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Planning and Scheduling for Optimizing Communication in Smart grids

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What are Smart grids? Why?

- Complex approach to enhance electricity distribution network
- Adds:
  - Data analysis systems
  - Compensational devices
  - Communication infrastructure
- Motivation
  - Making the infrastructure more monitorable, controllable, automatic…
    - Adding new functionality

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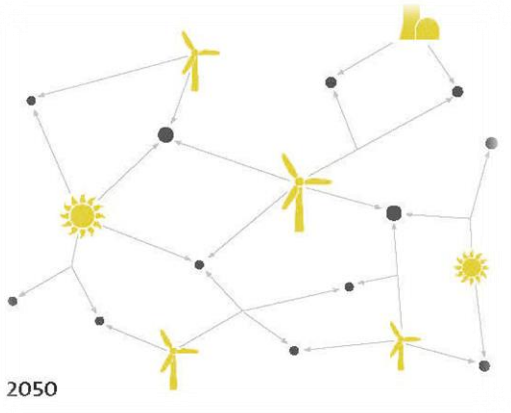
Smart grid functions (1/2)

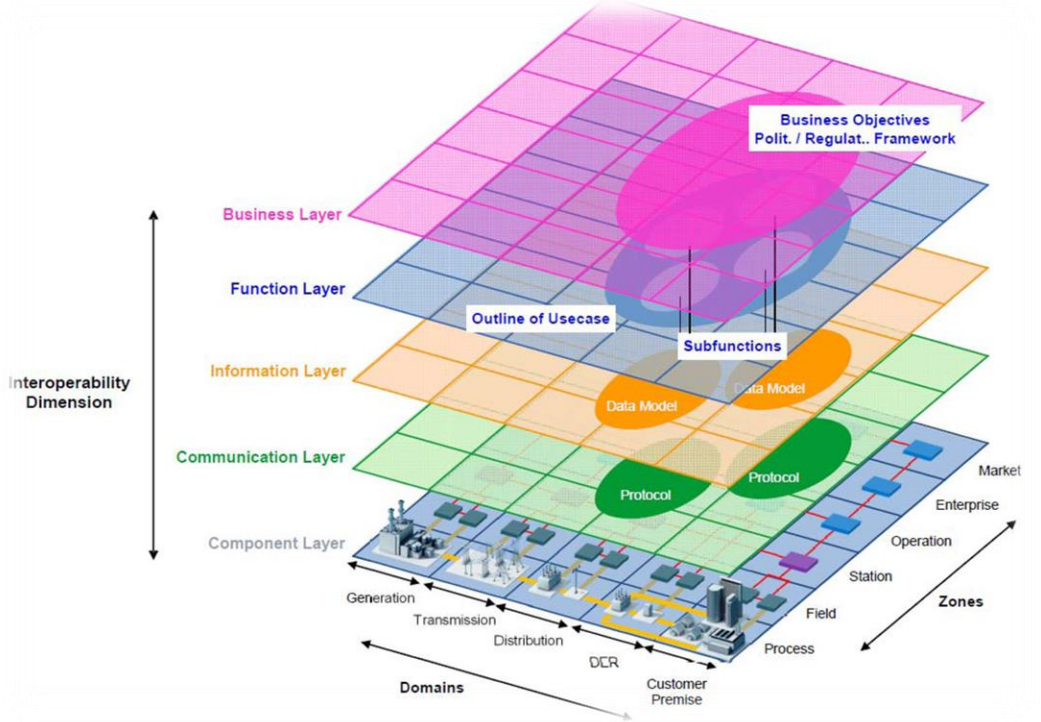
- Automatic Meter Reading (AMR)
  - More data, less effort
- Fault detection/recovery
  - Voltage sags, overloads, blackouts
- Fraud detection
  - Unregistered consumers
  - Unauthorized meter manipulation

Smart grid functions (2/2)



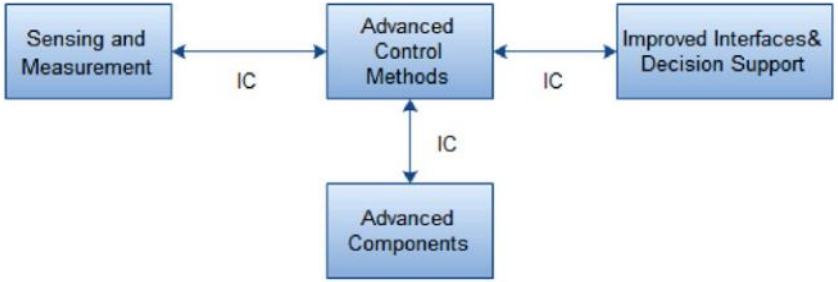
- Load balancing
  - Demand respose
- Distributed Energy Resources (DER)
  - Small household generators - „prosumers“
- Renewable source-based generators
  - Unstable electricity production
    - Another load balancing problem

