The “Smart” Grid as Distributed Cyberphysical system

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A Distributed System

A set of computing and communicating processes, collaborating for achieving local and/or global goals
A Distributed System

Figure: Computer Networking: A Top Down Approach, Jim Kurose, Keith Ross, Addison-Wesley.
A Distributed System

A Distributed System
A Distributed System

A Distributed Cyberphysical System

![Diagram of a smart grid](http://www.energy-daily.com/images/smart-grid-electricity-schematic-bg.jpg)
El-networks as distributed cyber-physical systems

Overlay network

El- link and/or communication link

Computing+ communicating device

Cyber system

Physical system
An analogy: layering in computing systems

Similarties: provide services; shield from hardware/system details; manage resources

Differences: system/”hardware”; distributed, nodes can use only neighborhood knowledge; critical infrastructure!!
In the Power Grid cyber-layer

Selected topics:

• Distributed resource management

• Data, information

• Orthogonal issues: cyber-security
In the Power Grid cyber-layer

Selected topics:

• Distributed resource management
  – Demand-side management: load balancing, load shifting (users)
  – Routing, aggregation (network)

• Distributed sources & processing of information

• Orthogonal issues: cybersecurity
On demand-side management
household/neighborhood-scale and more

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

Collaboration with G. Georgiadis
Interaction with C. Saunders, T. Le, L. Bertling
Distributed balancing with real-time info

Autonomy & collaboration: demand-side management
- Match availability (renewables), reduce peaks
- Each agent makes its own decisions using local information
  eg. Via Zigbee/Z-wave/etc-enabled local network “smart”-equipment;

Adaptability/responsiveness
- Reduce need for overprovisioning, smart cities, EVs; self-healing

Paving the way to microgrids

Collaboration with G. Georgiadis
Interaction with C. Saunders, T. Le, L. Bertling, EoN
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 what the aforementioned methods are for, plus
  - network overlays (over AMI mesh, e.g. [GP10, GP12])
  - Power routing ([NKGPLB10] and/or aggregation
  - Information!....

Picture sources: [http://www2.ee.ic.ac.uk](http://www2.ee.ic.ac.uk);
Katz et al. Sustainable computing 2011
In the Power Grid cyber-layer

Selected topics:

• Distributed resource management

  Data, information
  – Distributed sources & processing
  – Monitoring, facilitating resource services

• Orthogonal issues: cybersecurity
Information, Advanced Metering Infrastructure

Local (info aggregation) “agents” can

- Make sense out of data
- Manage info flow, influence power/energy distribution
- Monitor

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- Database
- Collector
- Electric Car
- Smart Meter
- ZigBee (etc.)
Distributed Computing and Information/Communication

- Aggregate at different hierarchy levels, for
  - Scalability [ES10]
  - Parallelism for massive data [GPT10,ST05]
- Distributed methods for data-network reliability [GKPT05]

CSE team, interaction with Göteborg Energi
In the Power Grid cyber-layer

Selected topics:

• Distributed resource management

• Distributed sources & processing of information

• Orthogonal issues: cyber-security
  • Extra important for overall system reliability
Imperative to address cyber security from the start! [F10]
Cybersecurity aspects

- **Case studies**
  - Possible to destabilize parts of the system by inappropriate access to e.g. remote on/off possibilities

- Careful ICT analysis needed

- Distributed system methods can help prevent/detect/mitigate malicious attempts

Collaboration with M. Almgren, M. Costache, V. Tudor

Interaction with C. Saunders
Cyber security and distributed information processing

- Recall aggregation at different levels + parallelism:
- Can also apply for data anonymization [CT11], privacy, localization & mitigation of intrusion [ALJ08, FPT11], energy theft

Unwanted/malicious attempts are possible

Collaboration with M. Almgren, V. Tudor

cf poster
Strategic relevance?

“... area of strategic importance ... advances fast, technologically & commercially...

Cisco expects the Smart Grid communication network will be 100 eller 1000 times larger than the Internet”

[Vinnova, ”SmartaNät” 2011] and references therein

“... any security vulnerability within this software-intensive critical system will attract attention from hostile groups ...”

[MSB, “If one goes down all goes down?”, 2010]
Strategic relevance - Conclusions

- Area of strategic importance ... advances fast, technologically & commercially...
- Cisco expects the Smart Grid communication network will be \( 100 \) or \( 1000 \) times larger than the Internet

- Any security vulnerability within this software-intensive critical system will attract attention from hostile groups ...

- 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 in the core of the cyberphysical infrastructure

Cf also Katz et-al, An information-centric energy infrastructure:
The Berkeley view; J. Sustainable computing, 2011
Thank you

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• Vetenskapsrådet, SSF, EU FP7

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