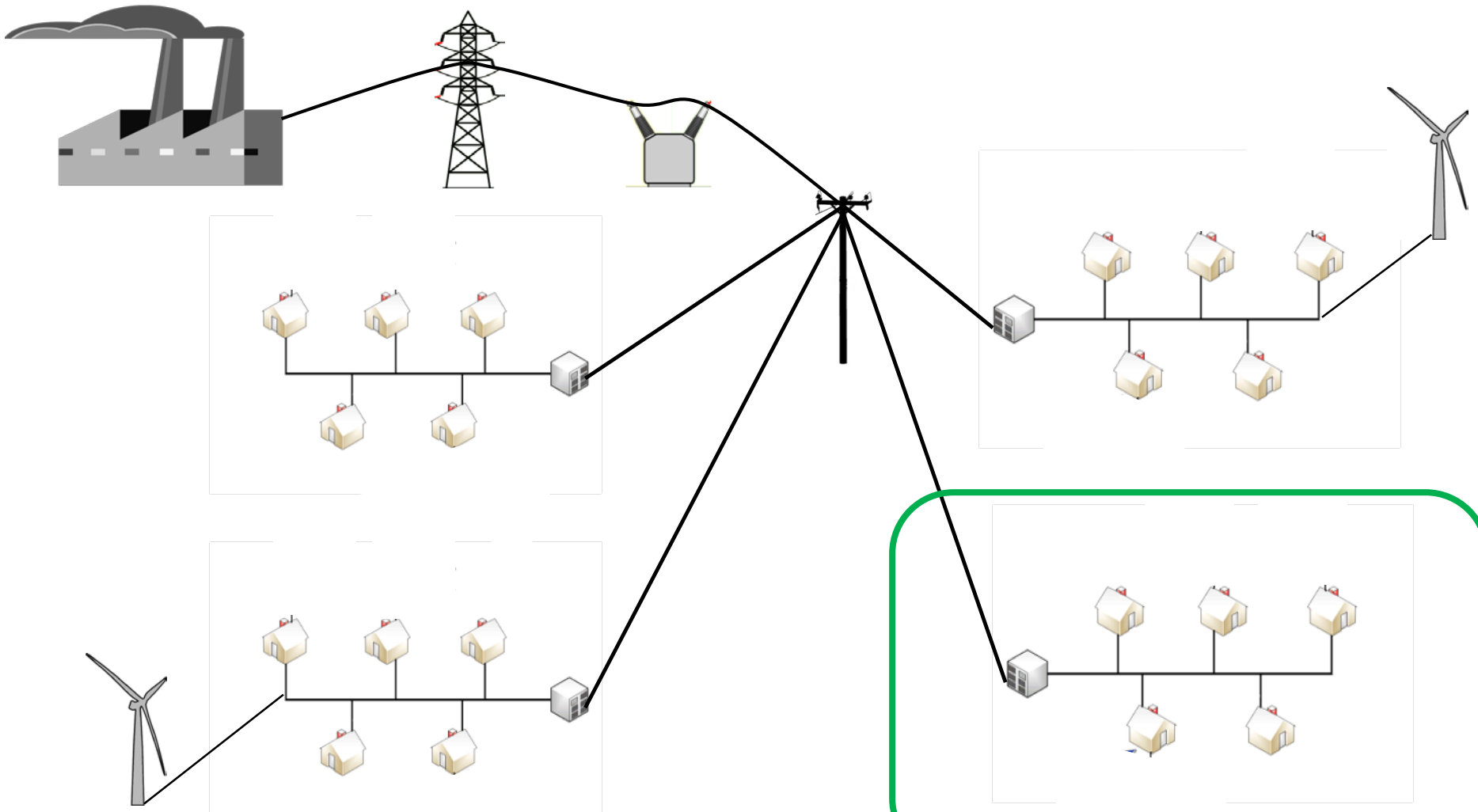
Managed and monitored by the SCADA system.



No dedicated real time monitoring system (yet).

