Trondheim 17.09.2015

Towards multilevel parallelization in applications for hydro power scheduling

G. Warland, A. Henden & B. Mo

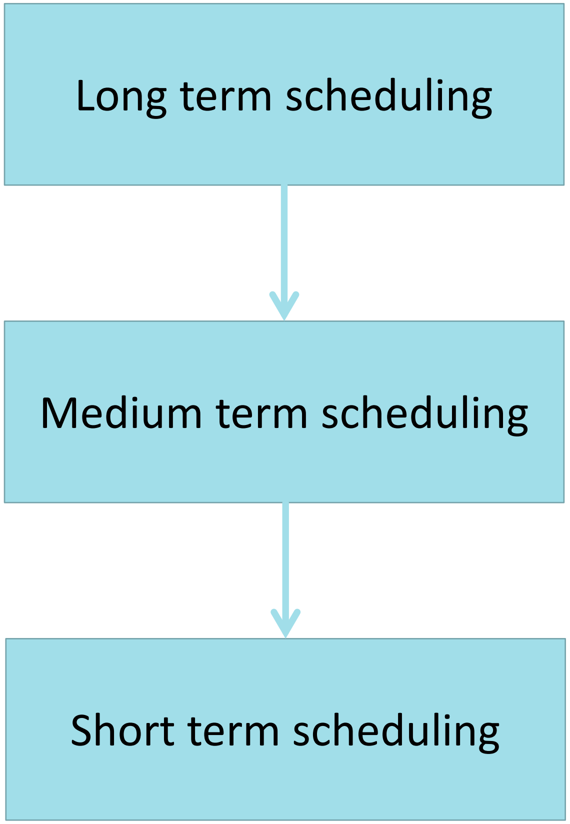
Geir Warland

SINTEF Energy Research

Geir.warland@sintef.no

Hydro-power scheduling

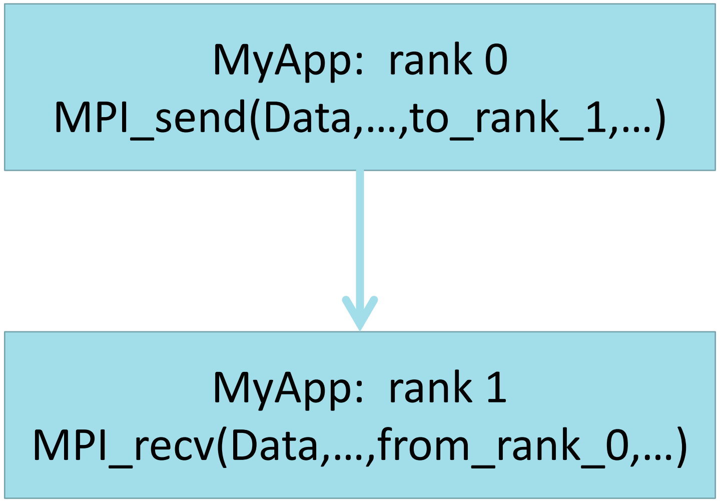
- The scheduling problem in a hydro-thermal system is in general very complex
  - Uncertain future inflow
  - Uncertain future prices (market-based system)
- The problem is too large to be solved as one large optimization problem – some form of decomposition is necessary



Application	Term	Description	Problem	Method
EMPS	Long	Multi area hydrothermal market model. Price forecasting, planning, expansion and power system analyses.	Stochastic	Optimization (SDP) and heuristic
EOPS	Long	Single area hydro-thermal scheduling. Scheduling, use of reservoirs and expansion planning.	Stochastic	Optimization (SDP) and heuristic
ProdRisk	Long and medium	Single area hydro-thermal scheduling. Scheduling, use of reservoir, expansion planning and water values for short term model (SHOP).	Stochastic	Optimization (SDDP)
Seasonal model	Medium	Calculate individual water values, operational decisions, or input to short term model (SHOP).	Multi-deterministic	Optimization (LP)
SHOP	Short and detailed simulation	Single water course. Scheduling, power market trade. Also include simulator for validation of the optimization.	Deterministic	Optimization (SLP, MIP) or simulation
Samlast & Samnett	Long	EMPS with physical power flow constraints.	Stochastic	Optimization (SDP) and heuristic

