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Adaptive monitoring and information access for network resource effective smart grid control

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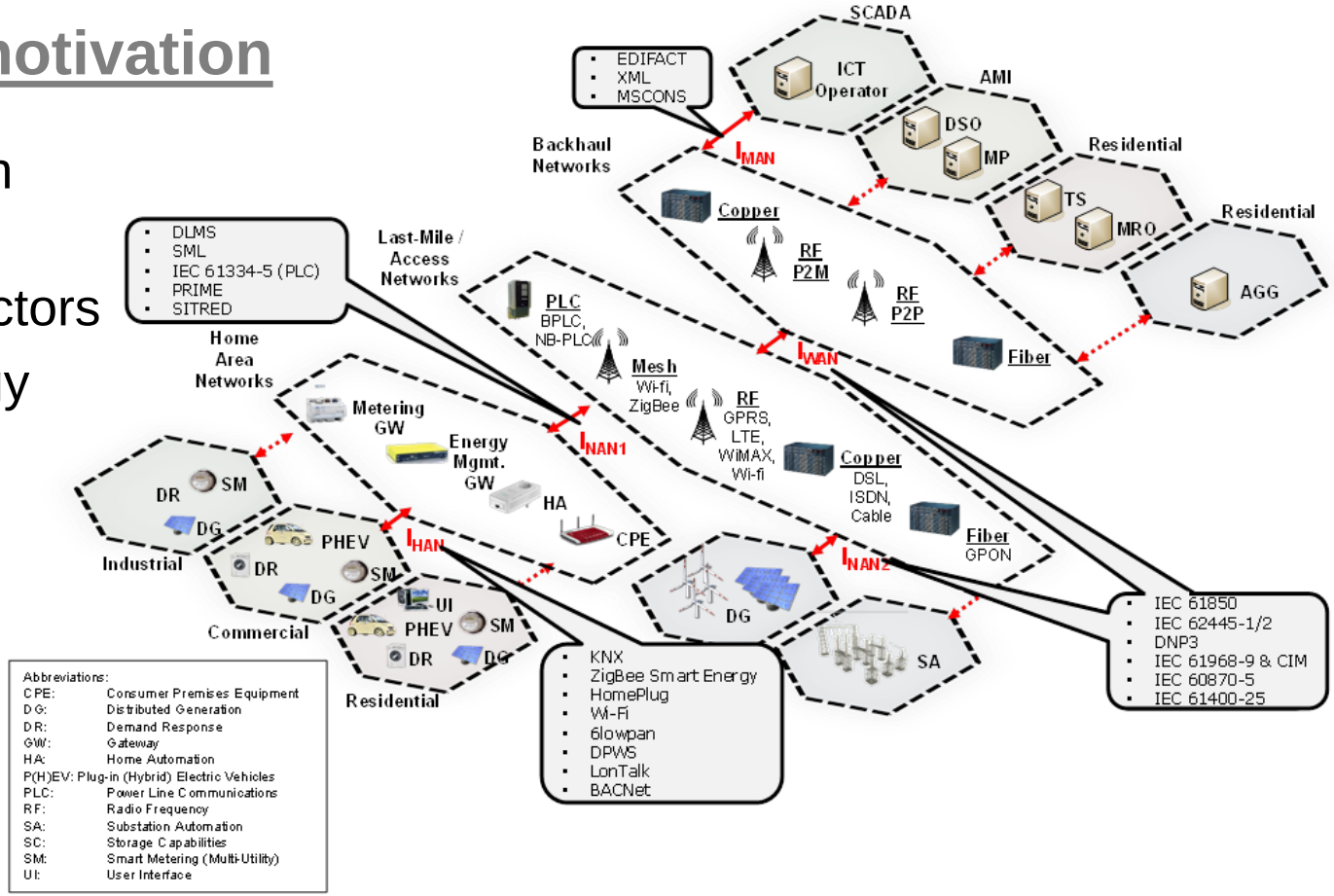
Background and motivation

- Several use cases in future smart grids
  - many different actors
  - renewable energy resources
  - use of existing communication networks
- ➢ Many interests in monitoring the grid



- Complex Network Architectures with many protocols
  - Complex information flow management
  - Hard to ensure reliable data transport
  - Exposed to cyber attacks

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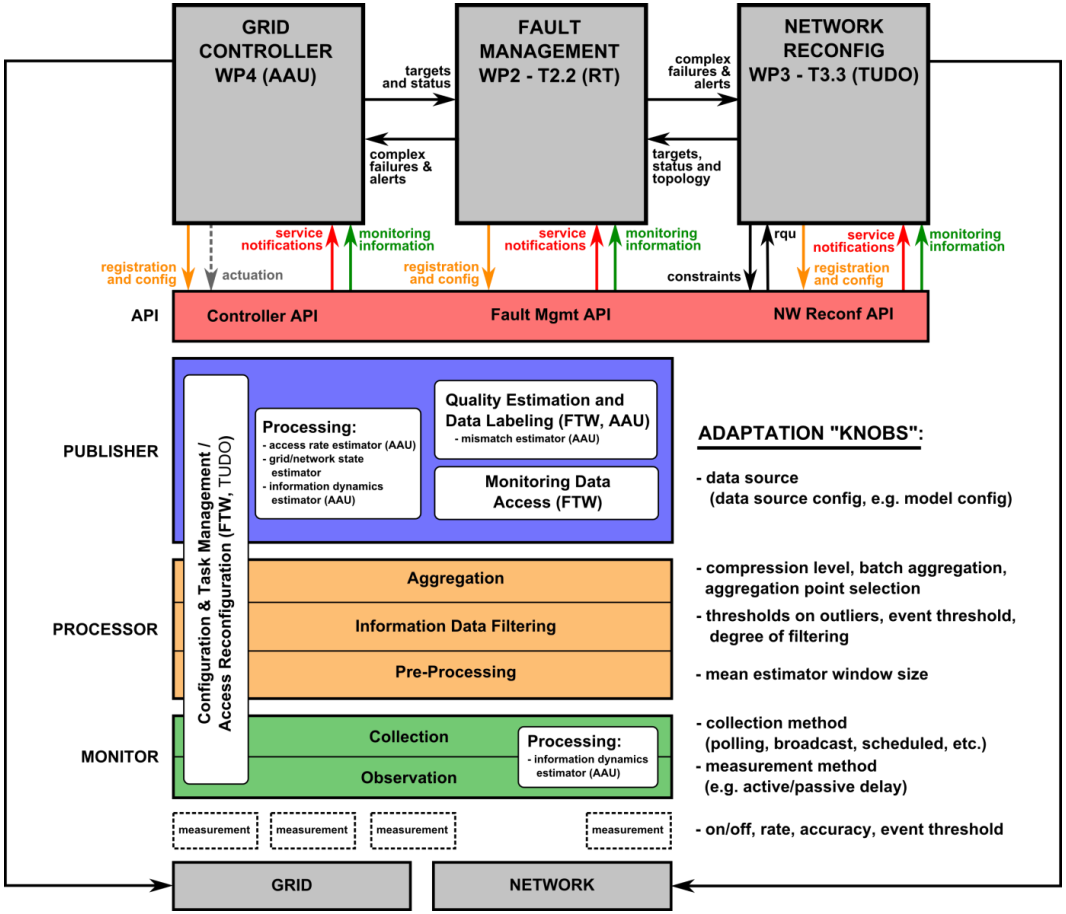
Adaptive Network and Monitoring Solutions