Pic. V. Tudor

From centralized to distributed generation



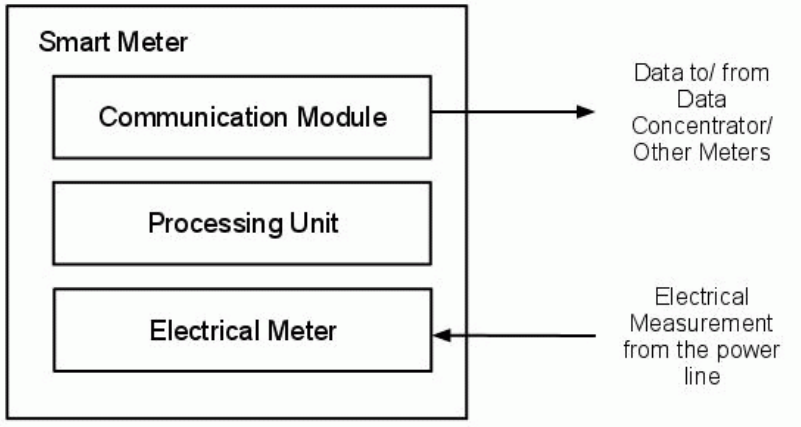
Pic. V. Tudor

Power Island

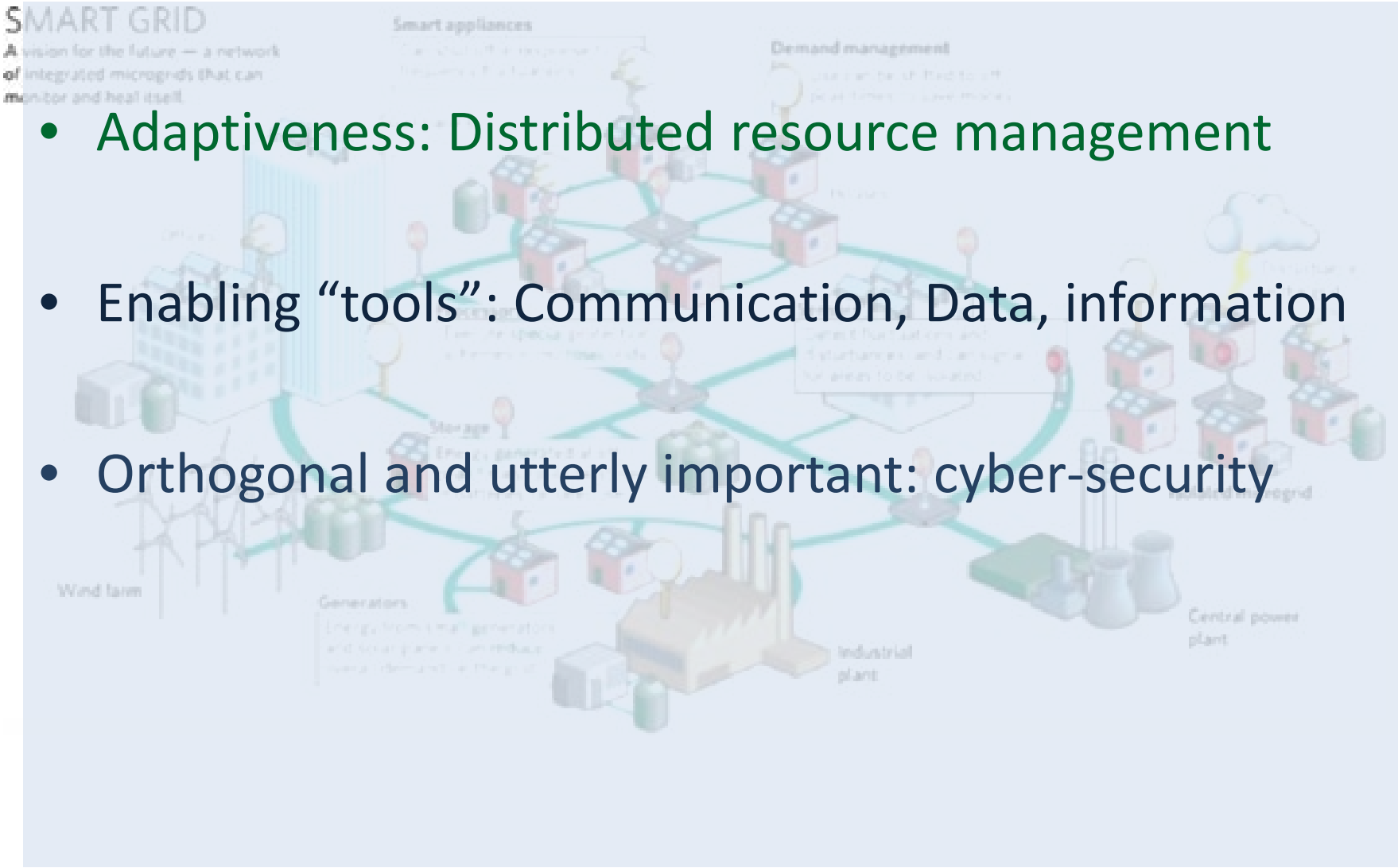
One of the enabling components: Smart Meter (Advanced Metering Infrastructure)

A "Smart" Meter:

- is a small embedded system
- automates (consumption) index readings
- instantaneous consumption
- in-door display
- time of use tariffs
- the base for the Advanced Metering Infrastructure