Parallel processing

- **Message Passing Interface (MPI)**
- **Some basic functions for communication**
- **Process identities known**



- **Start of processes:** MPIEXEC.exe <options> MYAPP.exe

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Some parallelization experiences (parallel processing in existing computer code)

- **Potential pitfalls**
  - Dead-locks
  - File access
  - Memory usage

- **Communication**
  - Few and large messages preferable!?
  - Collective communication?
    - One to all vs. all to all
    - Introduces synchronization

- **Potential limitations in speed-up**
  - Sequence of sub-tasks
    - may not scale well or applicable for parallel processing
    - Sequences of large LP's (Use warm start)

Future needs

- Increased level of modelling detail

- New, more time consuming models/algorithms

- Increase parallel processing by multiple levels of parallelization
  - Parallelization in independent sub-tasks
  - Parallelization of sub - tasks

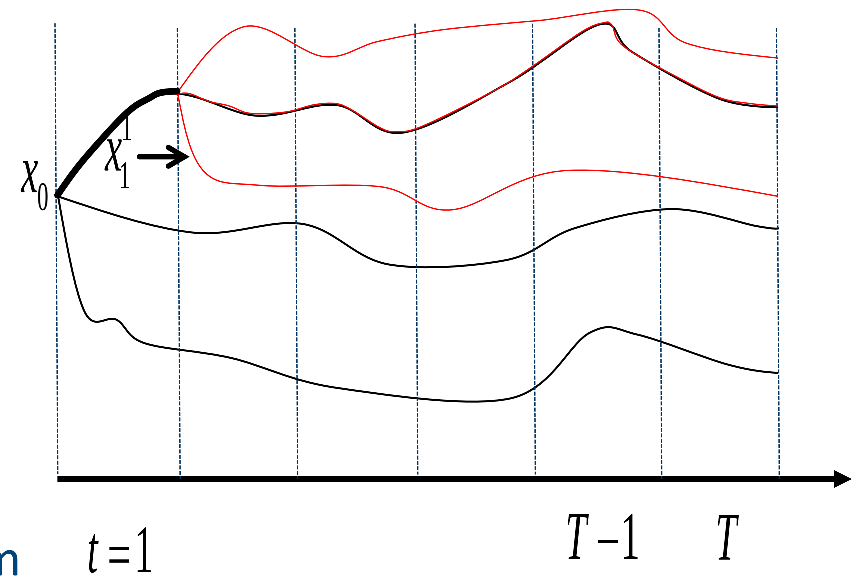
- Examples: Two prototypes
  - New market models, similar to EMPS
  - Use individual water values
  - SOVN: Scenario Fan Simulator (SFS): Multi-level parallel processing using MPI
  - ProdMarket: Multi-level by combining high-level and low level applications