Main objective: uniform and simple access to information distributed in the electrical grid

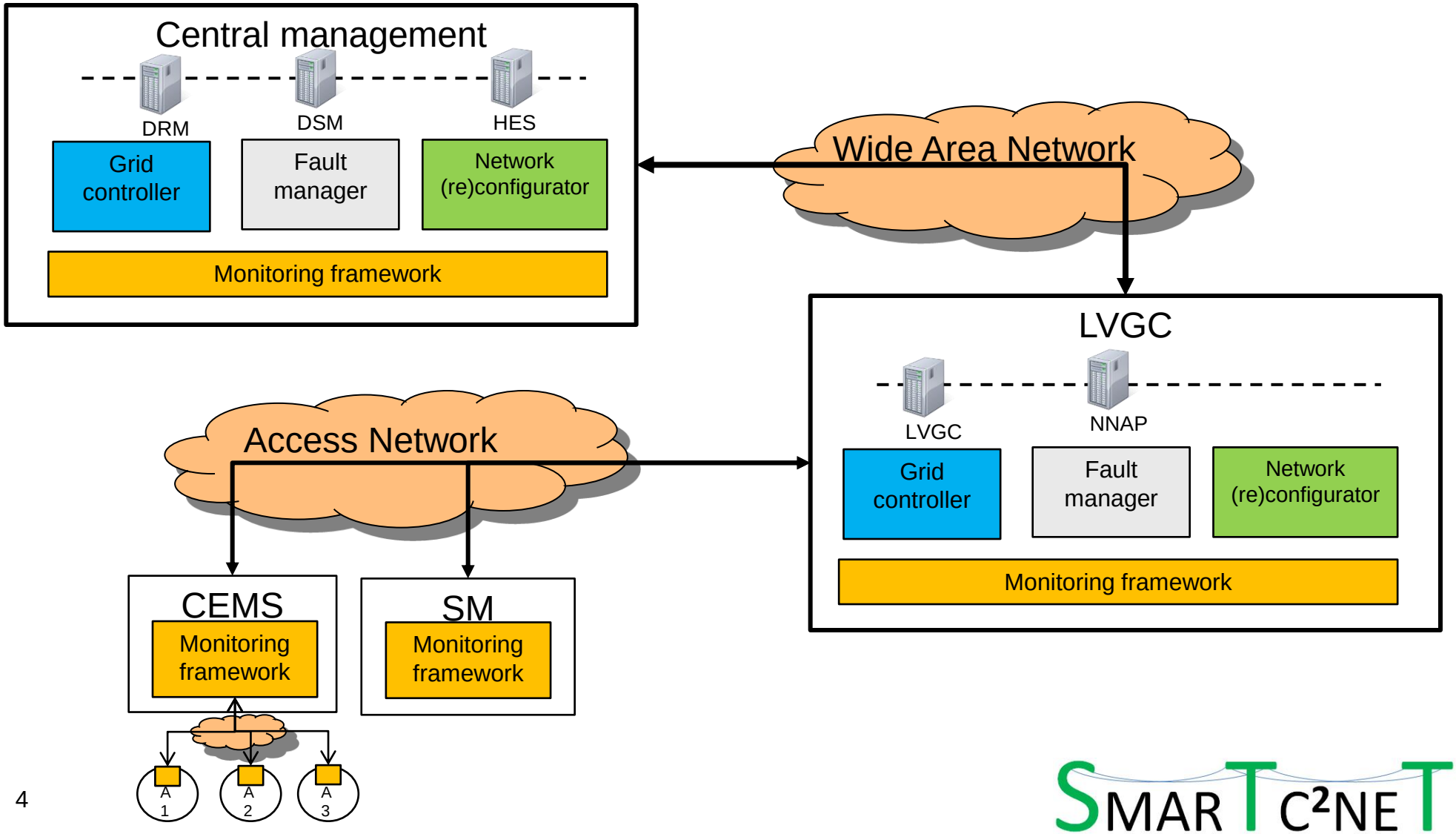
Main characteristics

A layered monitoring architecture supporting:

- Decentralized data collection
- Different aggregation levels
- Quality estimation of collected data
- Various adaptation approaches towards network performance degradations and faults
- Integration of legacy monitoring frameworks
- Interaction with network & control adaptation
- Combine grid and network data to provide improved fault detection and diagnostics