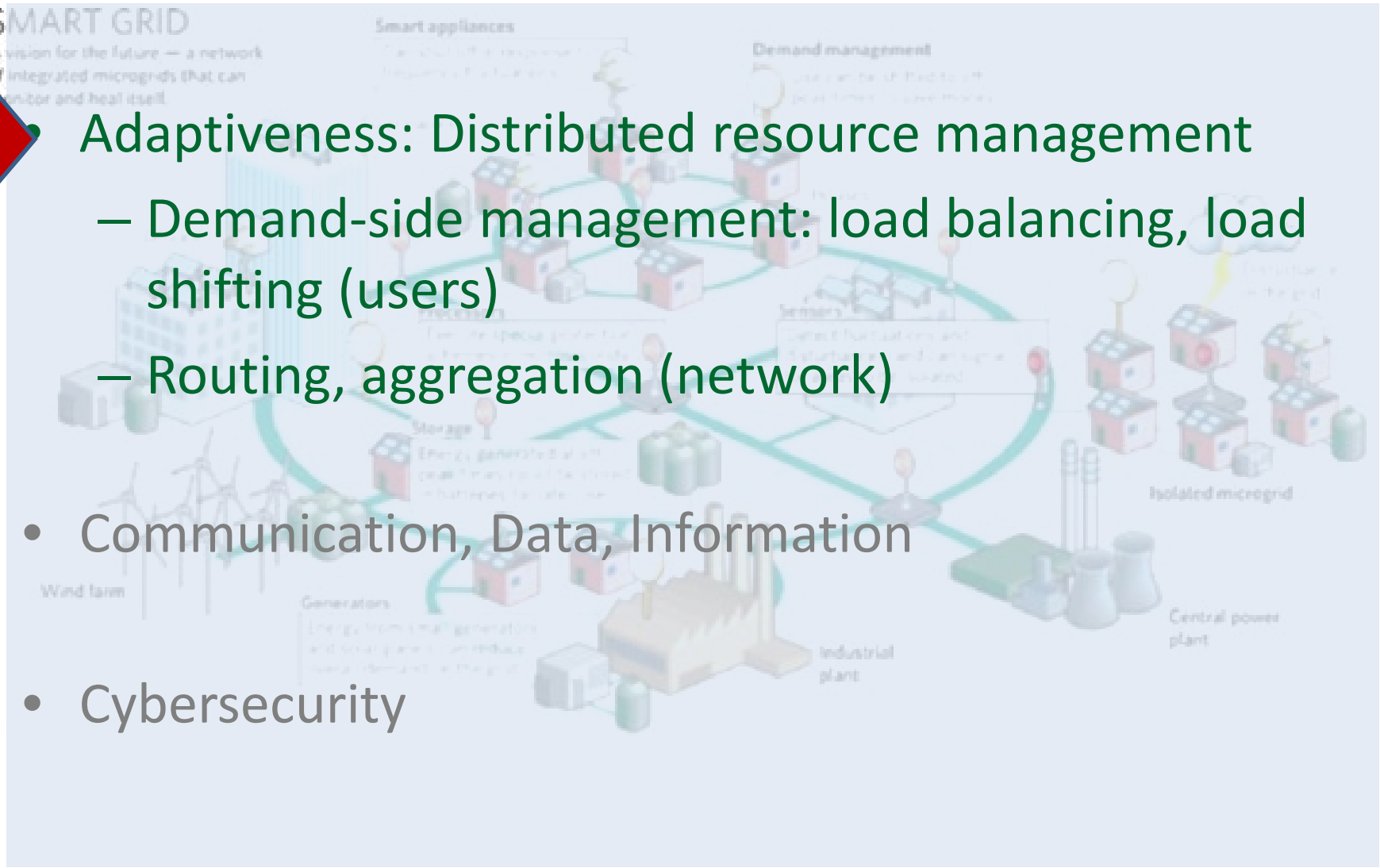


In the CPS cyber-layer



- Adaptiveness: Distributed resource management
- Enabling “tools”: Communication, Data, information
- Orthogonal and utterly important: cyber-security

In the CPS cyber-layer



- Adaptiveness: Distributed resource management
  - Demand-side management: load balancing, load shifting (users)
  - Routing, aggregation (network)
- Communication, Data, Information
- Cybersecurity

Adaptiveness: eg Demand-side management

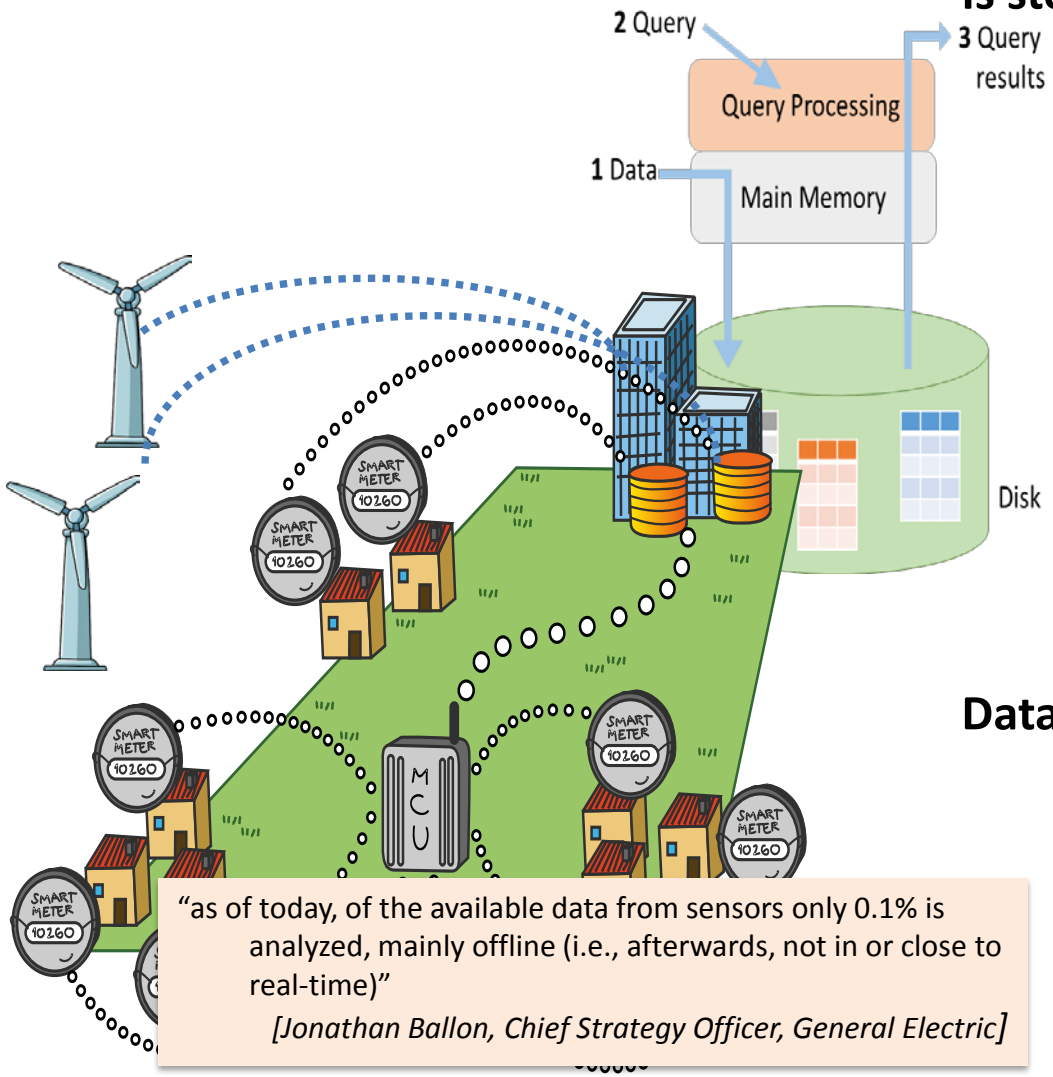
household/neighborhood-scale and more

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

In the CPS cyber-layer

- Distributed resource management
- Enabling “tools”: Communication, data, information
  - Distributed sources & processing
  - Wireless/sensor networks
  - Monitoring, facilitating resource services
- Cybersecurity

Info needed in near-real-time



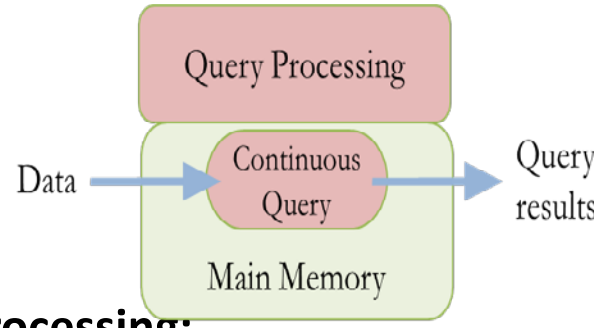
"as of today, of the available data from sensors only 0.1% is analyzed, mainly offline (i.e., afterwards, not in or close to real-time)"

[Jonathan Ballon, Chief Strategy Officer, General Electric]

fig: V. Gulisano

Is store&process (DB) a feasible option?