Parallel processing in SOVN

- Simulation of independent scenarios

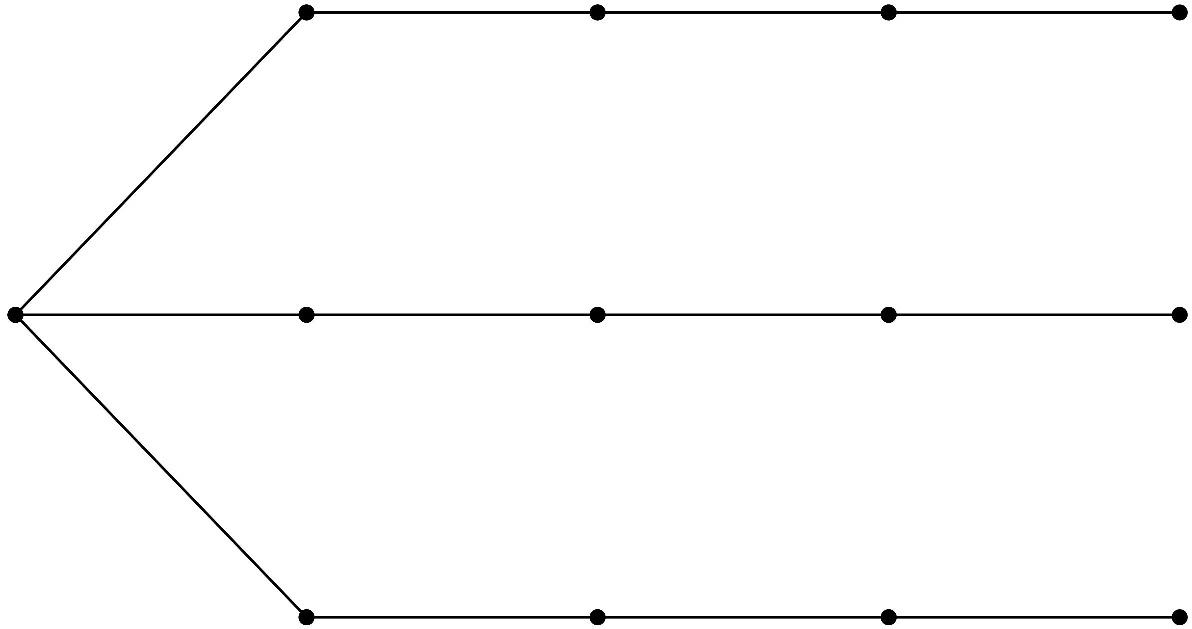
- Level 1: Master – slave concept
  - Master: distributes scenarios
  - "Slave" simulates given scenario

- Level 2: Solve optimization problem
  - "Slave" is a group of processes
  - Solves 2 stage optimization problem (Scenario Fan Problems: SFP) as sequence of LP's
    - One M(aster) LP
    - Several Sc(enario) LP's
    - Iterative scheme



Parallel processing in SOVN: Example

- Scenarios: NScen=3
- Processes: NP = 6
- Master & 2 "Slaves":



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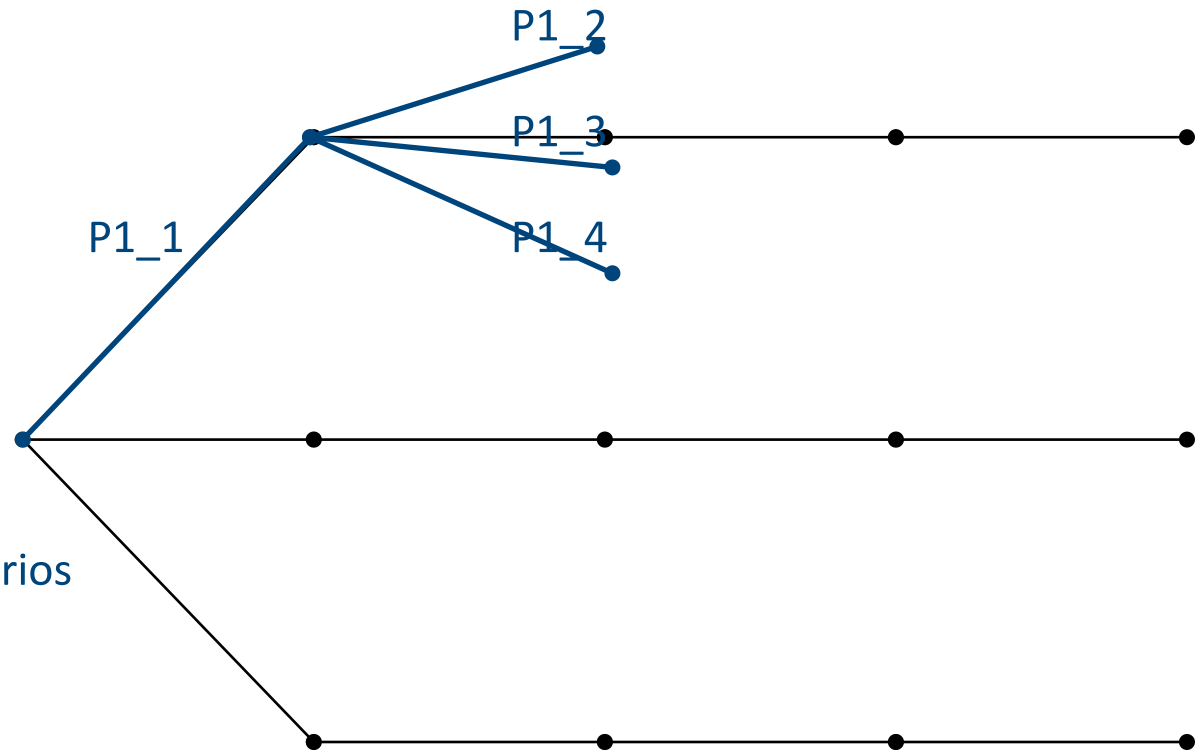