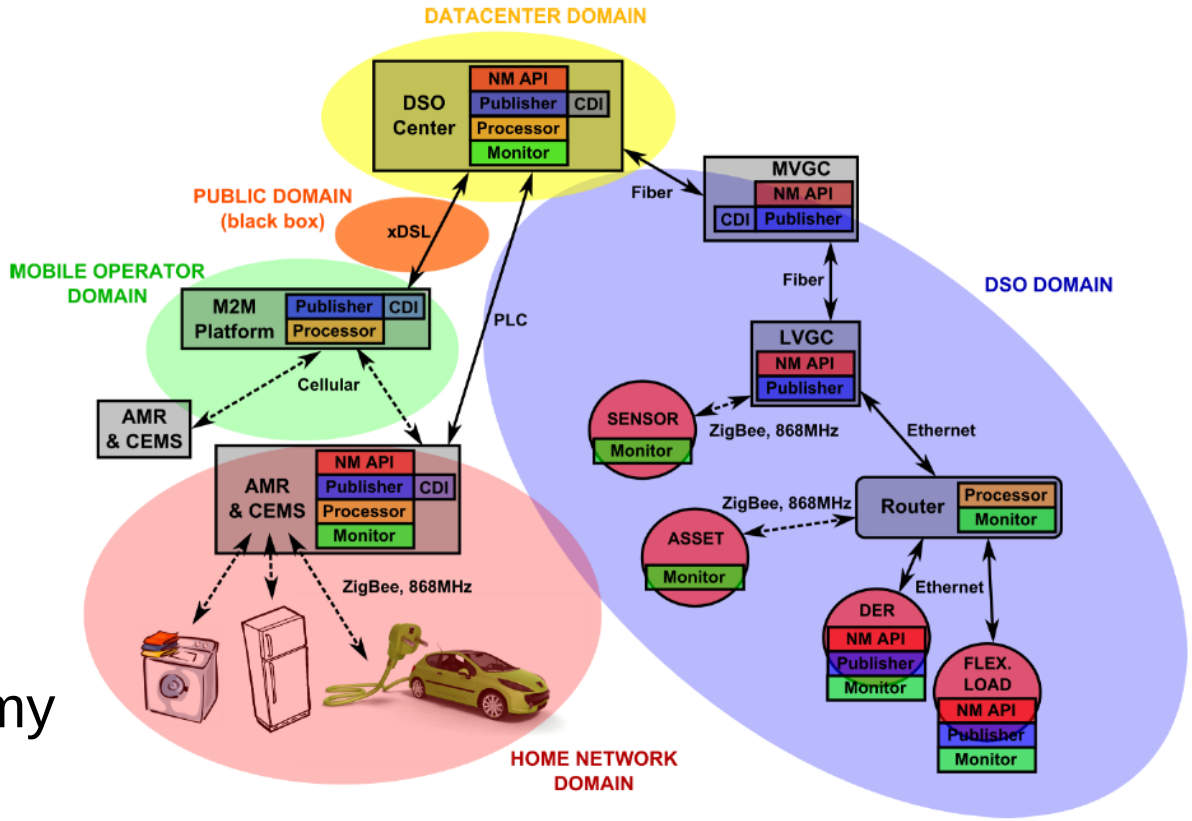


The monitoring as a distributed platform



Monitoring in a heterogeneous environment

- Data collection of
  - Events in the grid
  - Measurements
  - State information

