Some Ideas on Data Rate Reduction for Measurement Data Transmissions in Hierarchical Smart Grid Environments

Andreas Pillekeit

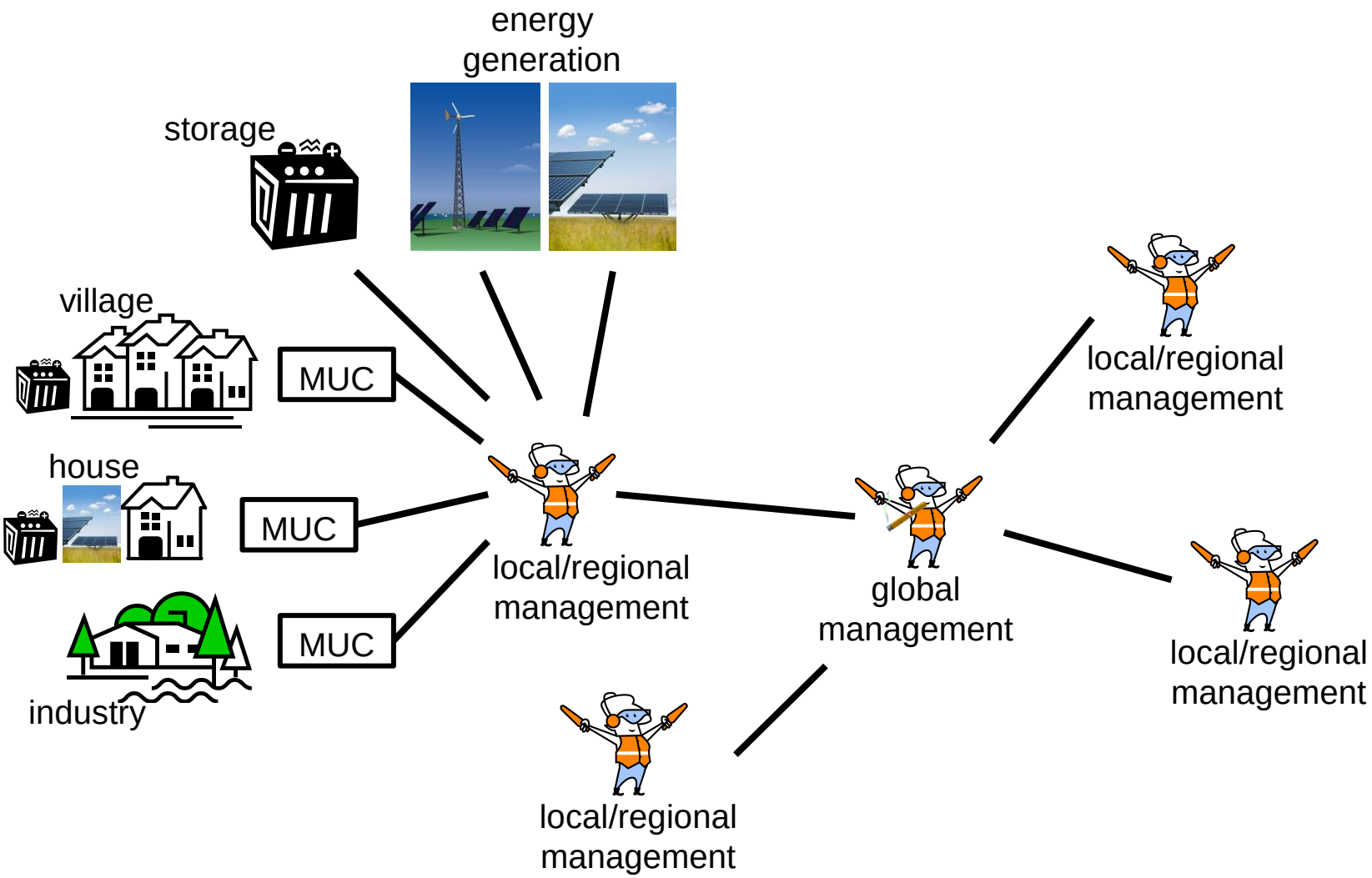
Research Group Systems Modelling, ICB,
University of Duisburg-Essen

