MasterClass on ICT Support for Adaptiveness and (Cyber)Security in the Smart Grid
DAT300, DIT668

Introduction:
Distributed Cyberphysical systems with the SG as example & Course Outline

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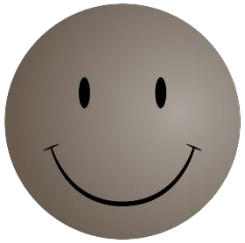
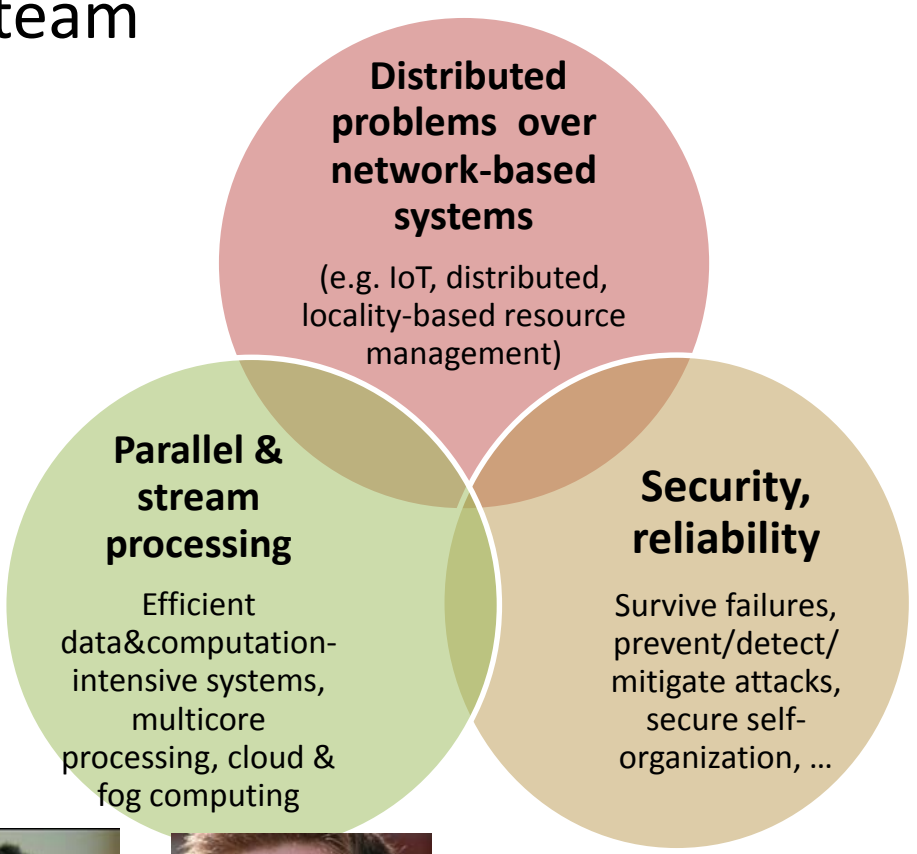
Briefly on research + education area of the supporting team



Babis Stylianopoulos

Valentin Tudor

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



Magnus Almgren

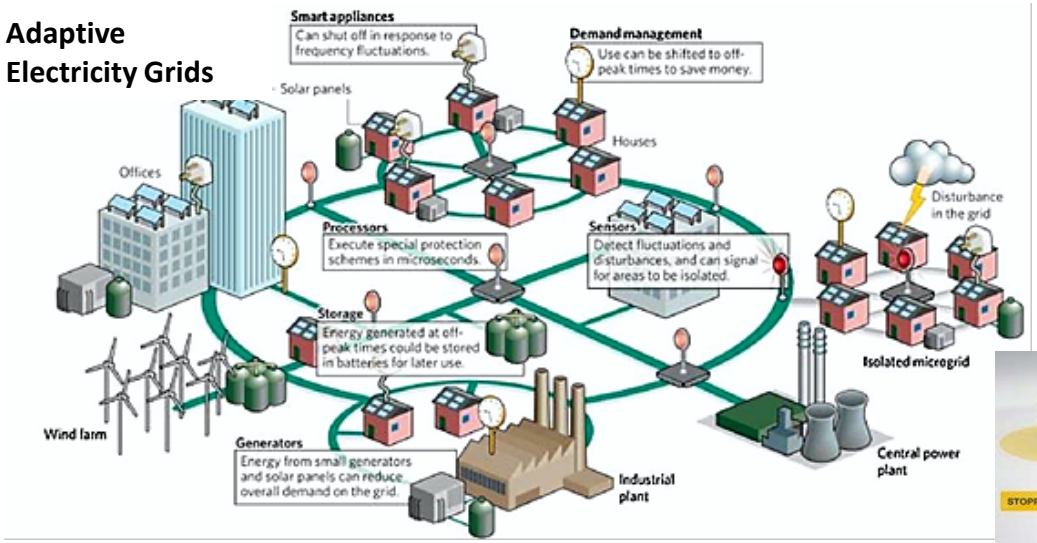
M. Papatriantafilou

Vincenzo Gulisano

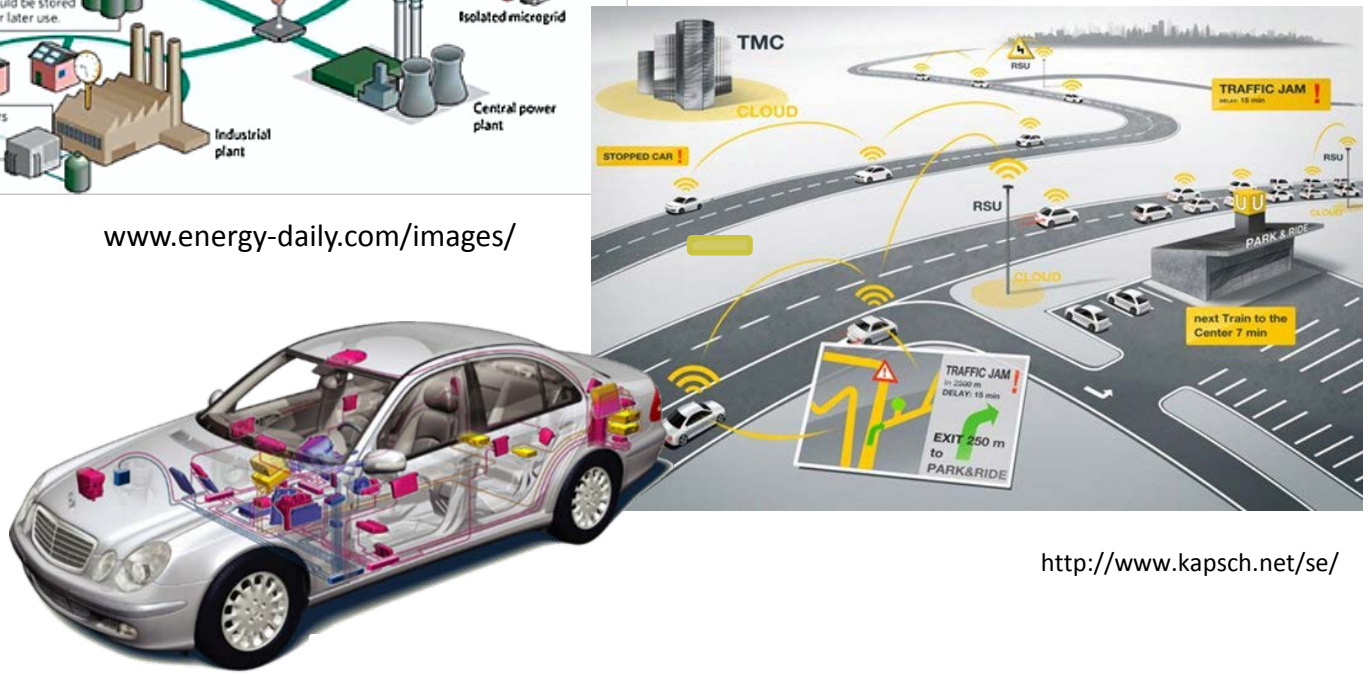
Olaf Landsiedel

Examples Cyber-Physical Systems (CPS)