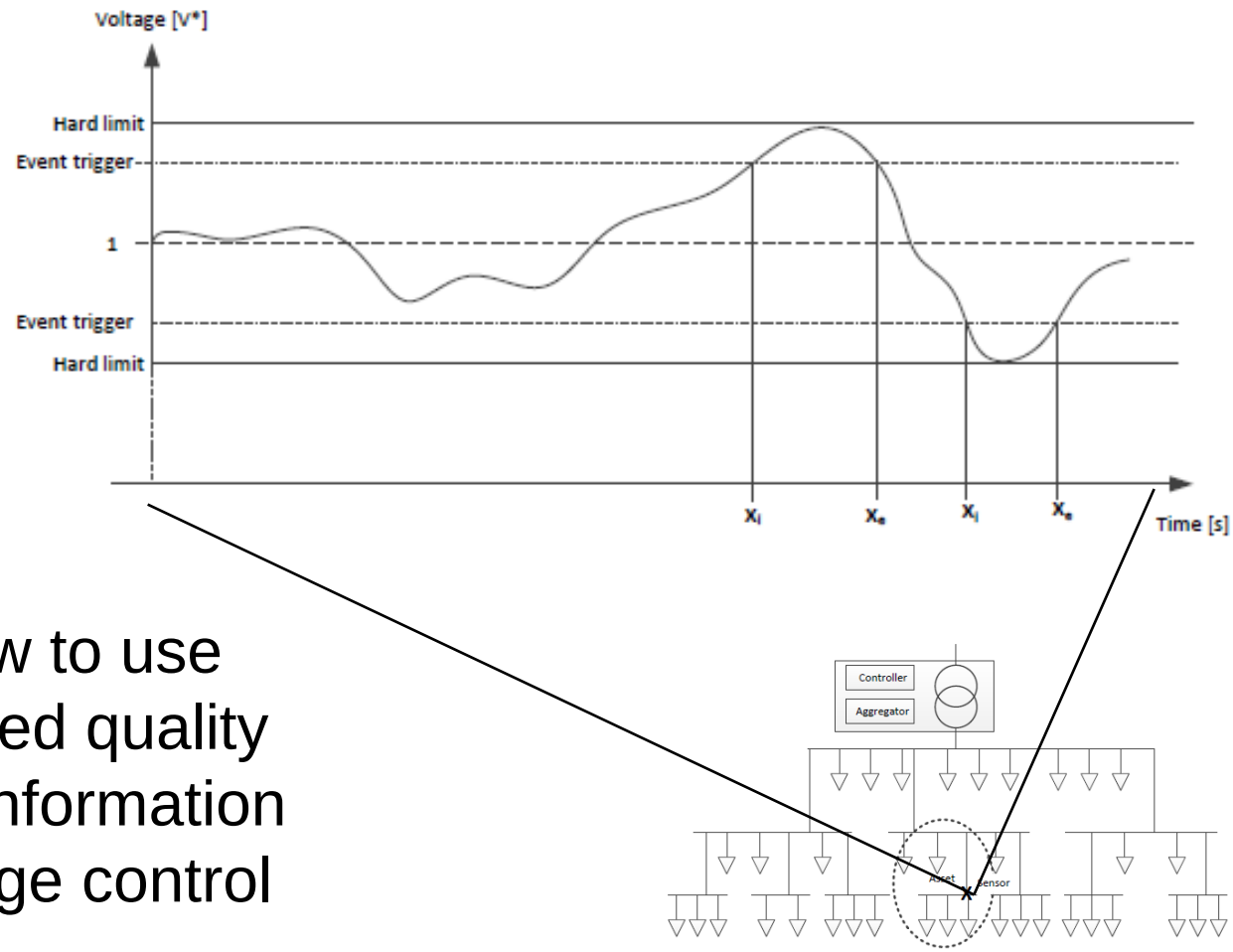


- Challenges
  - Interoperability
  - Discovery and autonomy
  - Security and privacy
  - Dynamics in network and information

- How would the monitoring framework help?

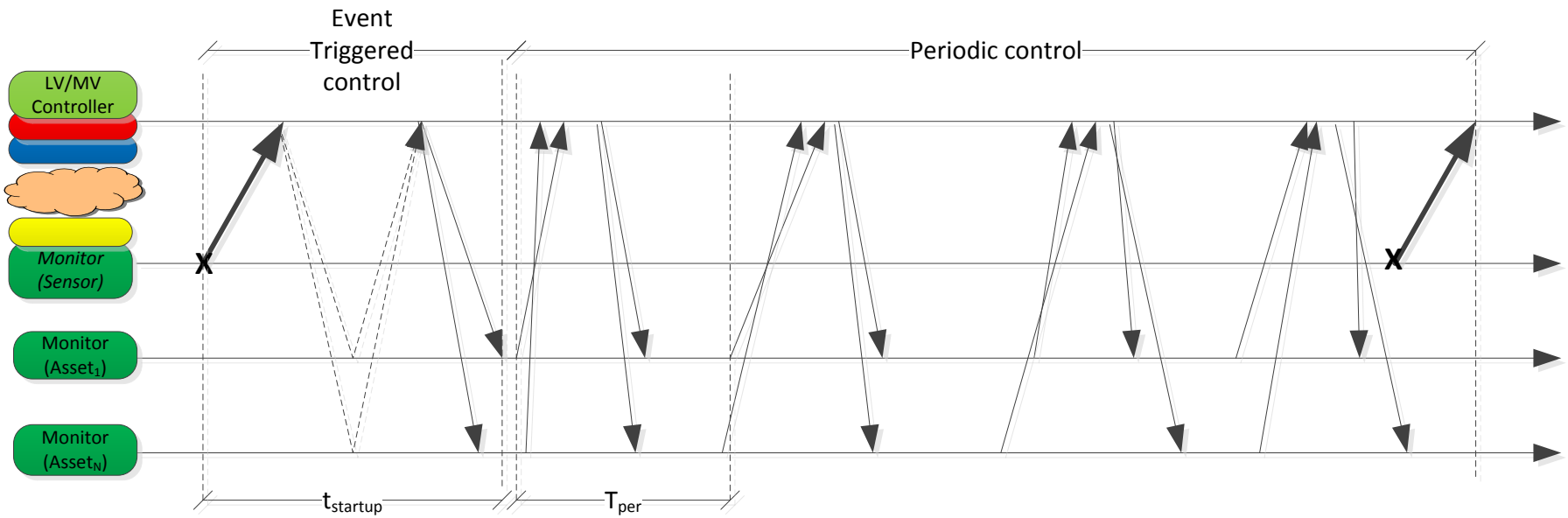
Use case: Low Voltage Control #1 – triggering the control

- What can we do?
  - Event detection for event based control
  - System health monitoring
  - Fault detection



- Example case of how to use monitoring with related quality metric of (delayed) information in event based voltage control

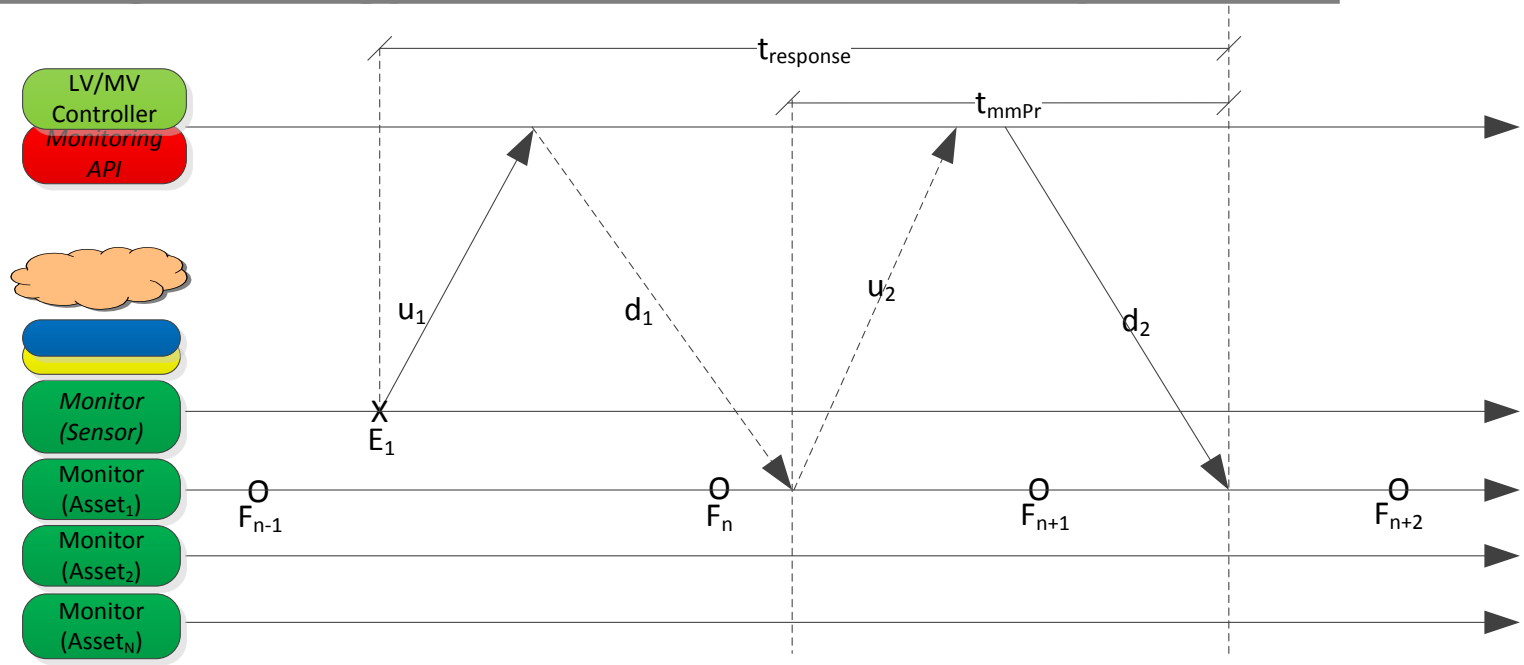
Use case: Low Voltage Control #2 – use of flexibility