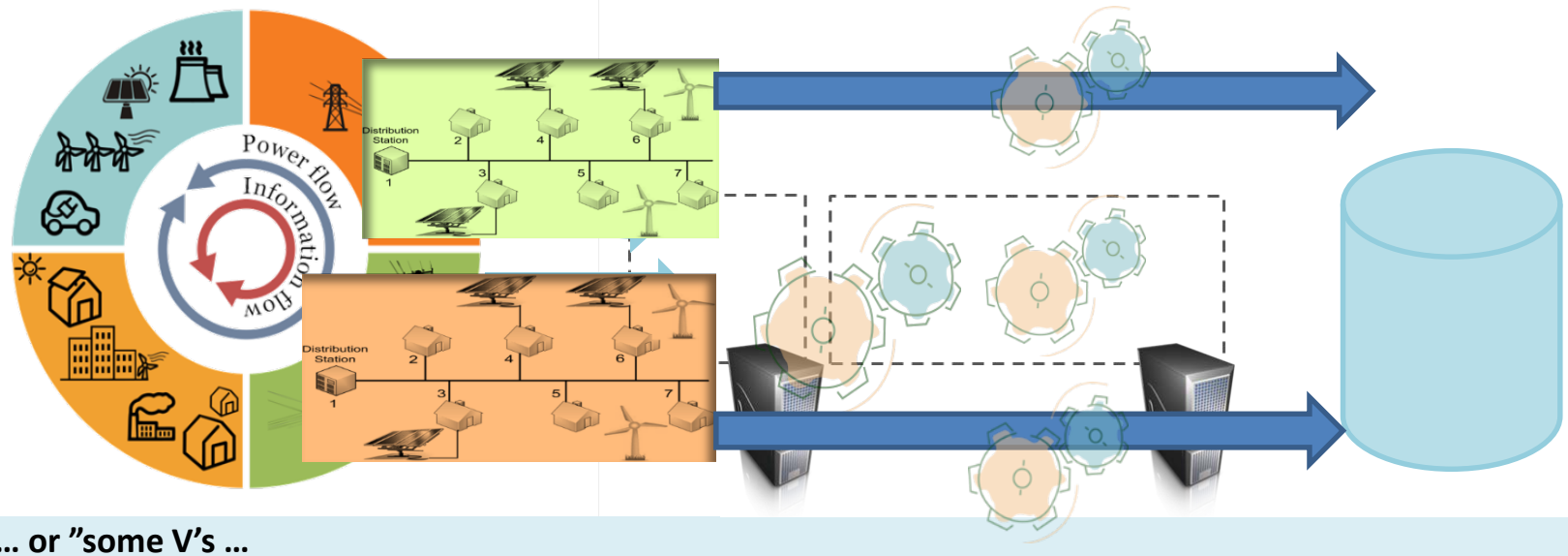
- high-rate sensors, high-speed networks, soc. media, financial records: up to Mmsg/sec; sometimes decisions must be taken **really fast** e.g., fractions of msec, even μsecs.



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 …

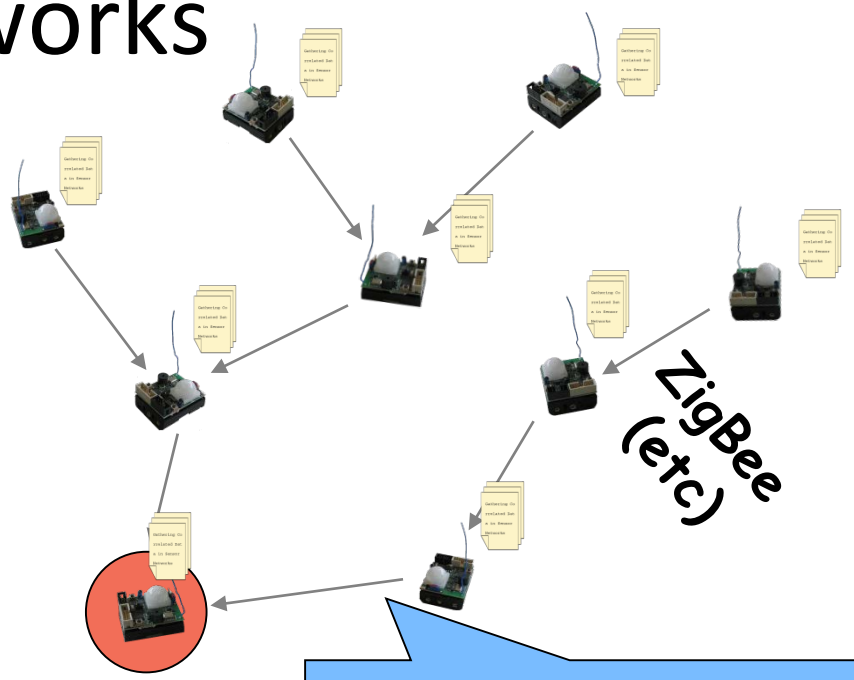
- Volume: terabytes – peta/exa/zetabytes — *i.e. BIG!*
- Velocity: streams — *Good! Process on-the fly can eg filter peta+bytes to megabytes*
- Variety: various types of data … — *with various relevance domains; locality: good!*

… and one D": Distribution

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

Data gathering&processing in Sensor Networks

- nodes produce relevant information about their vicinity periodically.
- Data is conveyed to an information sink for further processing.
- ….