- "Slave 1": 4 processes
  - P1_1: masterLP
  - P1_2 -P1_4: Scenarios

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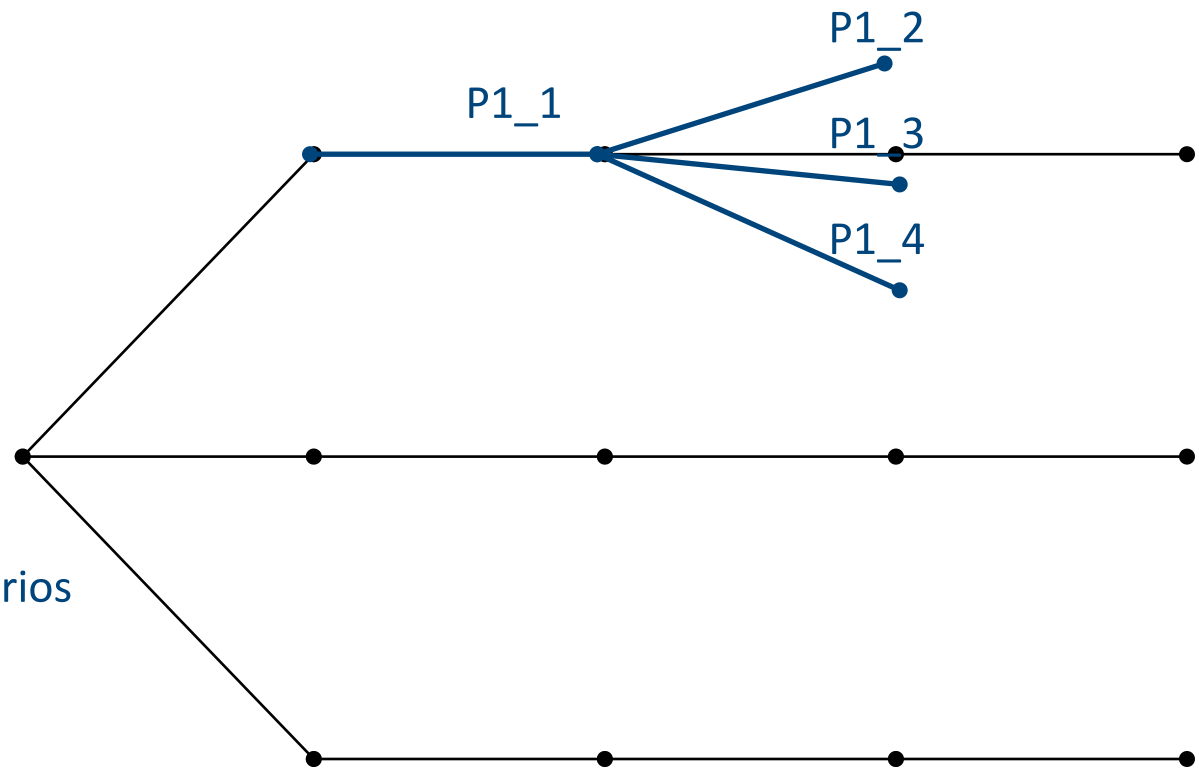