- In between voltage thresholds the controller is idle
  - No interaction with assets in the grid

- Exceeded voltage thresholds triggers a control period
  - First an initial response is taken
  - Second a periodic control is used to stabilize voltage
  - All using flexibility from the assets in the grid

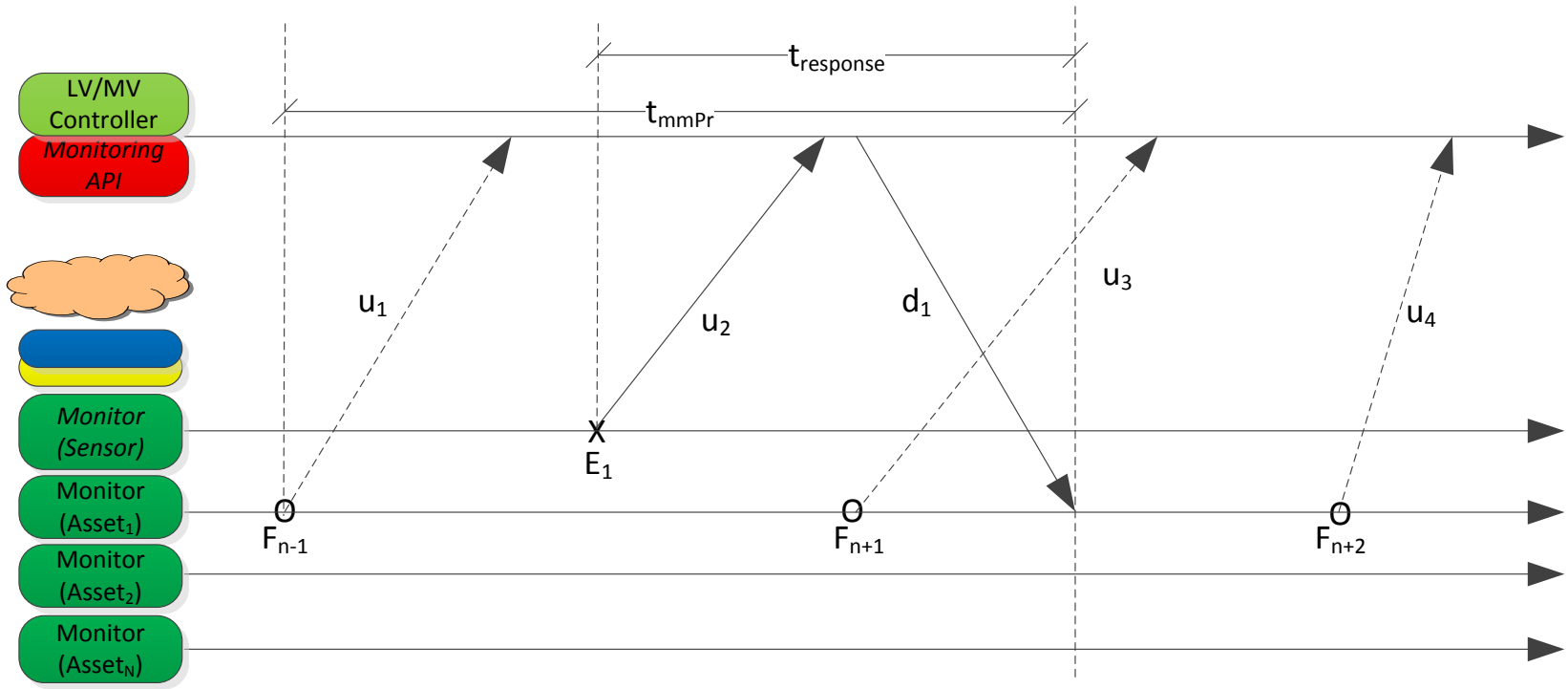
Monitoring strategy #1: Reactive flexibility access



- Discretizing the flexibility information in intervals we may quantize the reliability of the system