Adaptive Electricity Grids



www.energy-daily.com/images/



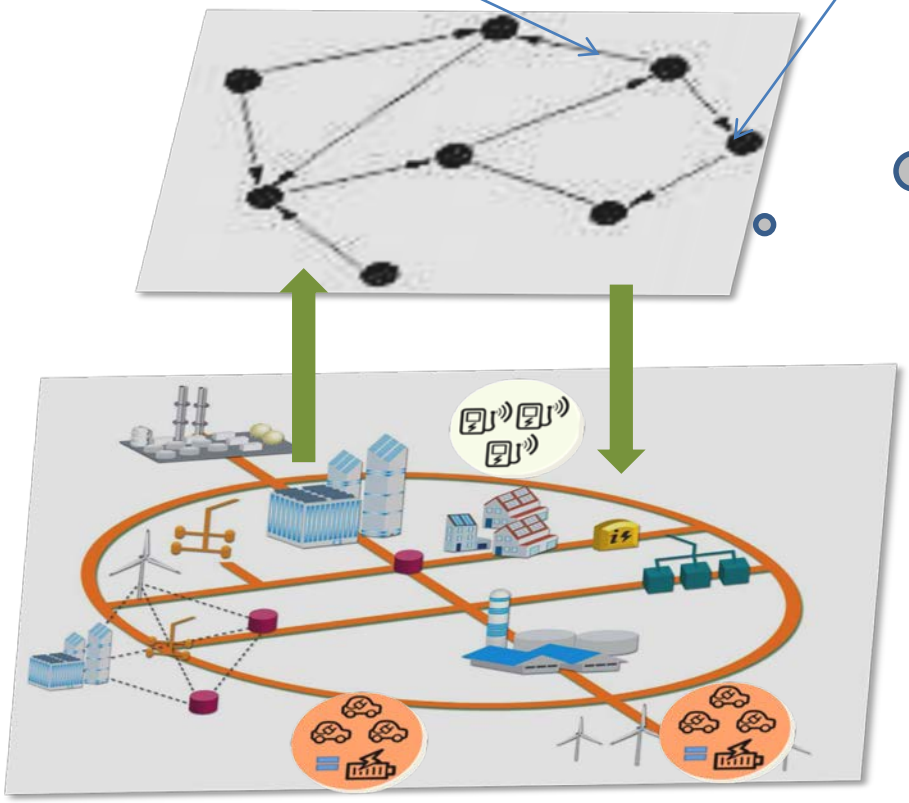
http://www.kapsch.net/se/

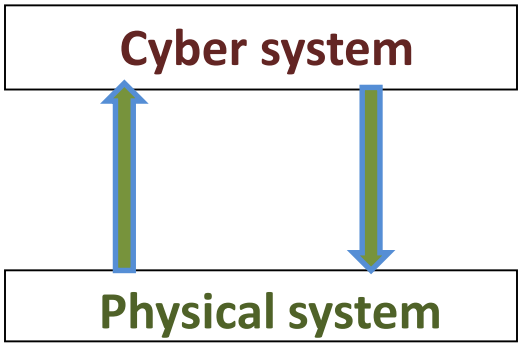
Cyberphysical systems as layered systems

communication link

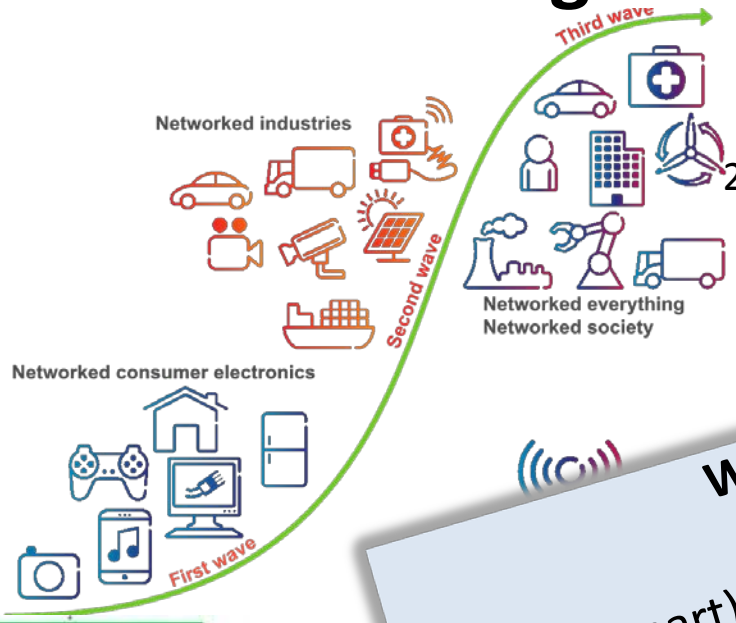
Sensing+computing+
communicating device

aka Internet-of-Things (IoT)





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

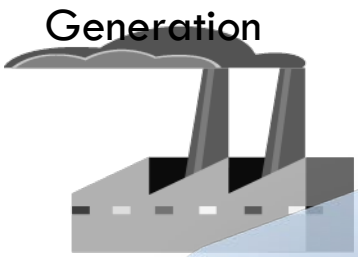


2020: More than 50 Billion connected devices [Ericsson, Cisco]

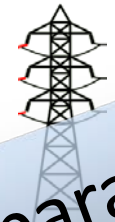
Why this complexity?

(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…

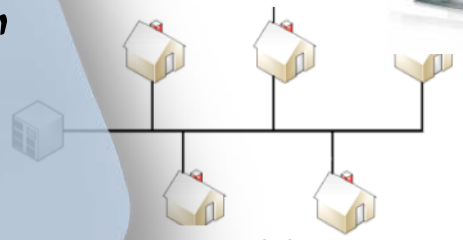


Dispatchable Sources



Transmission

Distribution



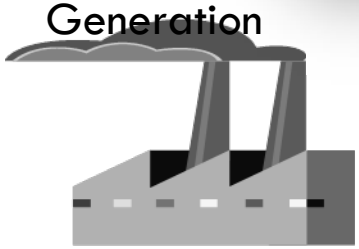
Oblivious Loads

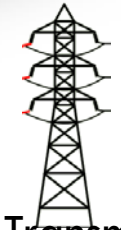
paradigm shift:
…from pre-planned "broadcasting"
to adaptive scheduling