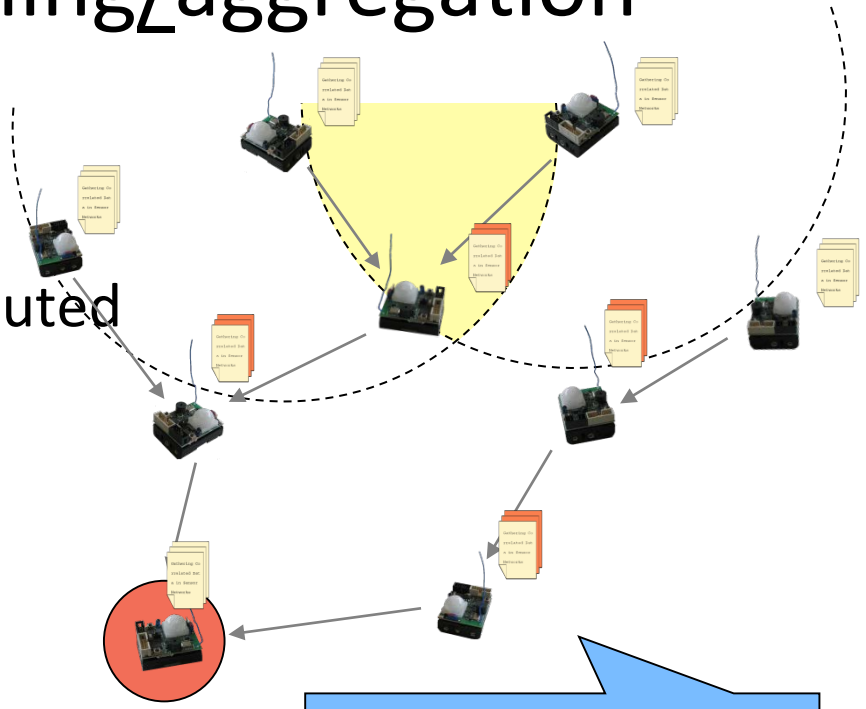


On which path is node u's data forwarded to the sink?

Routing

Processing/streaming/aggregation

… data can be processed as it is routed to the collector/aggregator (sink).



In-network aggregation/streaming/processing

Where/how is u's data processed?

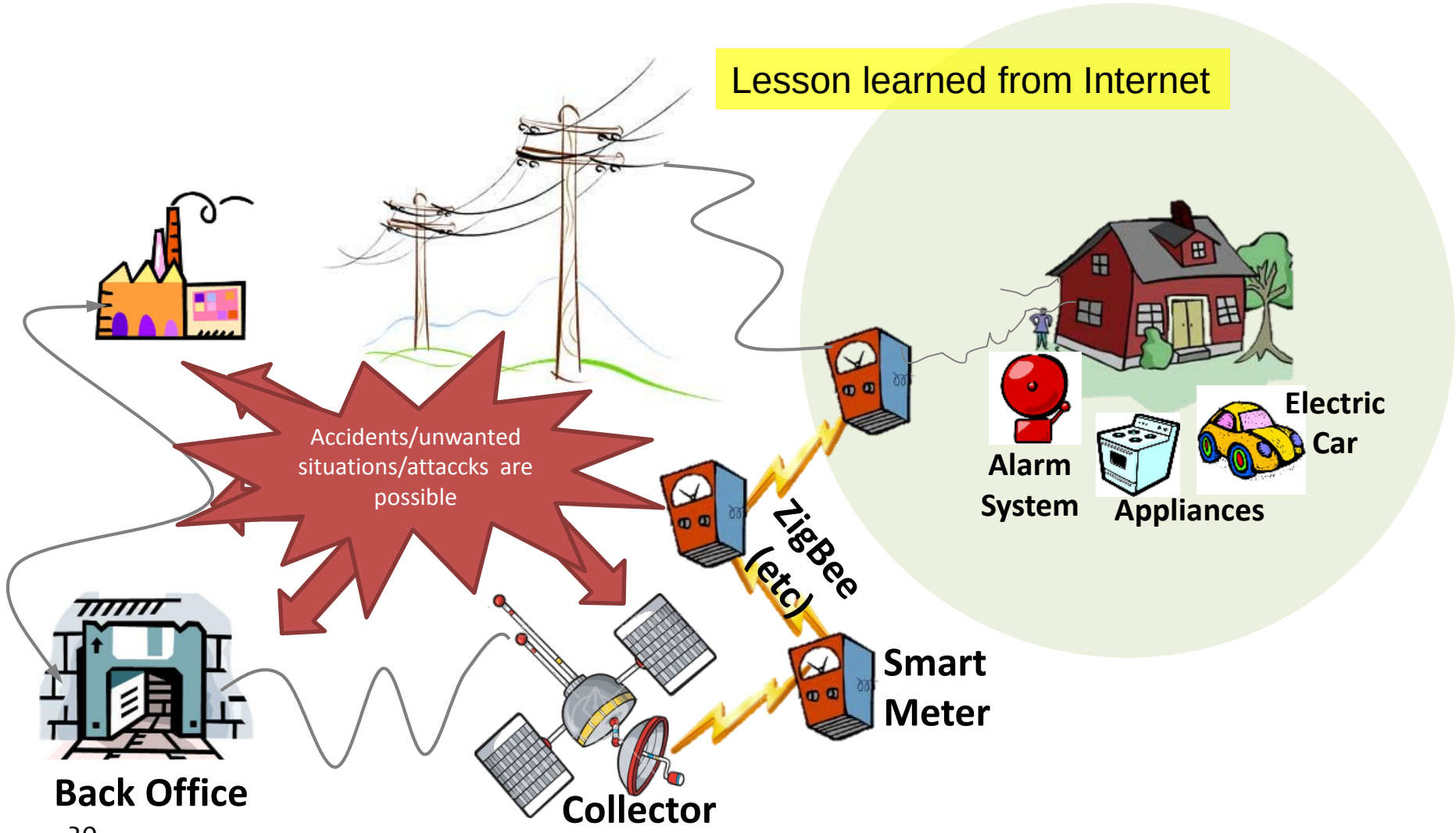
Work with routing, streaming, coding, processing schemes to deliver needed info to the sink (care also for privacy).