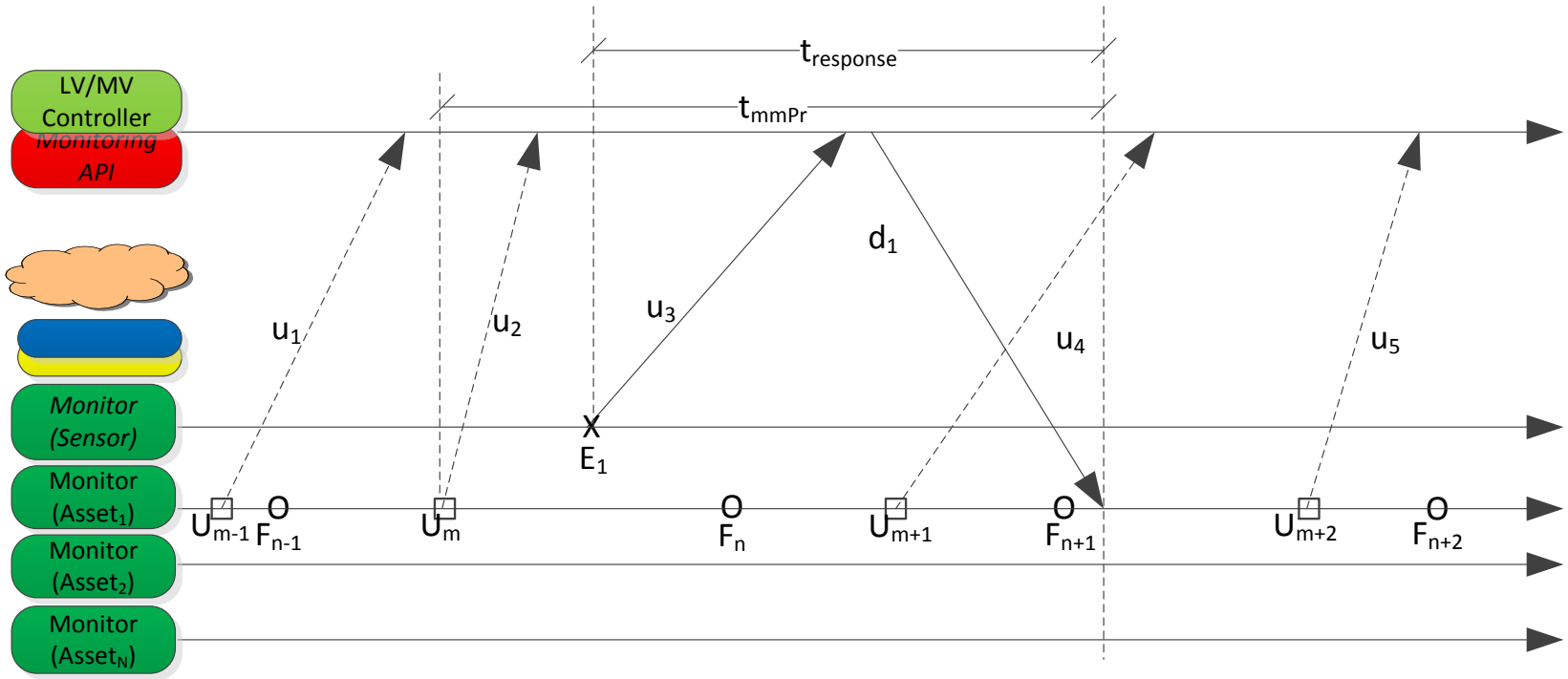
- Two time based metrics is of interest depending on the network and information dynamics (flexibility models)
  - The response time (from event happened until action is taken)
  - The mismatch probability (probability of using correct information)

Monitoring strategy #2: Event driven access to flexibility



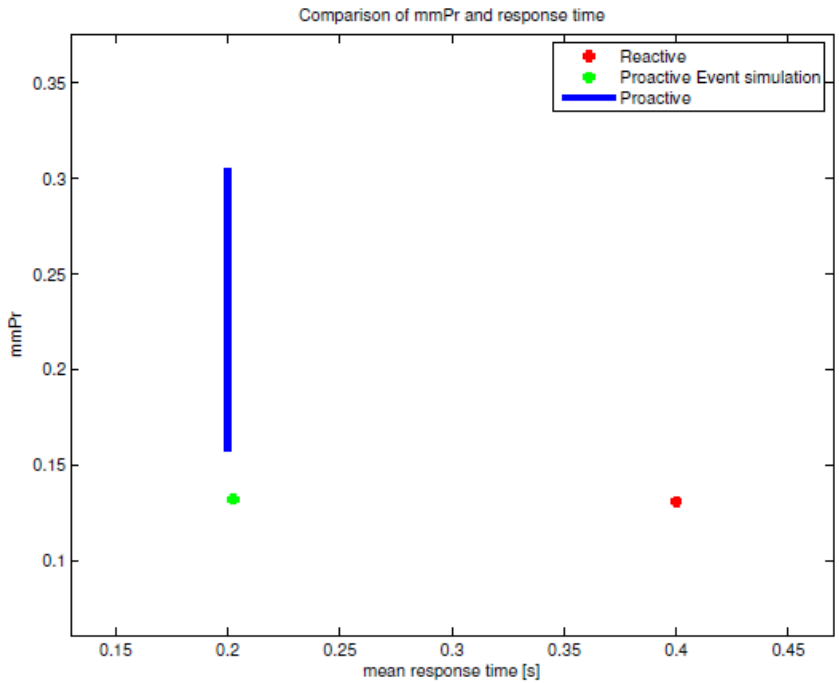
- Response time is short due to the use of cached information
- Mismatch probability is simple
- Traffic overhead is dependent on the information dynamics