…while in the greener El Grid

+ aware, Interactive loads

+ non-dispatchable, distributed sources



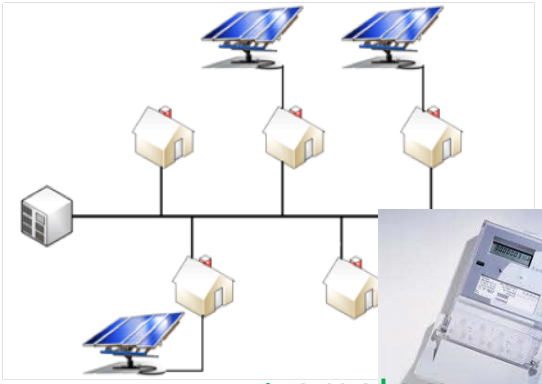


Transmission

Distribution

Dispatchable Sources

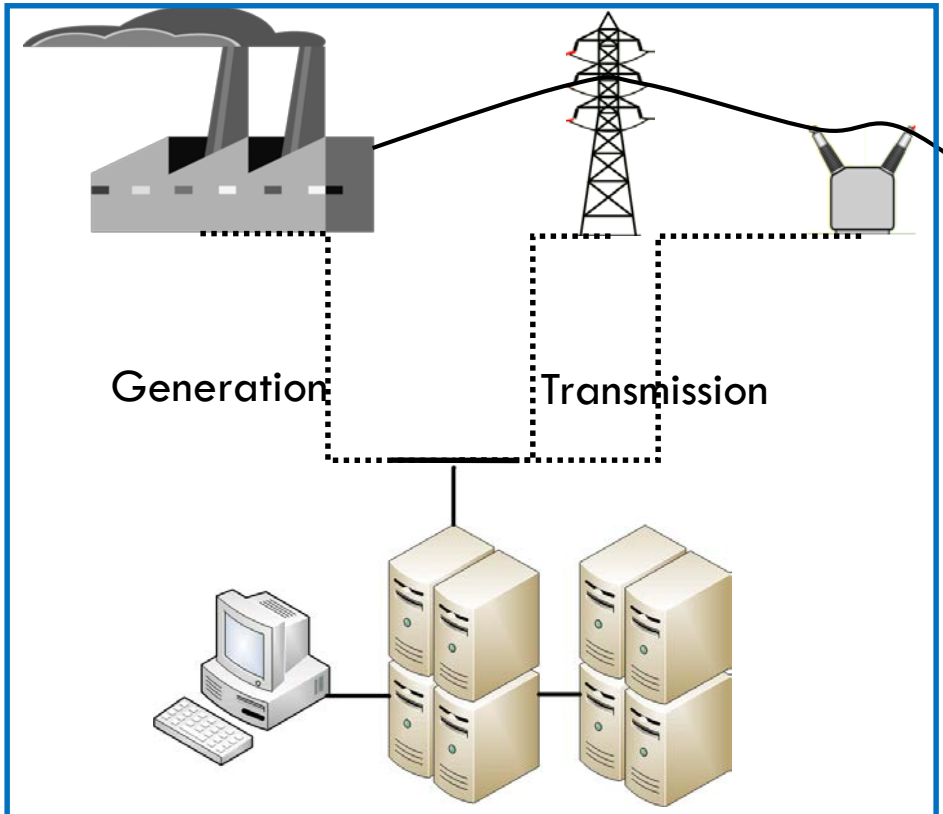
info, communication, computation



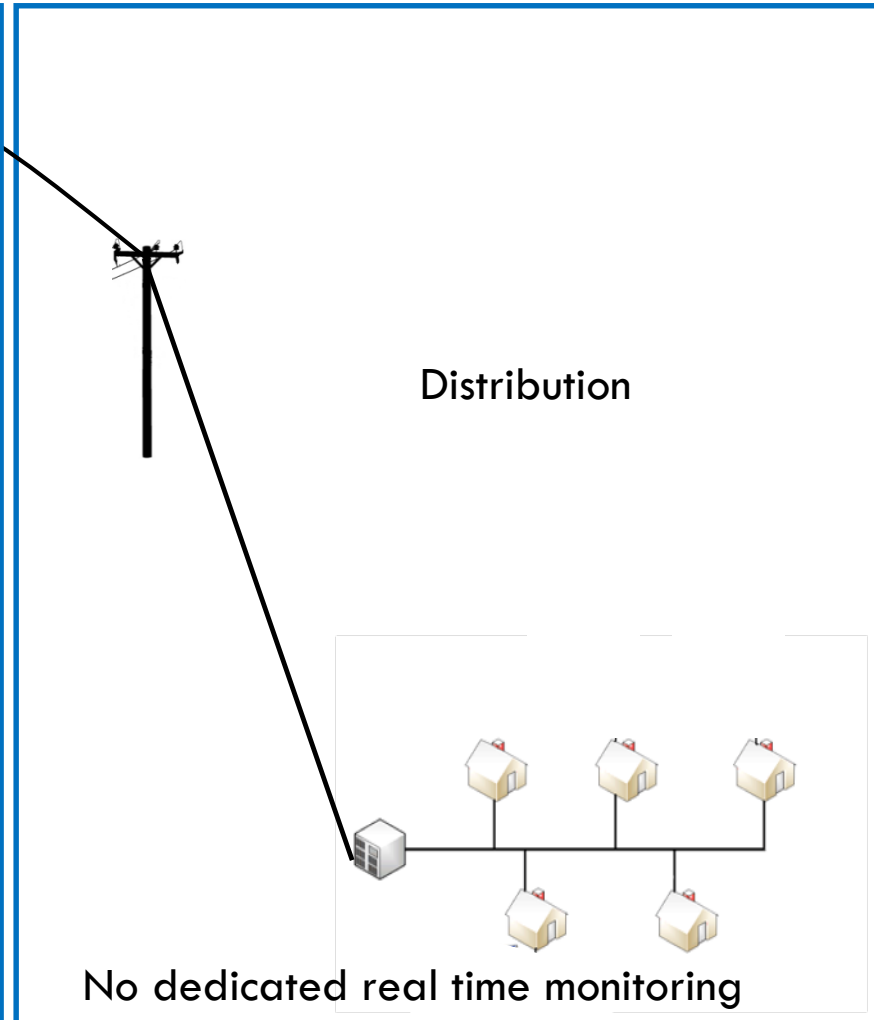
+ emeters

Zooming into an el-network

The traditional Electrical Grid