Role of communication in smart grid



Role of communication in smart grid

- **Smart meters**
  - Measure electricity usage
  - Send information
- **Data concentrators**
  - Collect and pass metering data from SM
  - Pass commands to SM
- **Central system**
  - Controll and decision making
- **Integrated communication**



Smart grids - summary

- **Smart grids**
  - Bring new functionality, solve current problems
  - Rely on communication inftrastructure

- **Communication**
  - The quality of communication affects the quality of featured applications

  - Space for optimization

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Role of communication in smart grid

- Message types
  - Periodical meter readings
  - Ad-hoc meter readings
  - Alarms and warnings
  - Firmware updates
  - TOU (time of use) tables
  - Control commands

Communication optimization - opportunuties

- **Communication infrastructure design**
  - Estimated communication profiles for selected smart grid application

- **Congestion avoidance**
  - Transport aggregator
  - Quality-aware reduction of the non-essential data
  - Communication in sensor networks over cognitive radio

- **Time-based message scheduling**
  - …

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Problem definition - general

- We are developing control central system for ČEZ, a. s. (Czech electricity distribution company)
  - Collecting data, sending control commands
  - Advanced algorithms for data mining and decision making
- Huge number of DTSs (tens od thousands in Czech Republic)
- Huge number of messages

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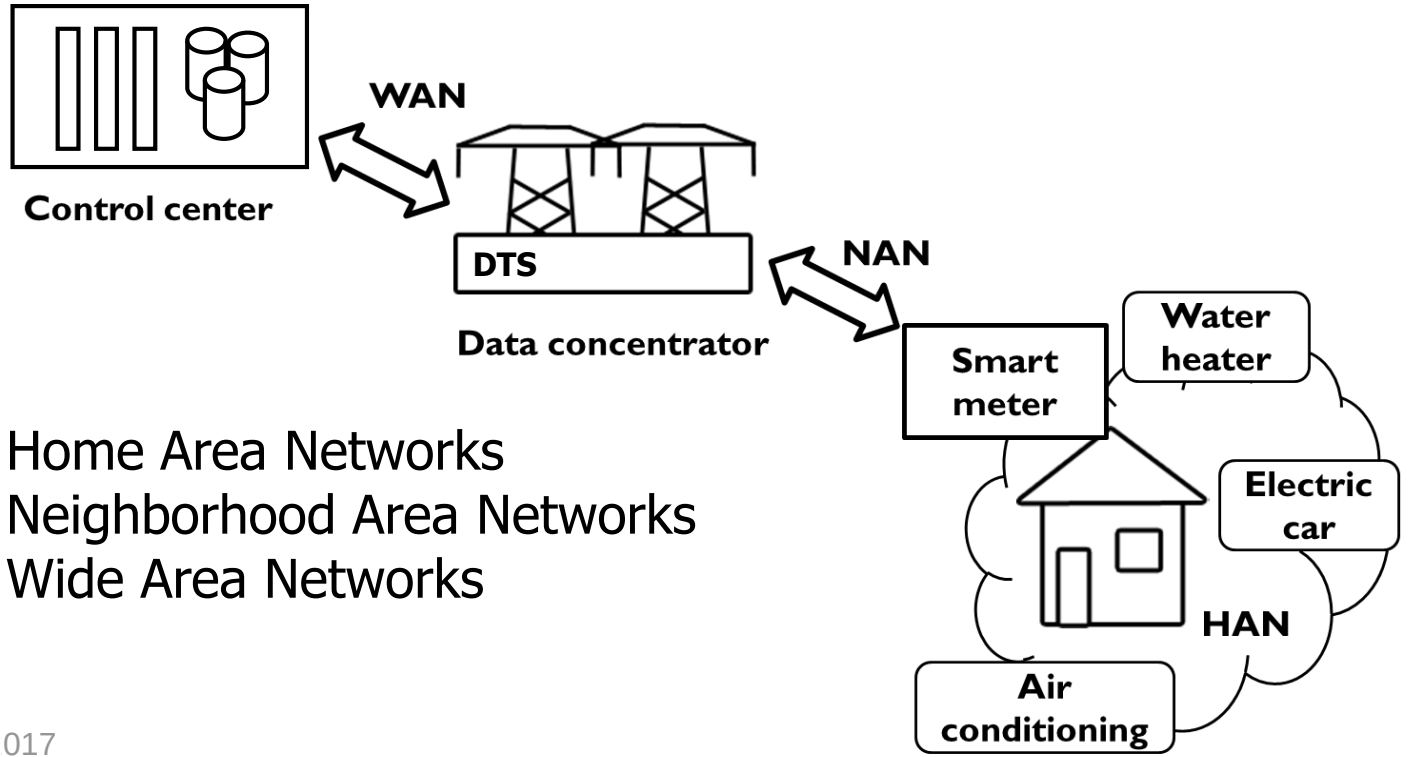
Problem definition - general