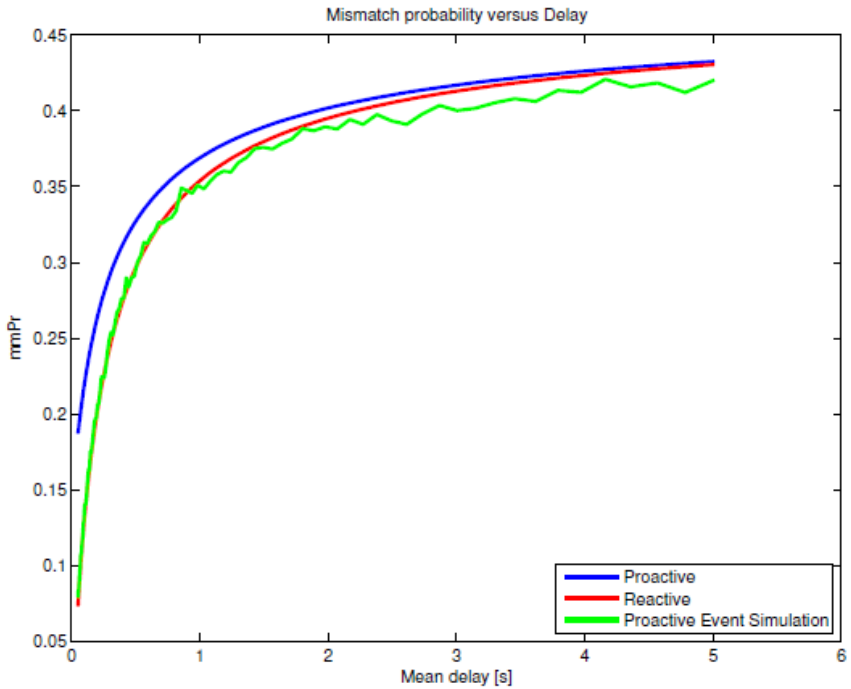
Monitoring strategy #3: Periodic access to flexibility



- Response time is short due to the use of cached information
- Mismatch probability depends now also on the update rate
- Traffic generation is depending on the update rate

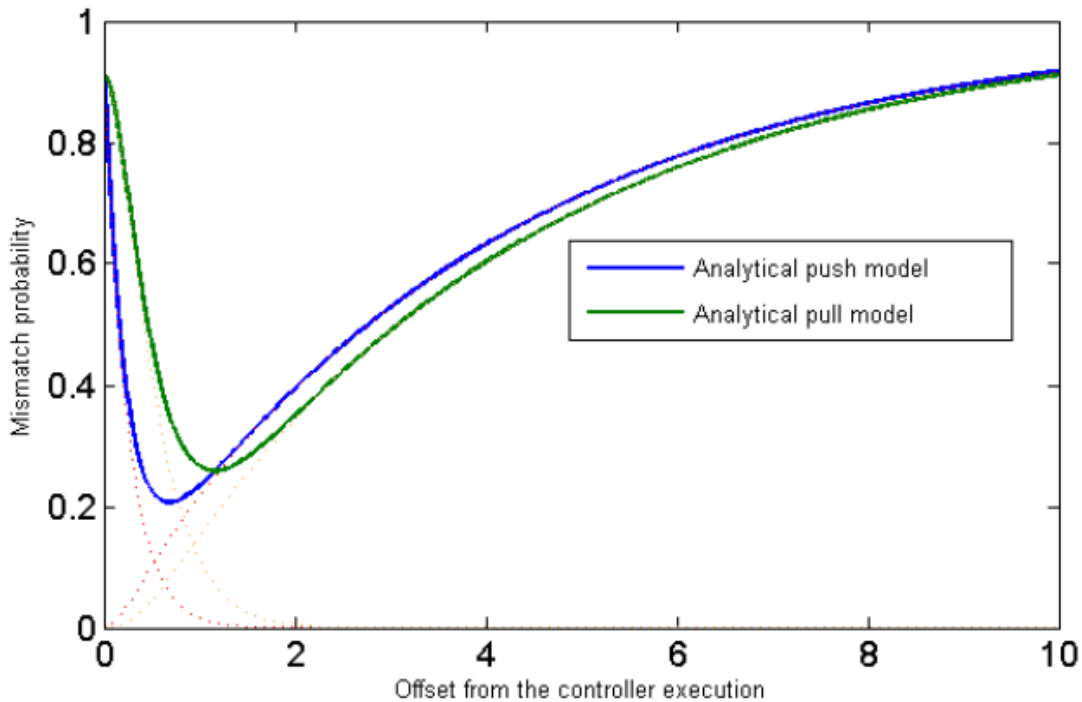
Which strategy is best? It all depends …

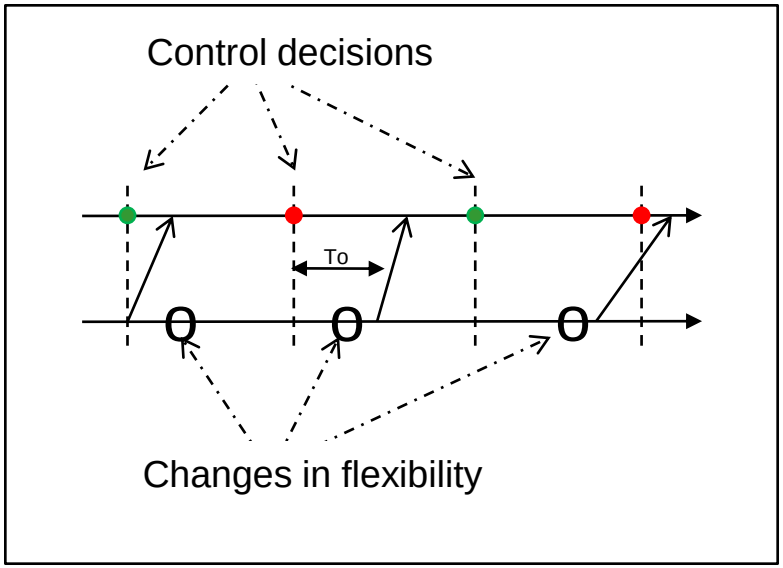




- The question is: **which strategy should be used**?
  - With the periodic we can adjust via the update rate
  - With the event we are either stuck or we need to adjust granularity of the information
  - With reactive we only create traffic on demand