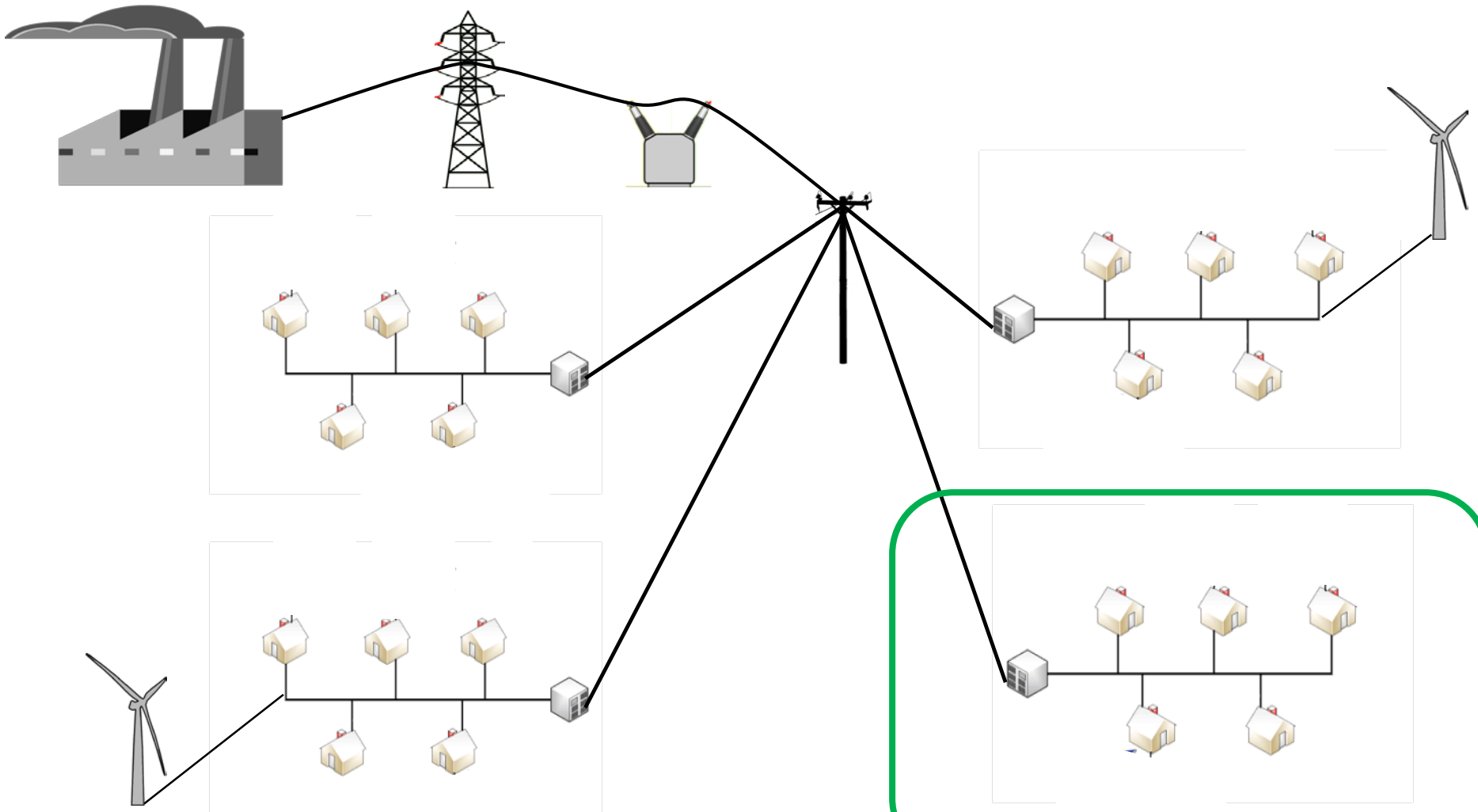
Managed and monitored by the SCADA system.



No dedicated real time monitoring system (yet).

Pic. V. Tudor

From centralized to distributed generation



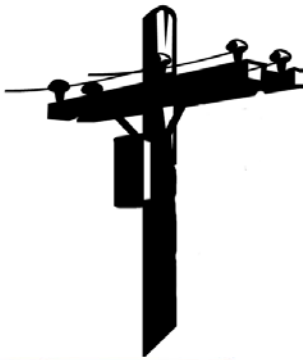
Pic. V. Tudor

Power Island

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

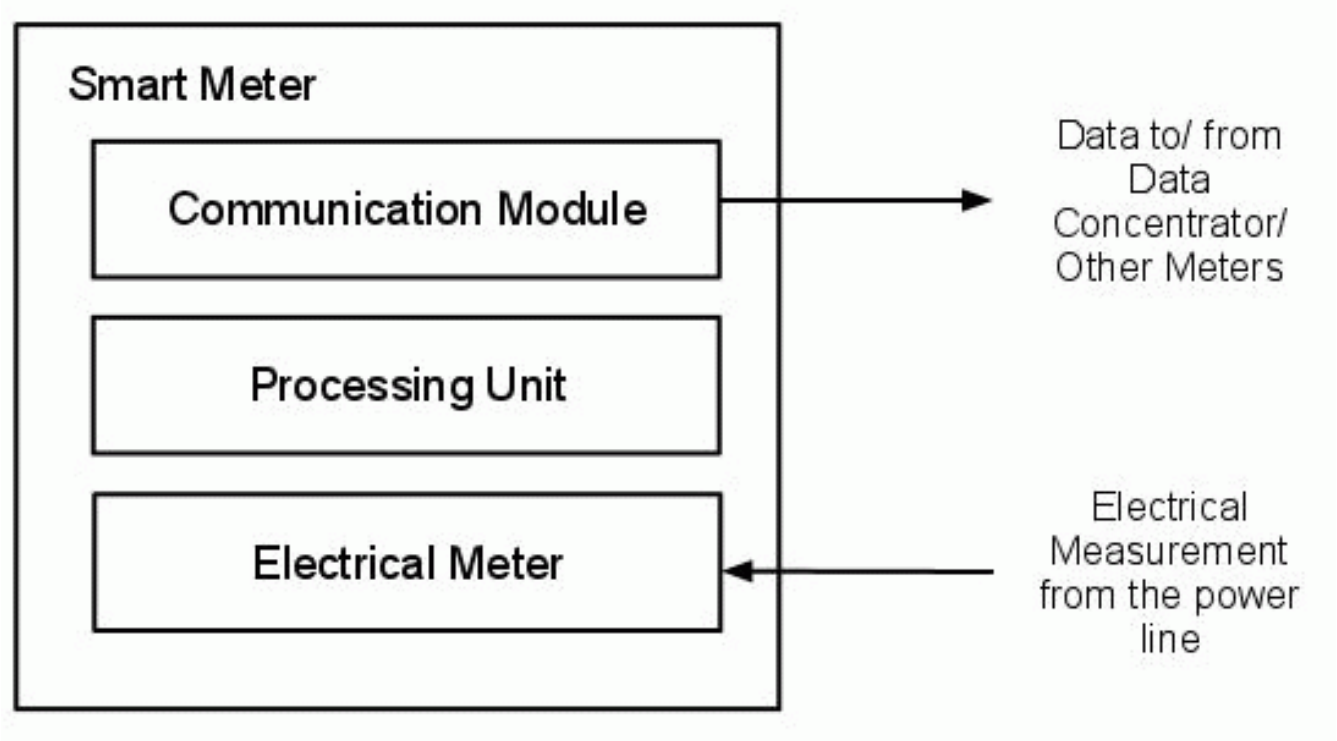
A “Smart” Meter:

- 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



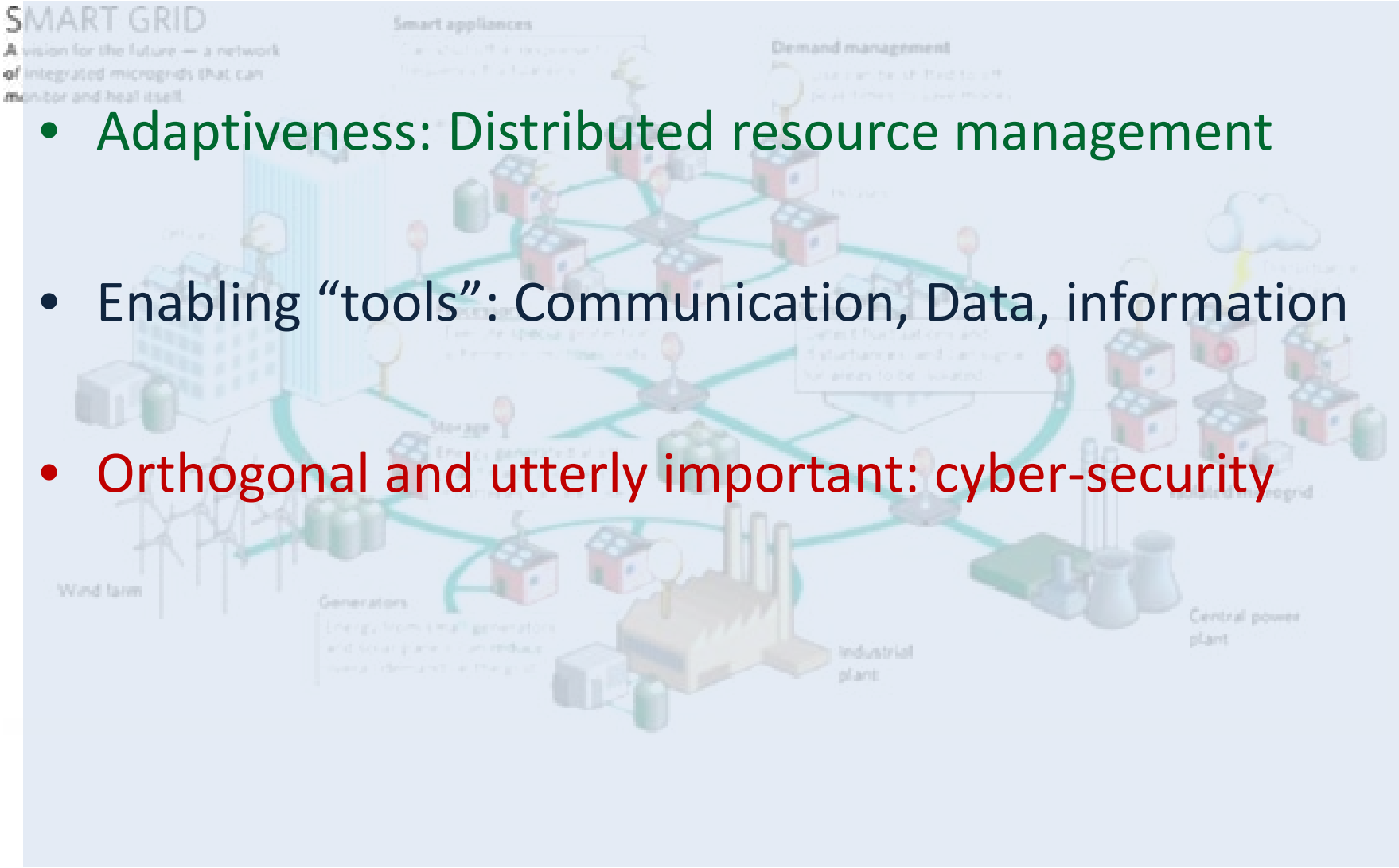
Pic. V. Tudor

Smart Meter components



Pic. V. Tudor

In the CPS cyber-layer / Basic topics in the course



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

In the CPS cyber-layer

Basic topics in the course:

- 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

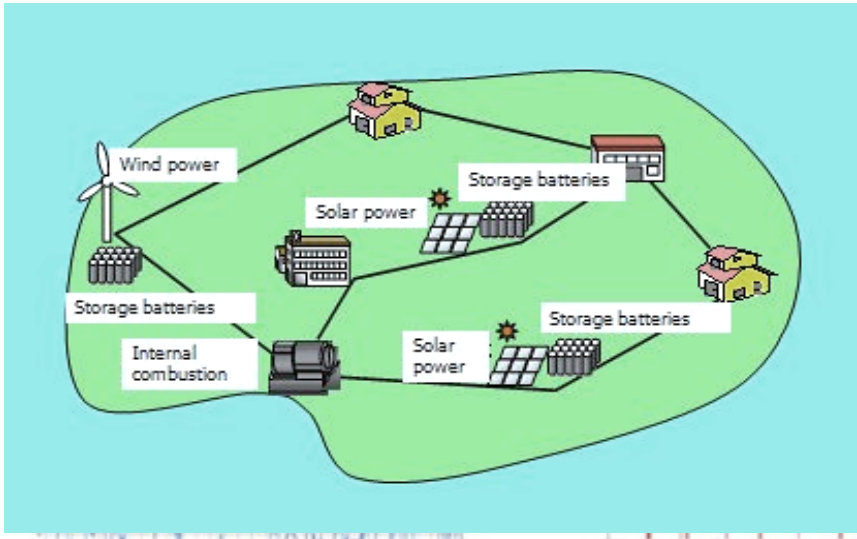
Problem: Fine-grained align supply & consumption; continuous decisions based on info on load, availability, constraints, possibilities ((non)shiftable load, thermal or other storage…)

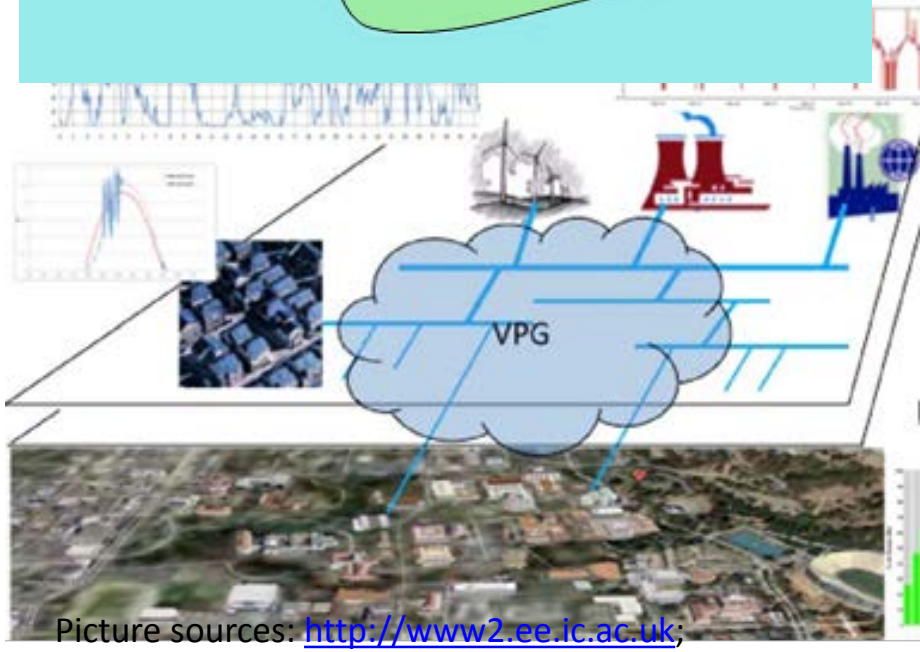
Vision for microgrids

for better use of renewables: Virtual Private Grids/microgrids

- communicating supplies and loads
- cooperating for 0-net energy or mixed use of renewable and other sources
- adaptive loads, to draw power when renewables provide it

- ie connect to the aforementioned methods are for, plus
  - **Power routing** and aggregation
  - **Info needed!**