In the Power Grid cyber-layer

Selected topics:

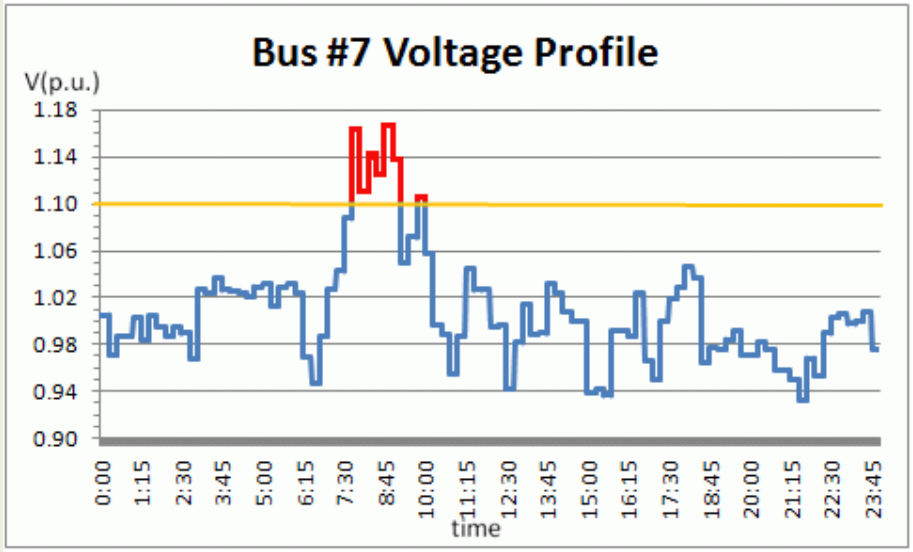
- Distributed resource management
- Communication, information
- Orthogonal issues: cyber-security
  - Extra important for overall system reliability

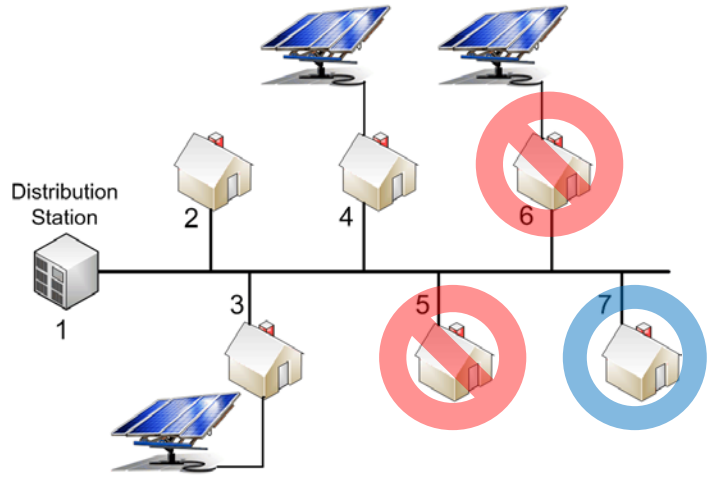
Imperative to address cyber security from the start



Cybersecurity aspects

- **E.g.**
  - Possible to destabilize parts of the system (-> blackouts) by inappropriate access to e.g. remote on/off possibilitiest
- Avoid the Internet examples of de facto standards
  - info-security from the start
  - Distributed/collaborative security methods can help to deal with scale



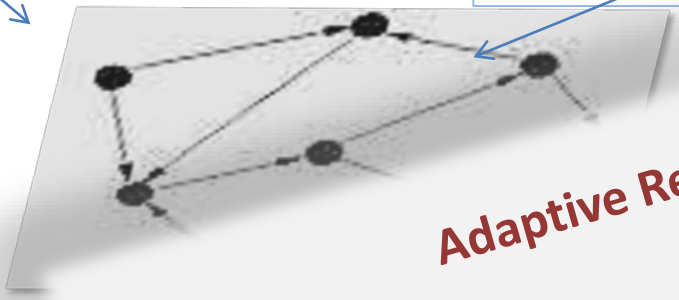


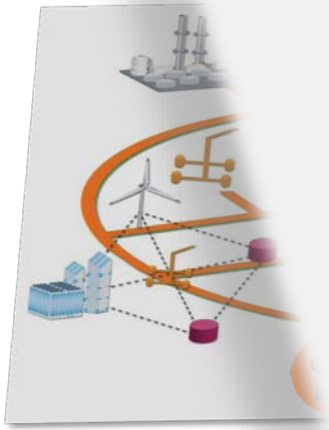
Reflecting ….