Planning updates in a periodic access scheme

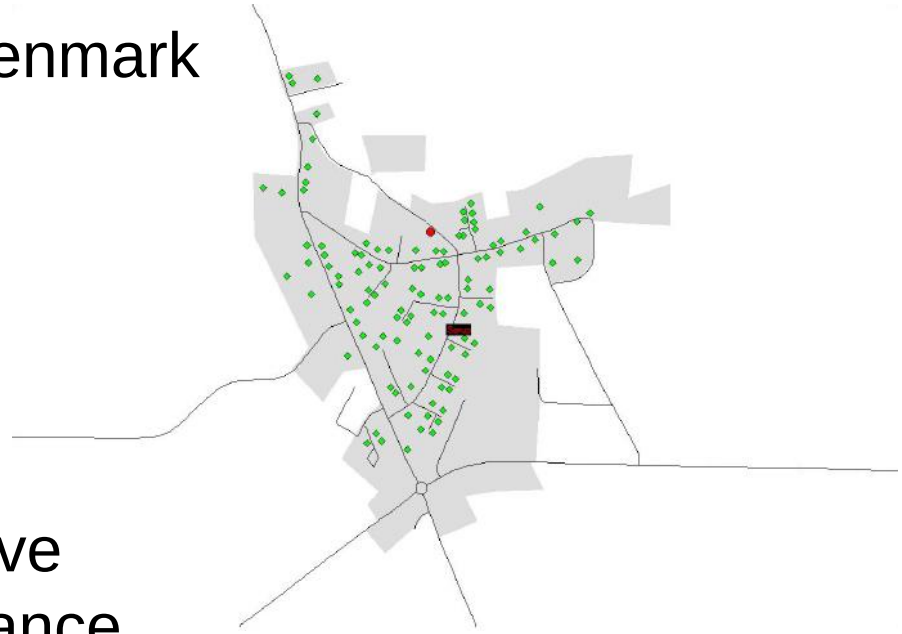




- The question is: **when should sensors send data to controller**?
- Too early and it might be outdated, too late and it might miss the deadline
  - Leads to possible optimal time offset at information provider for minimum mmPr
  - Clever scheduling needed to avoid numeours sensors to create bursts - which in turns leads to higher mismatch probability

Monitoring and task management

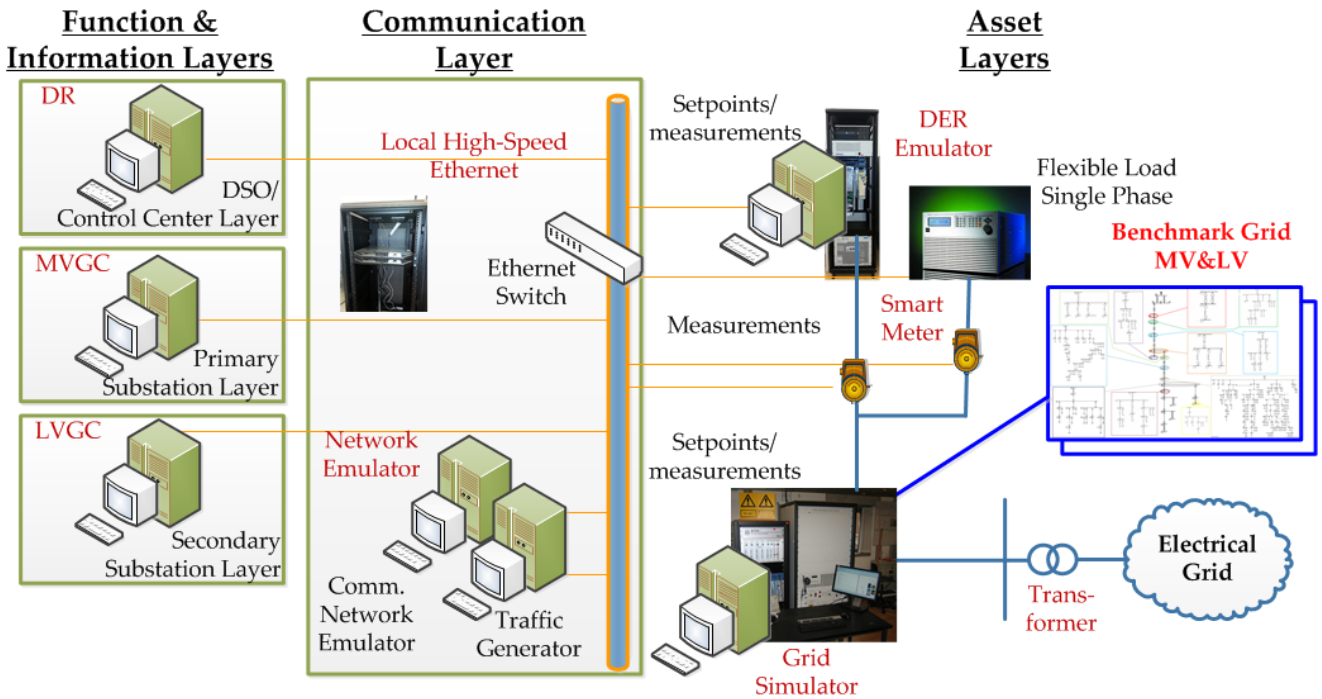
- Take a case in a typical town in Denmark
  - How to manage not one, but many sources of information?
  - Do we really need ALL of information available at all time?



- Task management enables effective use of mismatch probability to balance network resources

- Further, reducing mismatch probability also increases probability of taking correct control actions
  -> less resources used to solve grid issues

Evaluation of framework: External generation site test bed



Key features

- Three main control layers associated to DSO level, primary substation and secondary substation
- Industrial platforms for hosting developed control features
- Realistic representation of different types of communication networks
- Realistic representation of the distribution grids including assets and their flexibility.
- Communication protocols used currently within Smart Grid applications
- Realistic effect and impact of faults and performance degradation in the public communication lines between different control layers and assets in the distribution system.

Summary and conclusions

- Monitoring platform used to overcome heterogeneous nature of data collection and signal distribution in grid
- Challenges are related to the dynamics of
  - Information used to describe state (flexibility) of the electrical grid
  - Network used to carry information over (incl. local caching etc.)
- Mismatch probability introduced as a metric to describe reliability of used information
  - Consequences of mismatching information would potentially be
    - prolonged control periods, leading to inefficient use of resources (inclusive network resources)
    - exceeding voltage thresholds (and grid codes)
- A platform as this would be able to improve efficiency of resources

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