- Conditions
  - Communication network cannot manitain all communication requests
  - Some messages are preplanned and not time critical
    - Periodical meter readings, firmware updates
    - Need to be scheduled somehow
      - Currently - fixed times are assigned
- Goal
  - Optimize the probability that all messages are delivered
  - Reflect message importance and priority
  - React to network conditions

Problem definition - scale



- Home Area Networks
- Neighborhood Area Networks
- Wide Area Networks

Problem definition – communication technology

- Wire-line technologies
  - Dedicated fiber optics, DSL
  - Power-line communication
- Wireless
  - Cellular
  - ZigBee, WiMAX, Ethernet

- In the scope of Czech Republic
  - Public cellular network + fiber optics in WAN
  - PLC in NAN

Problem definition – communication technology

- In case of cellular networks, simultaneous requests sent through same BTS may collide
- External load
- Unexpected network problems
- Limited number of simultaneous requests accepted by DTS
  - Typically one

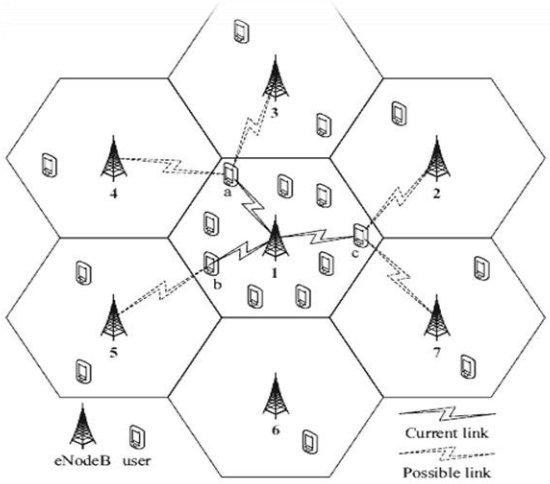


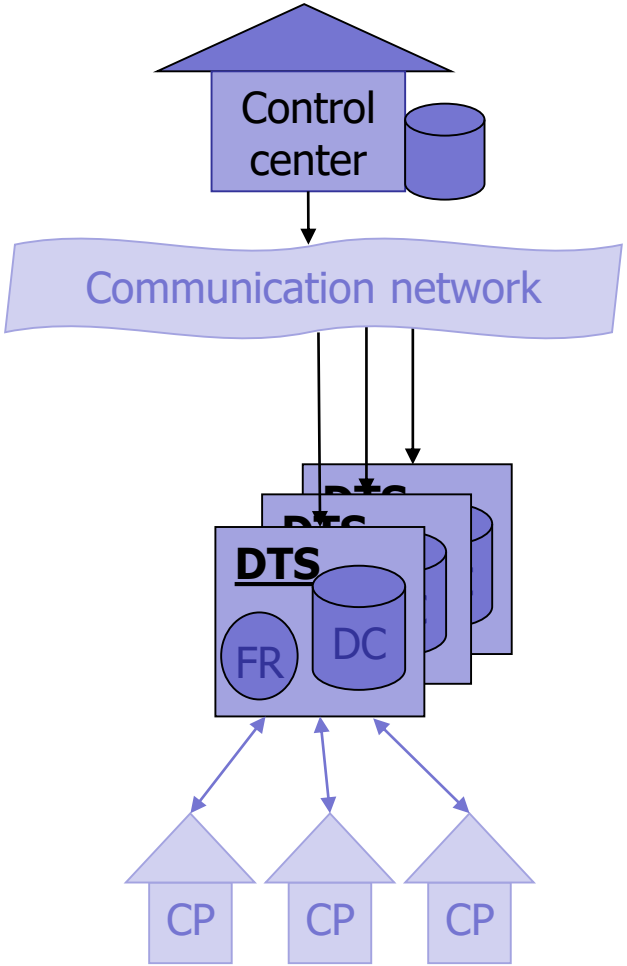
Figure 1: Network model.