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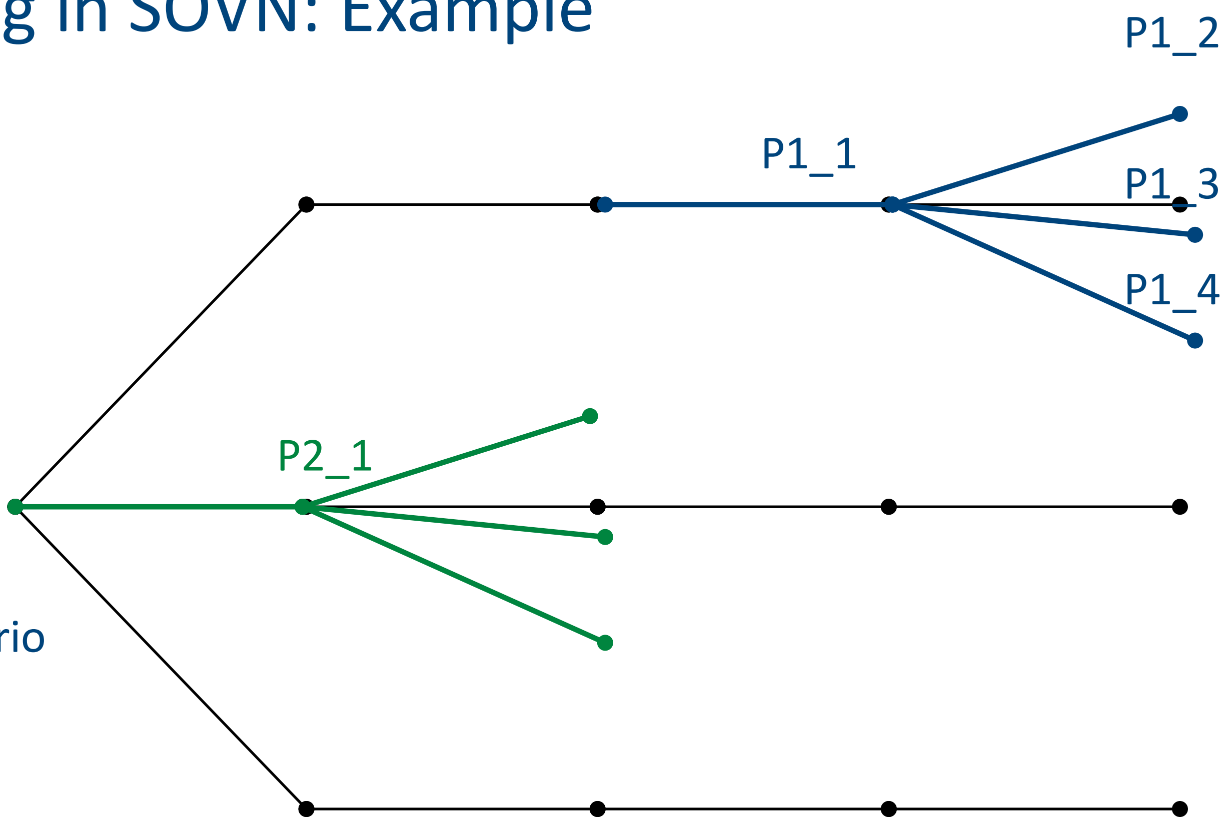
- "Slave 2": 1 process
  - P2_1: Solves masterLP **and** scenarios