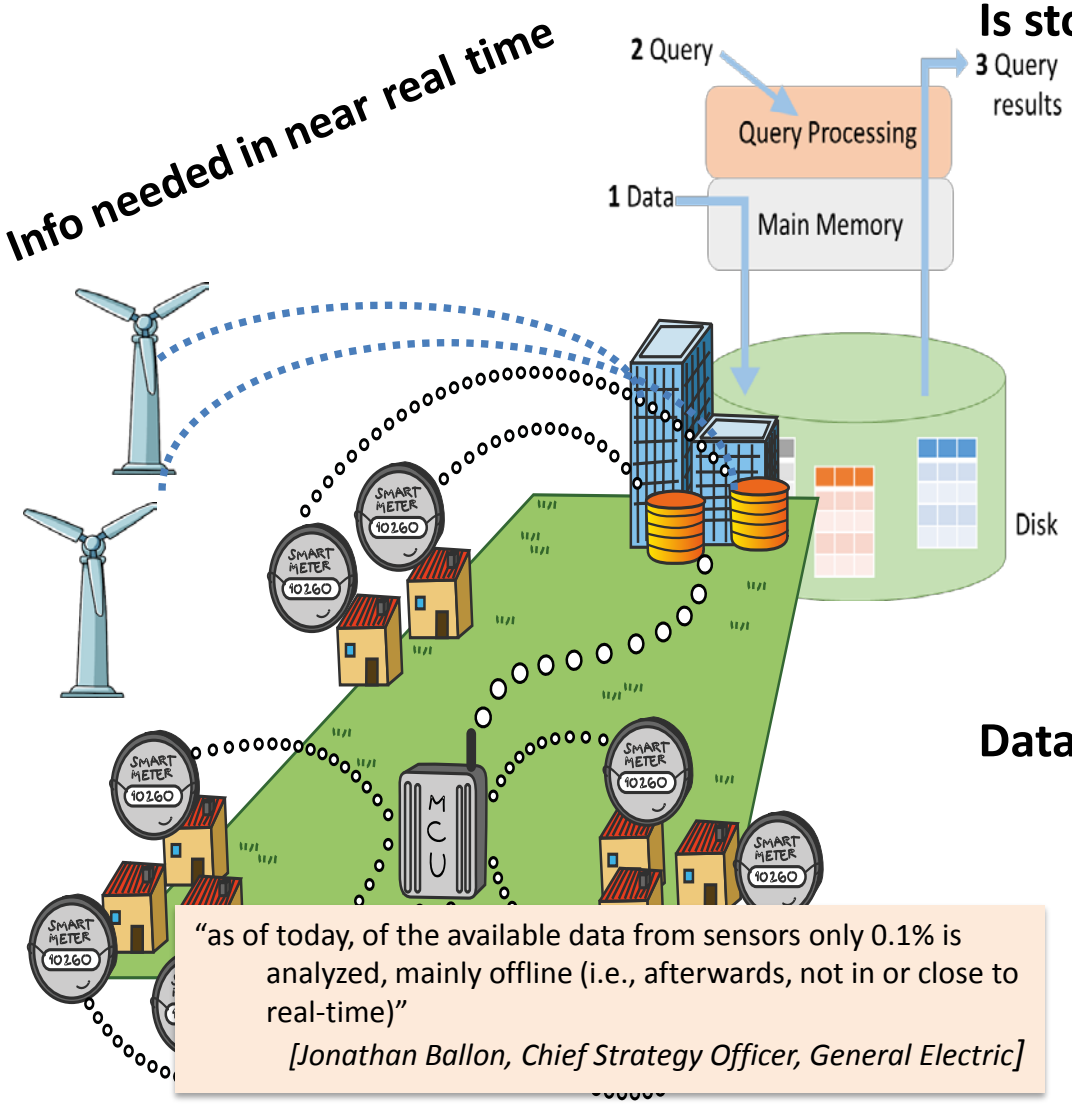
Picture sources: http://www2.ee.ic.ac.uk; Katz etal, Sustainable computing, 2011

In the CPS cyber-layer

Selected topics:

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

Information&Communication, Advanced Metering Infrastructure



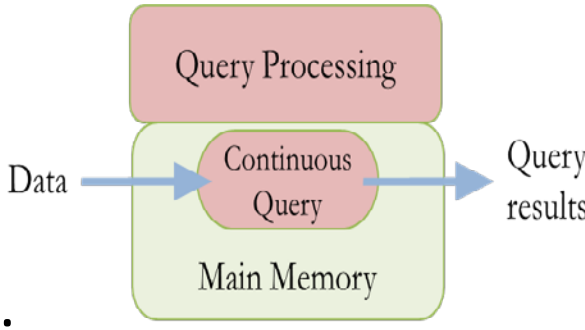
"as of today, of the available data from sensors only 0.1% is analyzed, mainly offline (i.e., afterwards, not in or close to real-time)"

[Jonathan Ballon, Chief Strategy Officer, General Electric]

fig: V. Gulisano

Is store&process (DB) a feasible option?

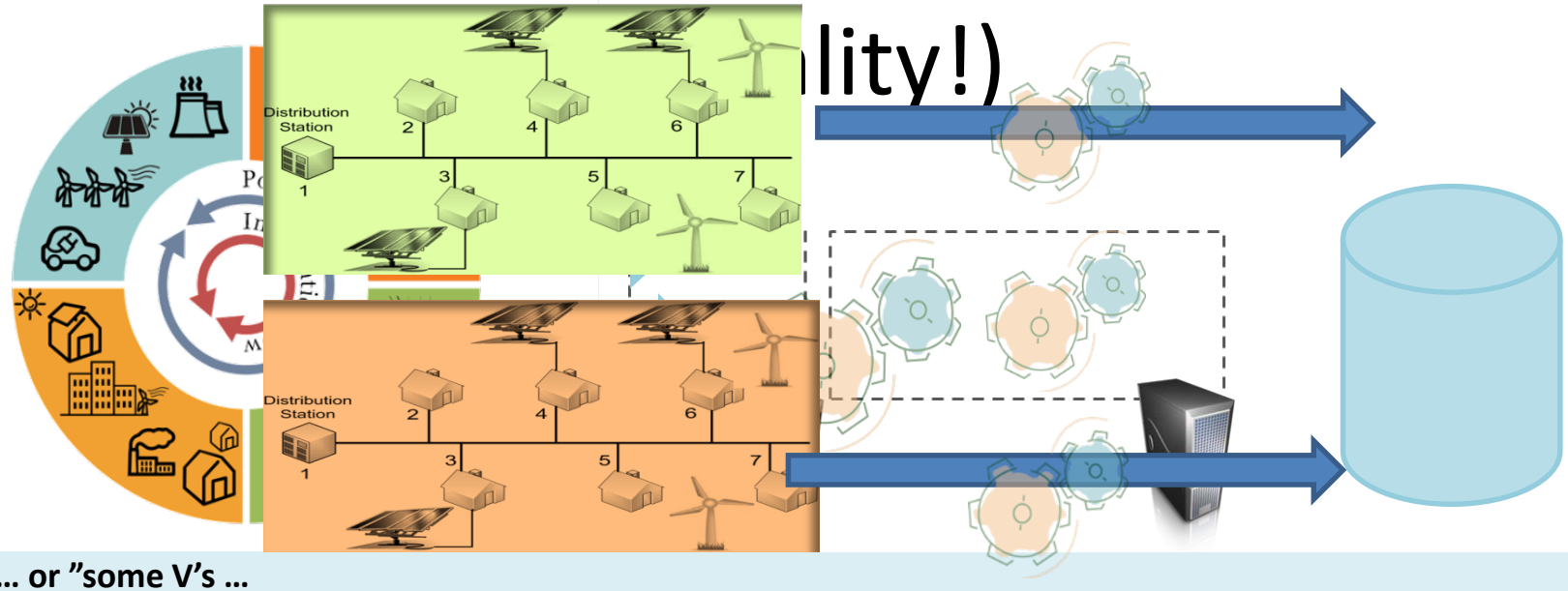
- high-rate sensors, high-speed networks, soc. media, financial records: up to Mmsg/sec; decisions must be taken **really fast** e.g., fractions of msec, even µsecs.



Data Streaming:

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

… system: Big! … data: Big! (but: lity!)