Problem definition – communication requests

- Communication requests have requirements
  - Deadline
  - Earliest possible start
  - Importance
    - Controll commands are more critical than periodical measurements
  - Priority preference (as soon/late as possible)
- New requests are comming continuously
- Not every unsuccessfull request should be rescheduled
- Requests vary in data size and duration

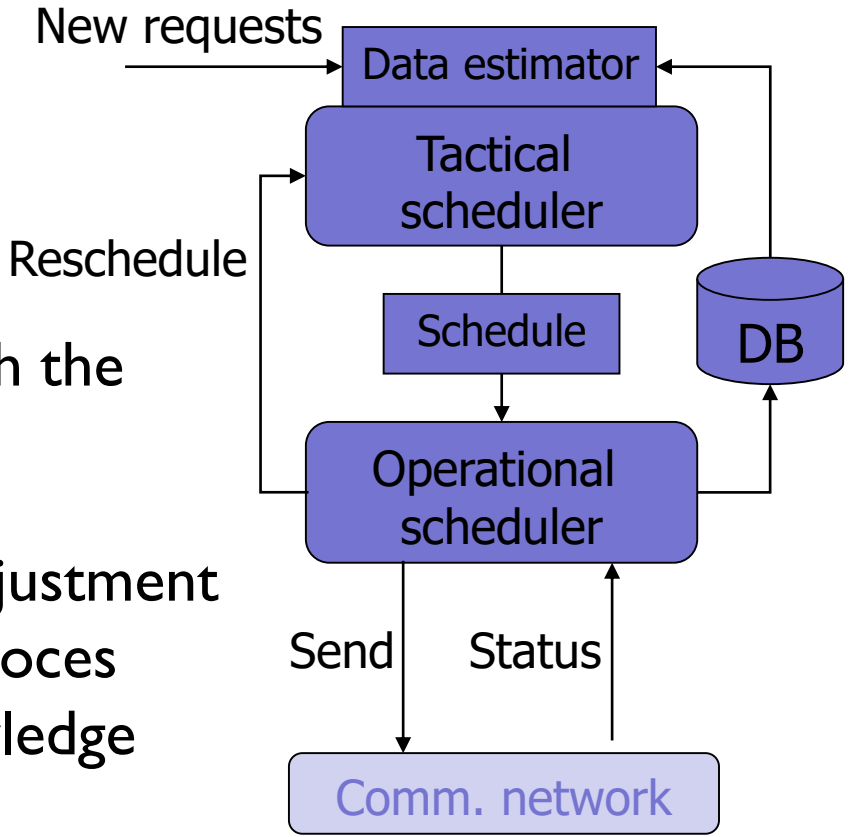
Problem definition - summary

- Huge number of DTSs
- Huge number of messages
- Various communication requirements
- Unreliable communication network
  - Unstable external traffic load
  - Topology does matter but exact data are unaviable



Proposed approach

- Two-level scheduling
  - **Tactical scheduler**
    - Assigns the request with the execute times
  - **Operational scheduler**
    - Short term schedule adjustment
    - Invokes rescheduling proces
    - Builds a statistical knowledge base



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Knowledge base

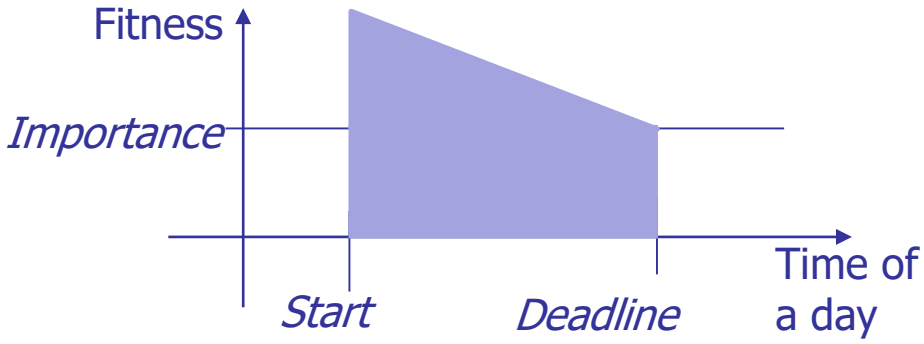
- Lack of data to assume
  - External load on communication infrastructure
  - Data sizes and durations for incoming requests