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

@NS division (approx 30 pers): Cyberphysical systems research

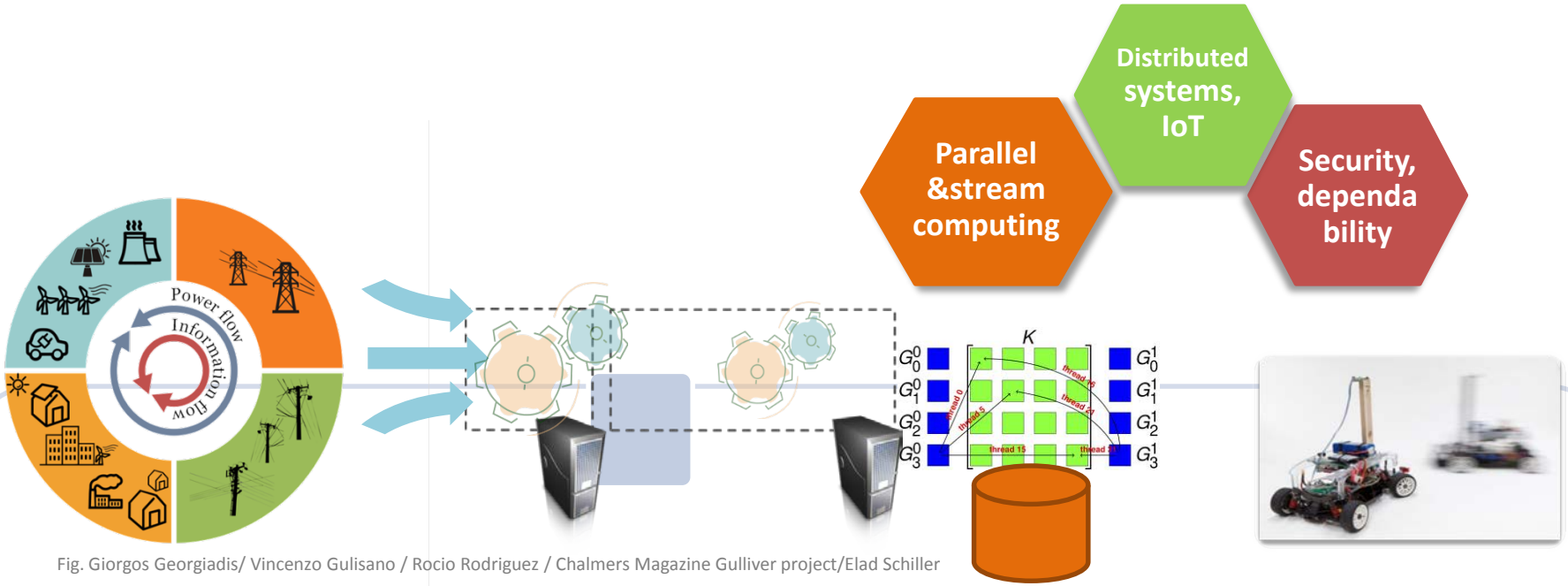


Fig. Giorgos Georgiadis/ Vincenzo Gulisano / Rocio Rodriguez / Chalmers Magazine Gulliver project/Elad Schiller

Energy, buildings, production

- data-driven distributed monitoring, resource planning
- Microgrids demo work

On-the-fly data processing & analysis

-Data validation, monitoring, …

-Security, privacy

Energy/efficient computation

- streaming , parallel/multicore computing, incl. on embedded processors

Vehicular systems

- data-driven situation-awareness
- communication &coordination, e.g. crossings
- Gulliver testbed

Other examples cyber-physical systems

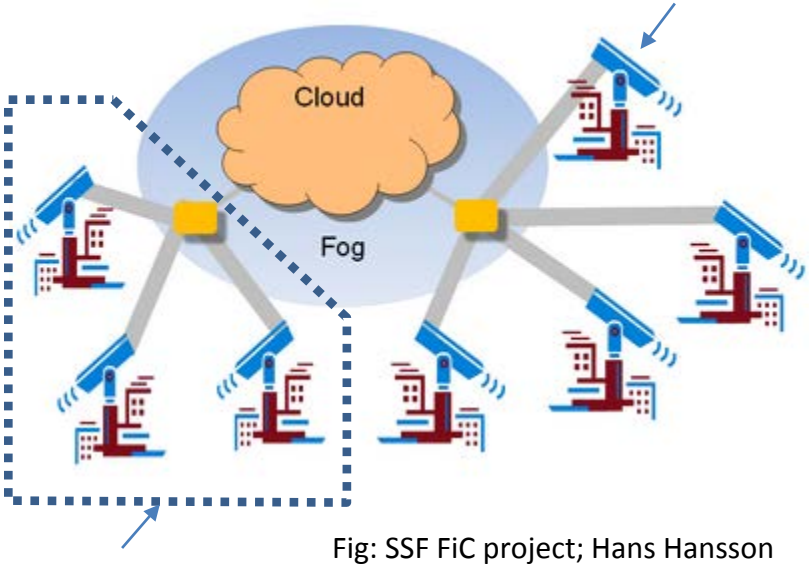
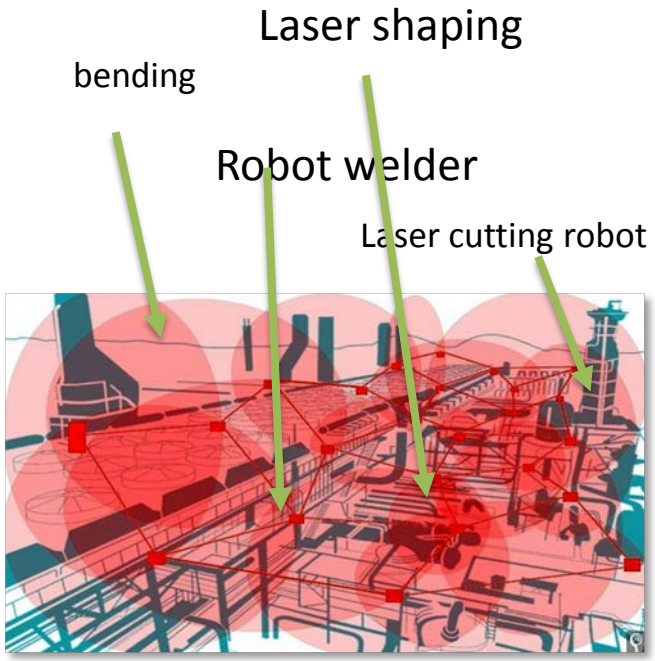
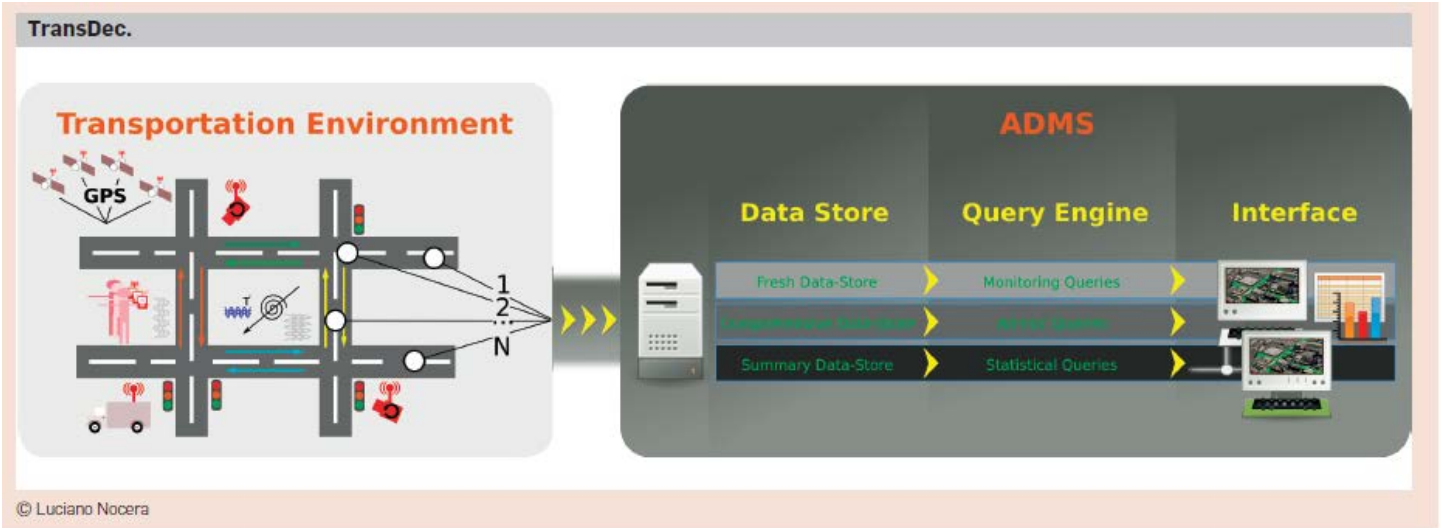