… or "some V's …

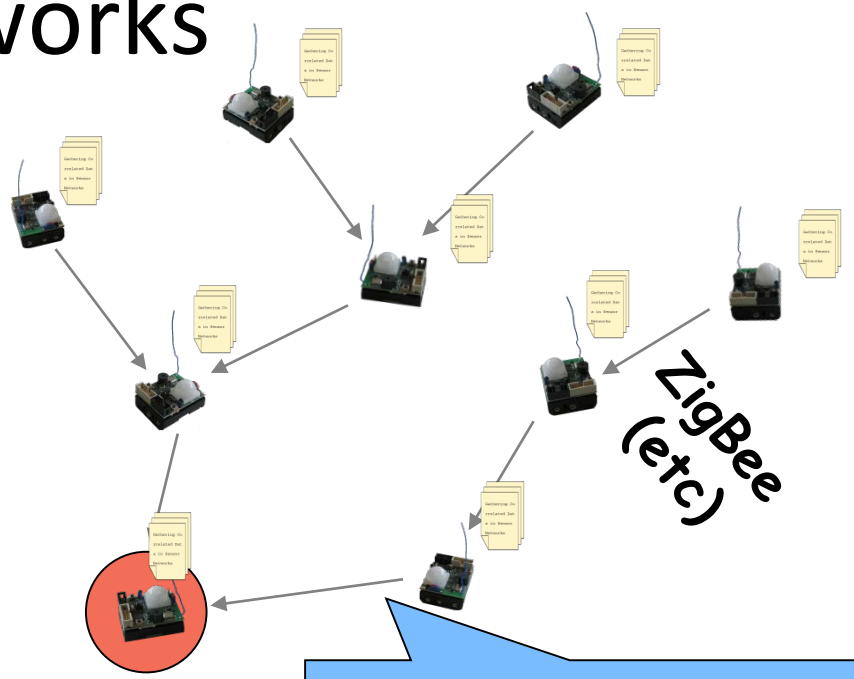
- Volume: terabytes – peta/exa/zetabytes — *i.e. BIG!*
- Velocity: streams — *Good! Process on-the fly can eg filter peta+bytes to megabytes*
- Variety: various types of data … — *with various relevance domains; good!*

… 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.
- ….

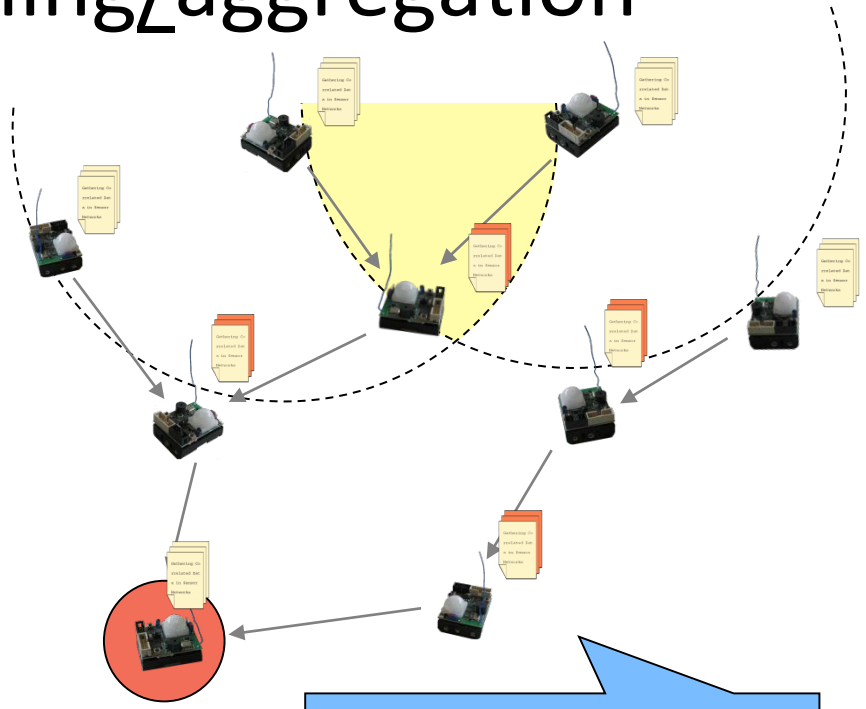


On which path is node u's data forwarded to the sink?

Routing

Processing/streaming/aggregation

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



Where/how is u's data processed?

➡ In-network aggregation/streaming/processing

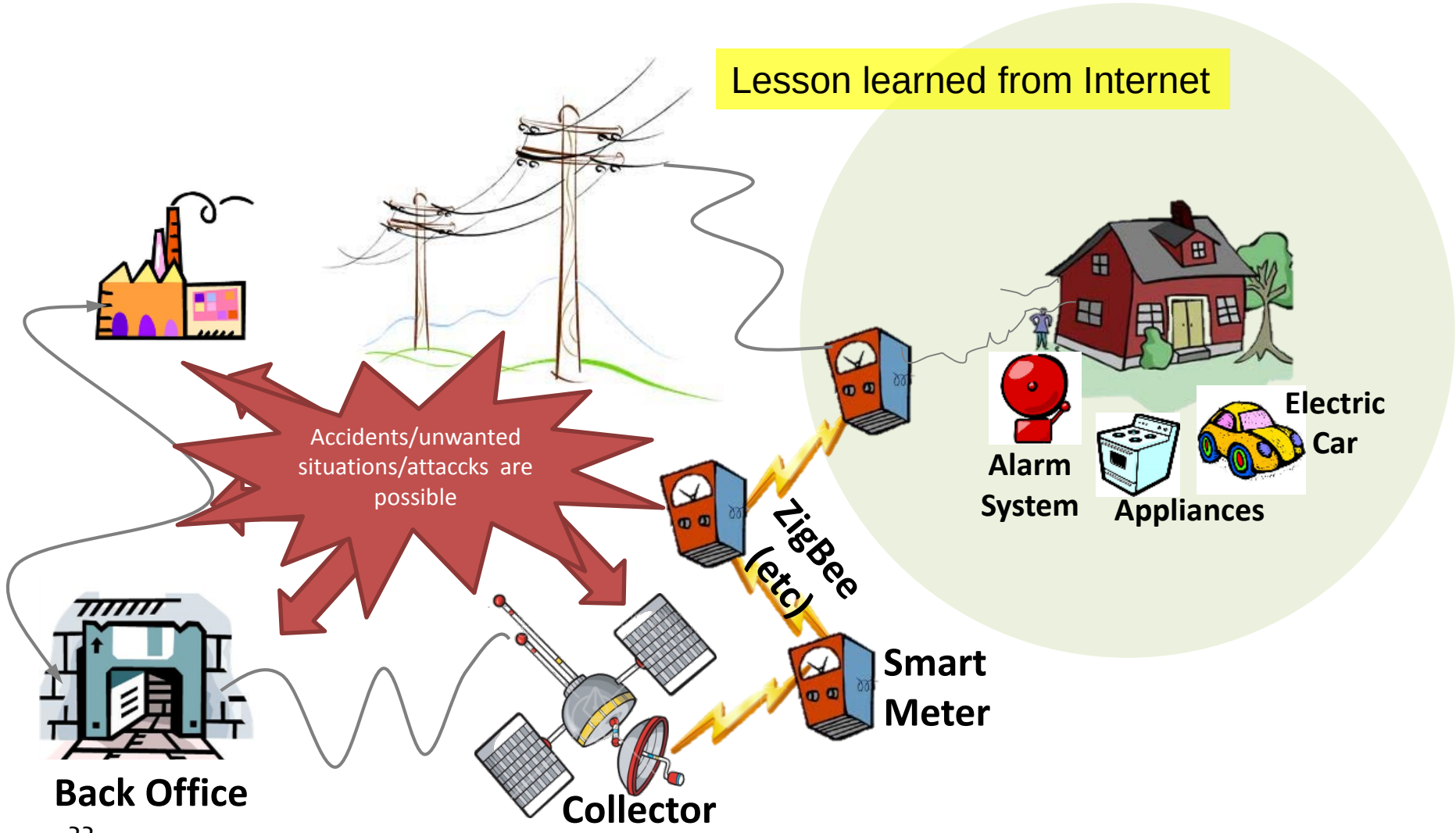
Work with routing, streaming, coding, processing schemes to deliver needed info to the sink (care also for privacy).