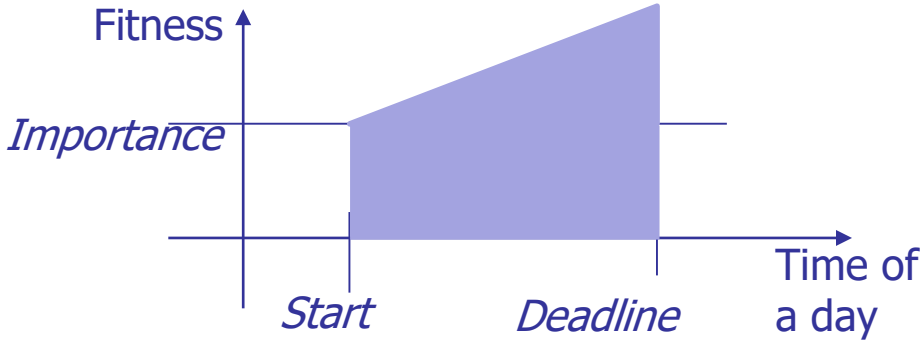
- 1) **Store information** about processed requests
  - Type of request, destination, time of a day, status, duration

- 2) **Search for** association rules
  - “Sunday afternoon has higher failure rate in general“
  - “Data size of request type A ranges from X to Y“

Priority preference function

- For each communication request
  - Aggregates the requirements of the requests
    - Start + deadline
    - Importance
    - Priority preference reference





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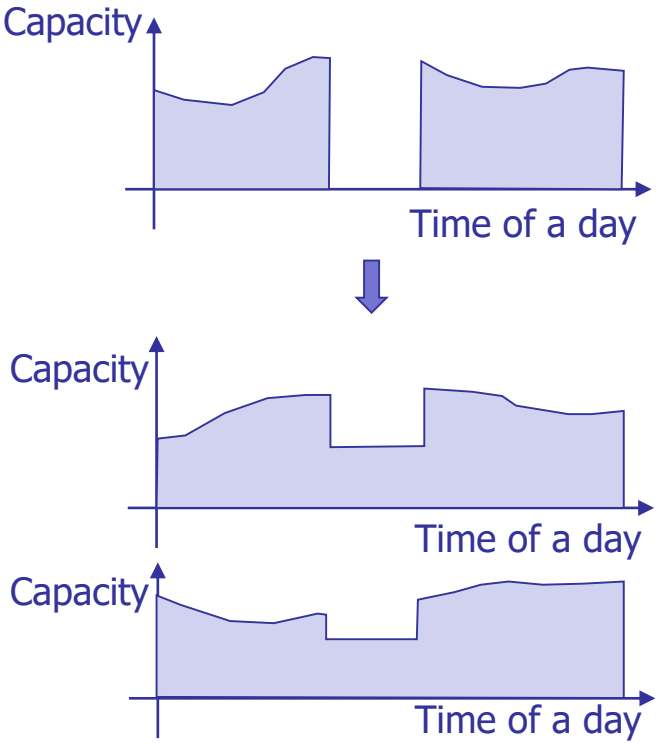
Mutual interference

- Mutual interference matrix M
  - **Abstraction** of communication network topology
  - N x N for N = number of DTS‘s
    - **Value *M(i, j)*** expresses the **chance** simultaneous requests sent to DTS‘s *i* and *j* **will collide**
  - We can use **various data sources** to compute the matrix
    - Statistics of BTS used by each DTS (if available)
    - DTS and BTS location (if available)
    - DTS geographic locations (distances)

Capacities, Partially shared resources

- Communication channel capacity for each DTS
  - Expresses the fitness of communication with given DTS at given time
  - Data sources?

- Partially shared resources (network capacity)
  - Resource reduced after
    - for given DTS
    - for other DTSs **proportionally** to mutual interference coeficient



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Solution search

- Searching the space of candidate solutions (schedules)
  - Schedule = mapping of all requests to times of execution
- Change operators – traditional
  - **Shift** particular request, **swap** two requests of similar characteristics
- Conditions and criteria
  - E. g. Minimize the risk of requests collisions
  - Aggregated into **objective function**
- Metaheuristic
  - Hill climbing, Simulated annealing, Genetic algorithm

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Future work

- Detailed algorithm design
  - The behavior of the operational scheduler
- Tests design
  - What shows the quality of scheduling
  - Testing environment
  - Virtual control central, pilot project
- Implementation
- Testing and analysis

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Summary

- Correct, up-to-date and complete data are an essential prerequisity for smart grid applications
- It is worth to schedule communication requests
  - Bottle-necks in the communication infrastructure
  - Various requirements
  - Big numbers of requests DTSs
- Complex and specific problem
- Approach to solve is porposed

Thank you for your attention

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