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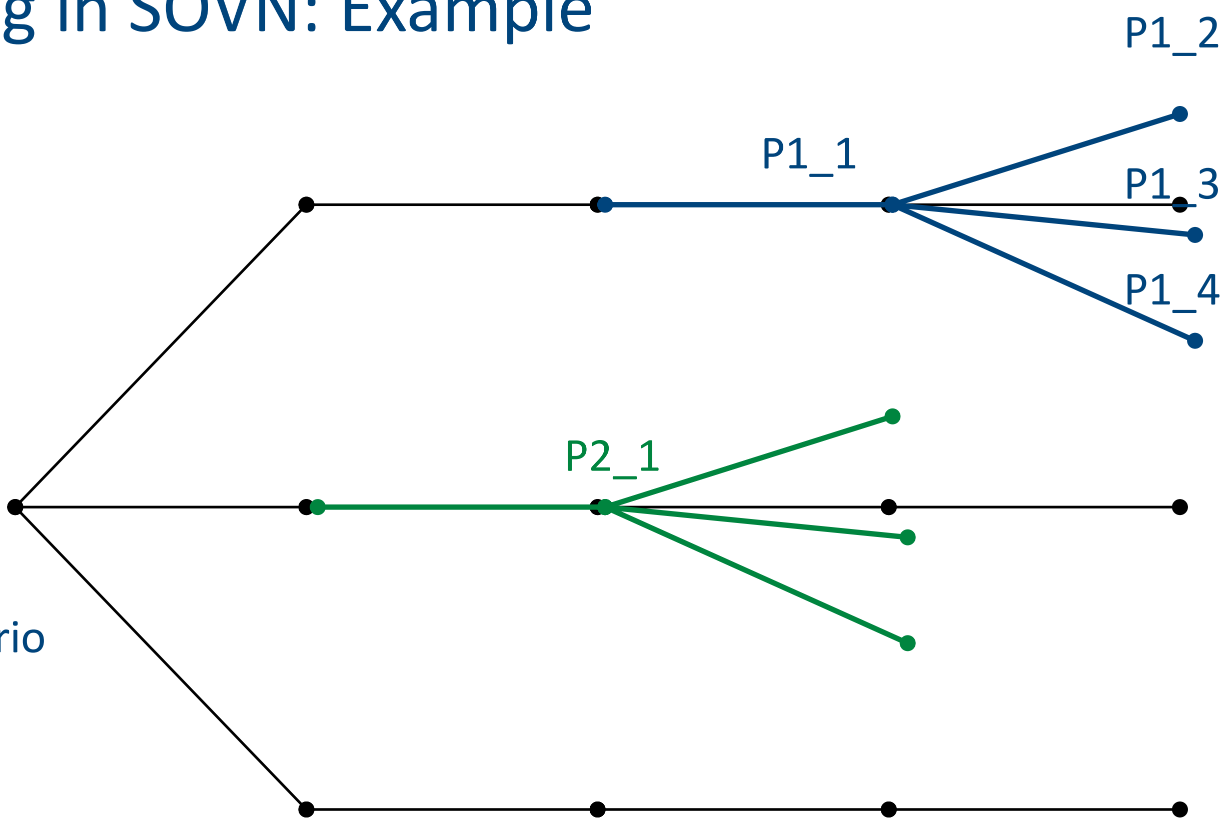