Fig: SSF FiC project; Hans Hansson





Example CPS data-processing ++: Distributed monitoring

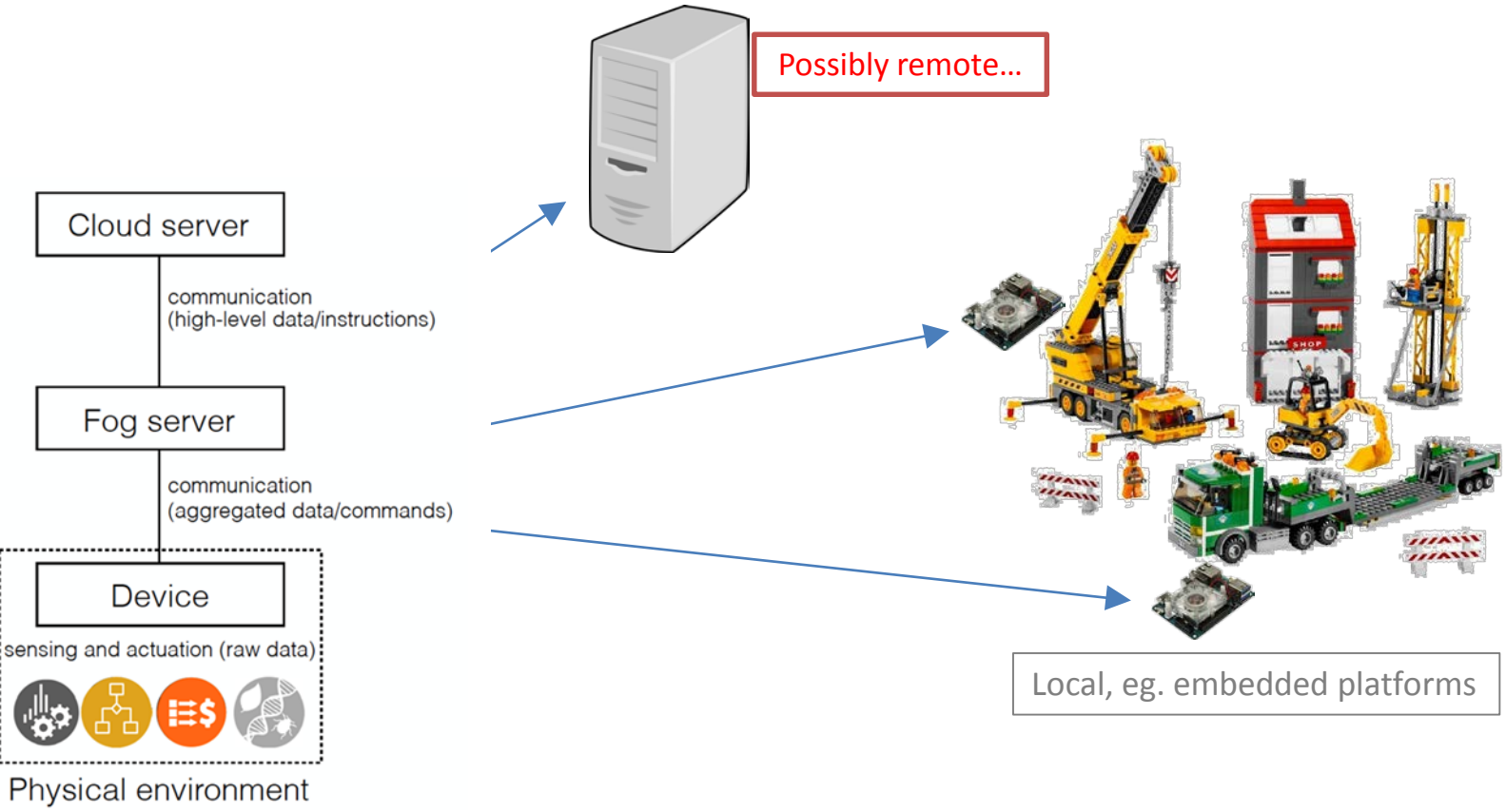
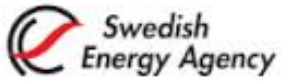


Fig: SSF FiC project; Hans Hansson

Recent&current related research project support @NS





CHALMERS AoA Building Futures, Energy, ICT, Transport

Faculty researchers responsible/involved:

Magnus Almgren

Vincenzo Gulisano

Olaf Landsiedel

Tomas Olovsson

Marina Papatriantafilou

Elad Schiller

Philippas Tsigas

In this course:

Topics:

- System perspective, eg adaptiveness, distributed resource management in electricity grids
- Enablers: Communication, Data processing
- Cyber-security

Structure, todo's:

- Projects
- Guest lectures by the supporting team + industry and related parties
- Self-study, projects and presentations

How?

- Cf *Administrative Details.pptx*

Cf examples from earlier projects @ the shared box folder

List of deadlines

- Projects
  - W1 Choose group + project
  - W2 Planning report + list of supporting papers (schedule, resources, goals)
  - W4 **(individually)** 1--2 pages: project + reflections; (team) outline of report
  - end Successfully complete project
    - Written report + demo & presentation
- Other reporting
  - Every week, write a **short** summary of what your team has done and if you **need our help.** → **BOX**