In the Power Grid cyber-layer

Selected topics:

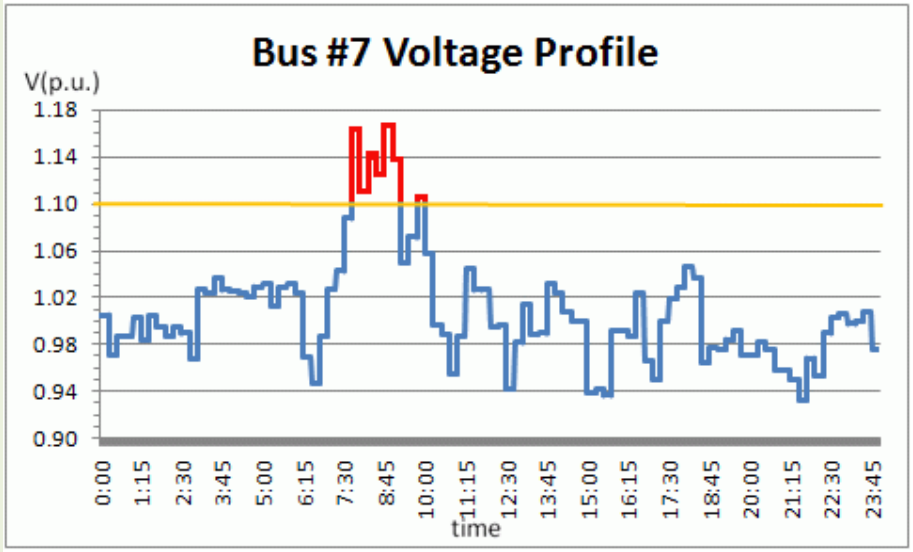
- Distributed resource management
- Communication, information
- Orthogonal issues: cyber-security
  - Extra important for overall system reliability

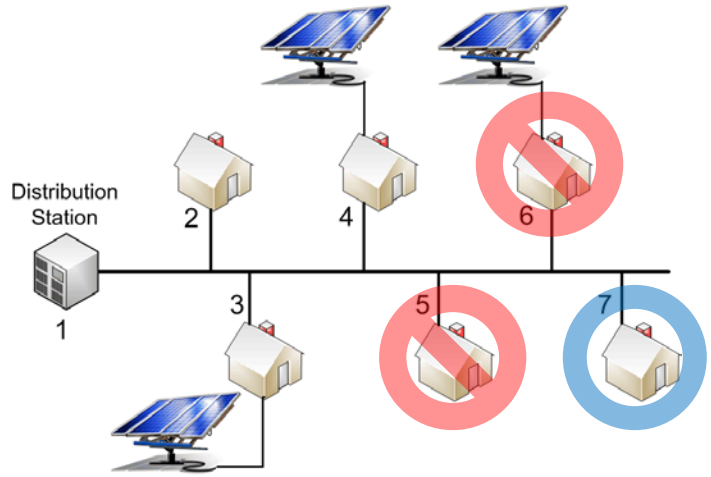
Imperative to address cyber security from the start!



Cybersecurity aspects

- **E.g.**
  - Possible to destabilize parts of the system (-> blackouts) by inappropriate access to e.g. remote on/off possibilities [TKAPS11]
- Avoid the Internet examples of de facto standards
  - info-security from the start
  - Distributed/collaborative security methods can help to deal with scale



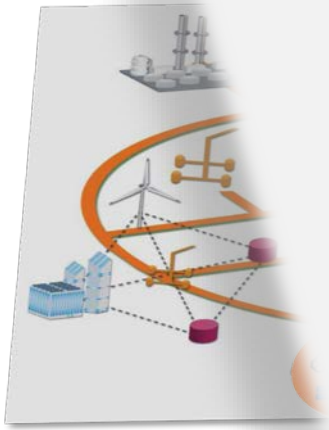


Reflecting ….

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 …**

Distributed approach & parallelism

for solving problems locally & keeping up with scale

Relevance for research and education?

- large investments
- off-the-shelf info/software solutions are not there

- careful, informed, multidisciplinary expertise needed in deployment
- cf. lessons learned from Internet

- Distributed computing and systems and Security in the core of the cyberphysical infrastructure

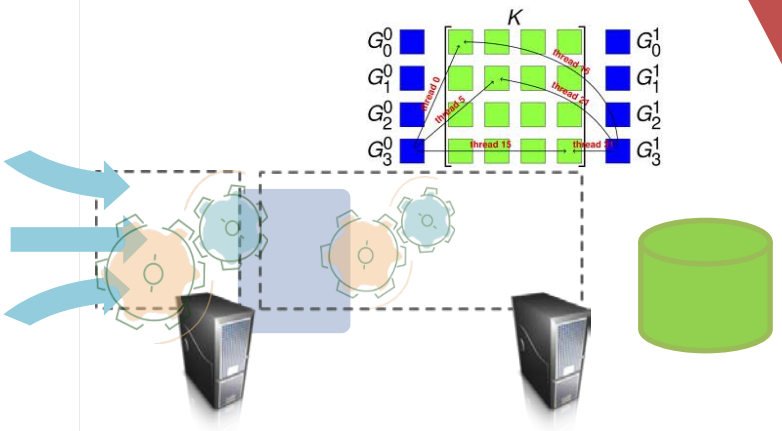
At our research team (approx 30 pers):

Cyberphysical systems research

Systems Security

Distrib. systems, IoT

Parallel &stream processing



Demand-response in energy

- Resource management, load shaping
- Microgrids demo/ testbeds

Data – Security - Internet of Things

-Data processing: validation, monitoring, prediction

-Security, privacy in critical infrastructure

- Energy efficient networking

Energy/efficient data processing

- streaming , parallel, multicore, big/fast data processing

- energy efficiency : estimated savings 30-70%

Cooperative vehicular systems

- Communication &coordination,
- data-driven situation-awareness (new postdoc SAFER)
- Virtual traffic-lights/safer crossings
- Gulliver demo/testbed

In this course:

Topics:

- Adaptiveness: Distributed resource management
- Enablers: Communication, Data processing
- Cyber-security

Structure, todo's:

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

How?

- Cf *Administrative Details.pptx*

Course/Masterclass: ICT Support for Adaptiveness and Security in the Smart Grid (DAT300)

- Goals
  - students (from computer science and other disciplines) get introduced to advanced interdisciplinary concepts related to the smart grid, thus
  - investigating a domain-specific problem relevant to the smart grid that need an understanding beyond their traditional fields.

Idea

- Based on both the present and future design of the smart grid.
  - How can techniques from distributed systems be applied to large, heterogeneous systems where a massive amount of data will be collected?
  - How can such a system, containing legacy components with no security primitives, be made secure when the communication is added by interconnecting the systems?
- The students will have access to a hands-on lab, where they can run and test their design and code.

Research projects' support & collaboration