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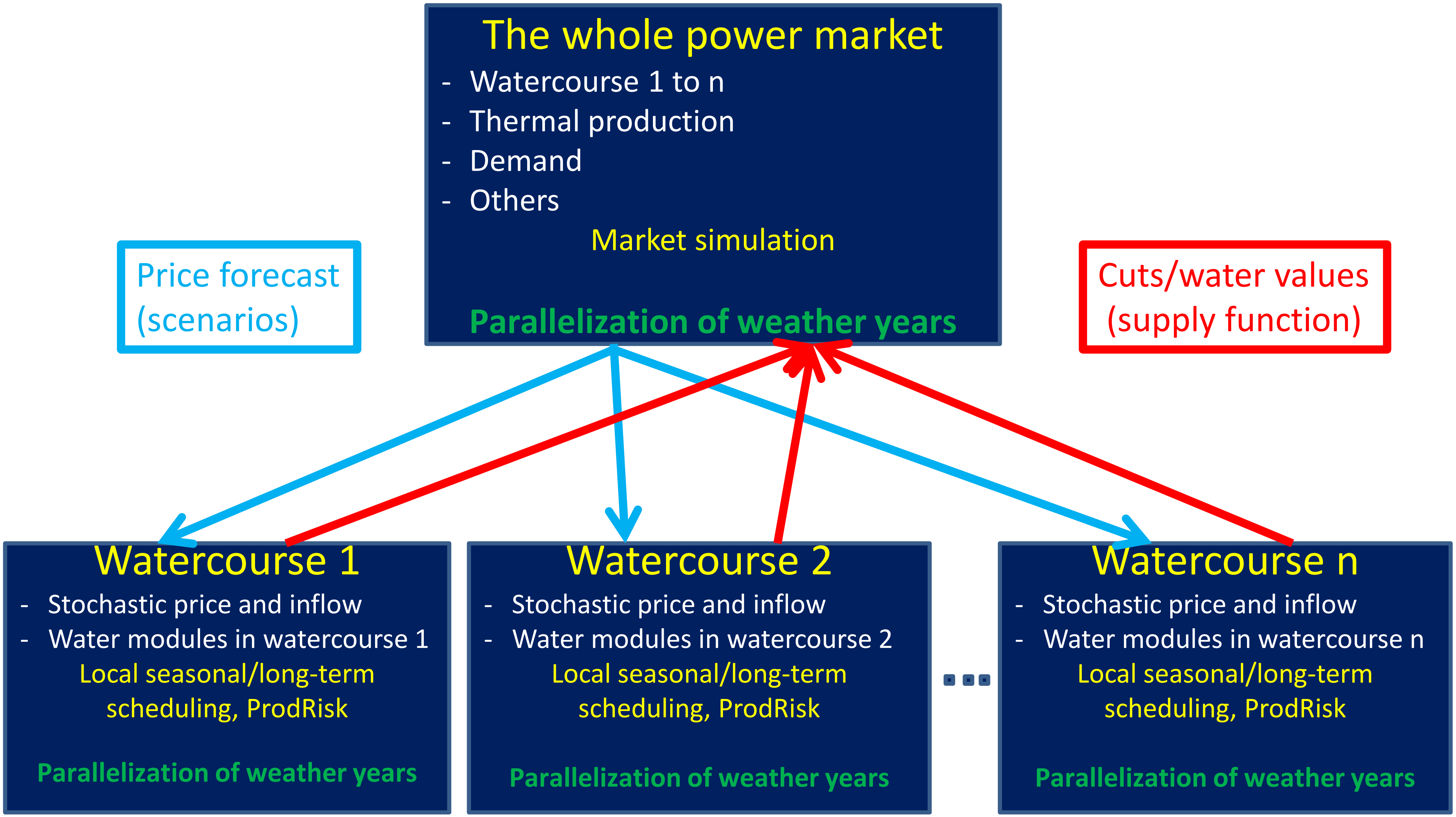
Principle in ProdMarket



Parallelization in ProdMarket

- Python – High level
  - Administrate the process and the processors
  - Handle input/output
  - Parallelization of sub – tasks (solved by Fortran - application)

- Fortran – Low level
  - ProdRisk, strategy
  - Parallelization with MPI (etc.)

Summary/Experience

- Can "easily" speed up calculations in old and new applications using parallel processing
  - Utilize hundreds or thousands of cores
  - Large servers or Computer cluster
  - Computation time: weeks to hours, or hours to minutes
  - But there are pitfalls

- Multi-level parallelization:
  - High level language
    - Easy to implement parallelization, and combine with existing code
  - Low level language
    - MPI, by defining groups of processes

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