Andreas.Pillekeit@icb.uni-due.de

Aim

- Usage of regression models for reducing communication demands of measurement data transmissions
- Original time series of measured data is represented by a regression model
  - Lossy representation of time series!
  - Increased level of uncertainty!
- Only model parameters and a few additional parameters are transmitted
- Model is used to forecast behavior until next model parameter transmission

Environment



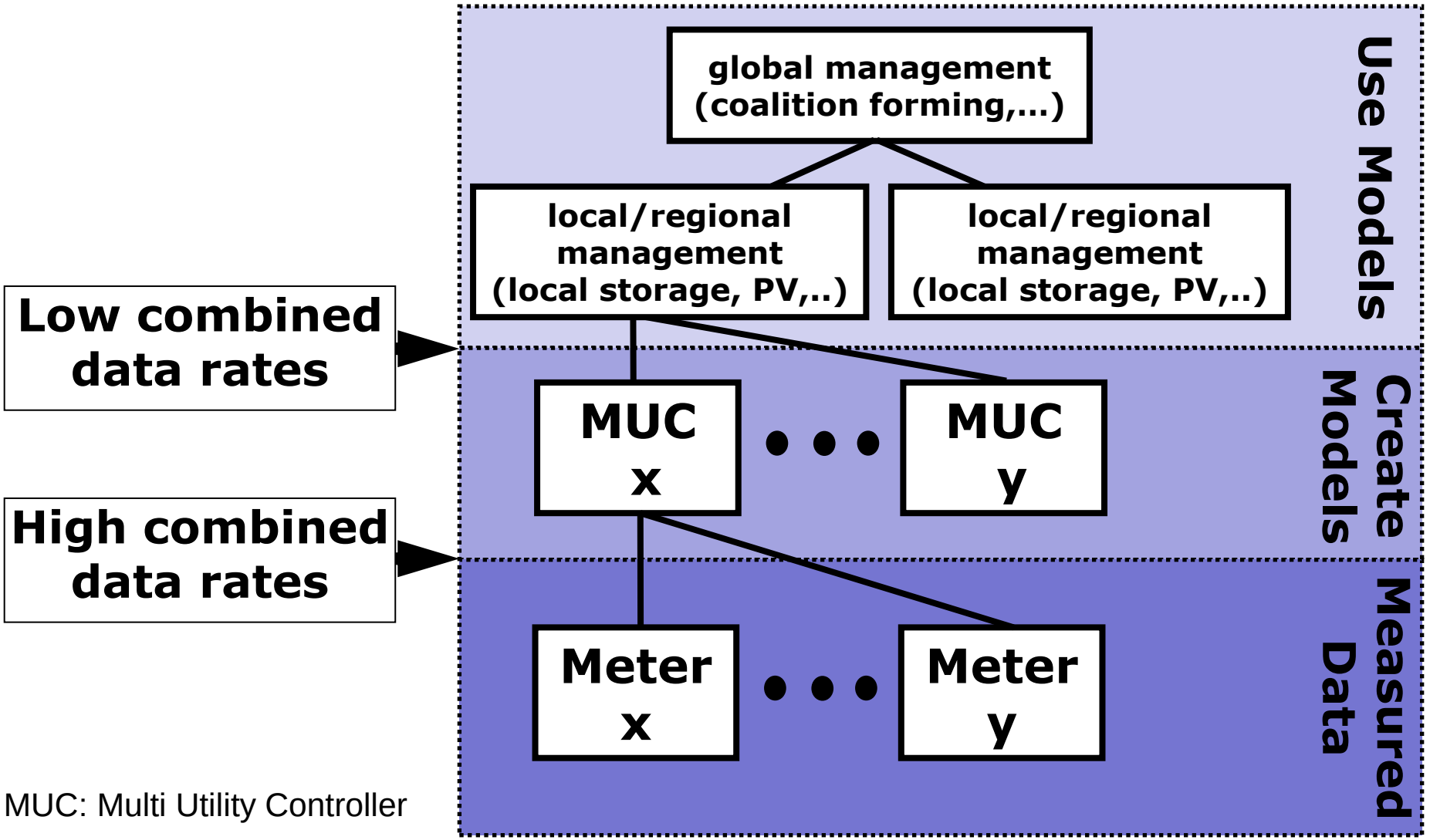
Outline

- System Model Description
- Example
- Open Questions

Outline

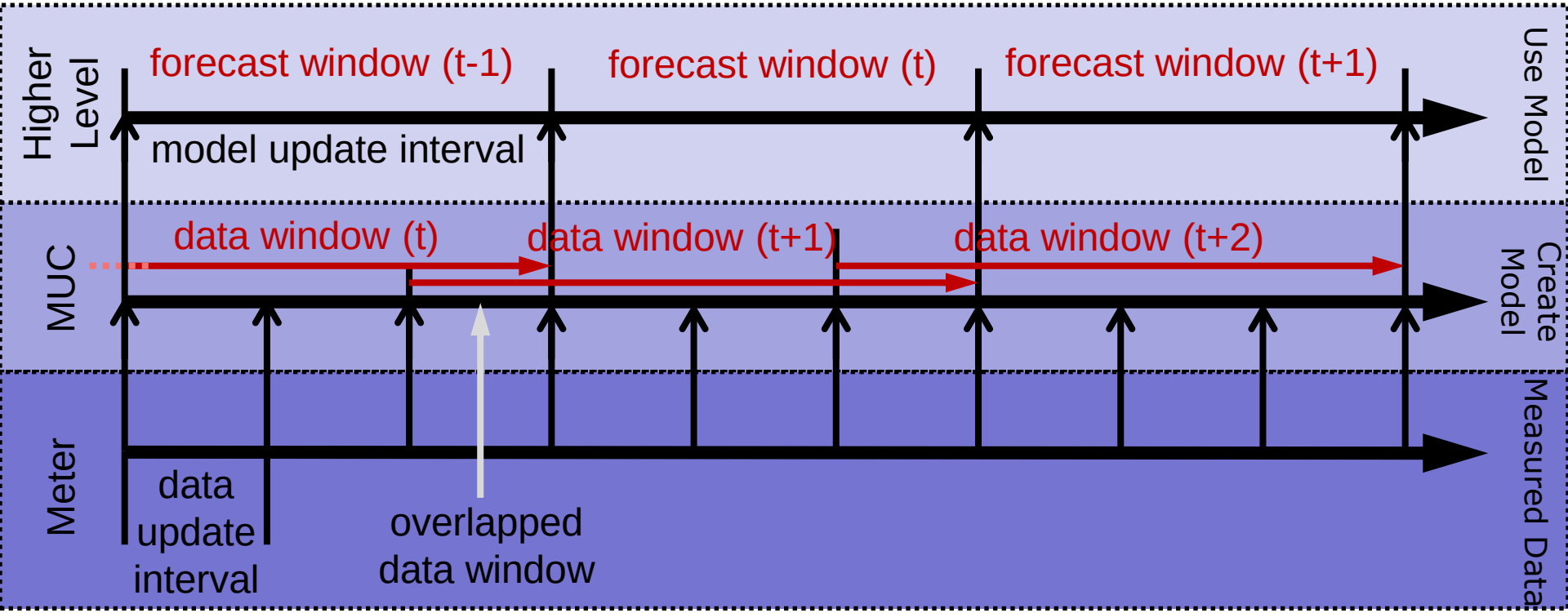
- **System Model Description**
- Example
- Open Questions

General System Model



MUC: Multi Utility Controller

Model Update Process



intended time horizon: sec up to hour

Model Update Process - Commentary

- Data updates from meter represent time series at MUC
- Data update interval is not necessarily constant! (e.g. due to intelligent recording)
- Data updates within one data window are used to estimate regression model parameters and variance
- Model parameters are sent to higher level according to the model update interval (interval is not necessarily constant!)
- Model parameters are used to forecast behavior until next model update event
  - Short term forecasts! Intended time horizon is seconds up to hours

Implications Derived from Update Process

- Size of model parameters has to be smaller than size of time series information within one data window
  - Model update interval has to be large enough
  - Lossy model -> increased uncertainty
- Data window should cover enough data updates to obtain a sufficient time series for model parameter estimation
- Time series information can be reused for model parameter estimation (overlapping data windows)
  - Higher storage requirements in MUC
  - Model is less responsive to short term changes if overlapping window increases
- Forecast window should be shorter than data window to achieve sufficiently accurate forecasts
  - Short enough to be accurate and long enough to reduce data transfers sufficiently

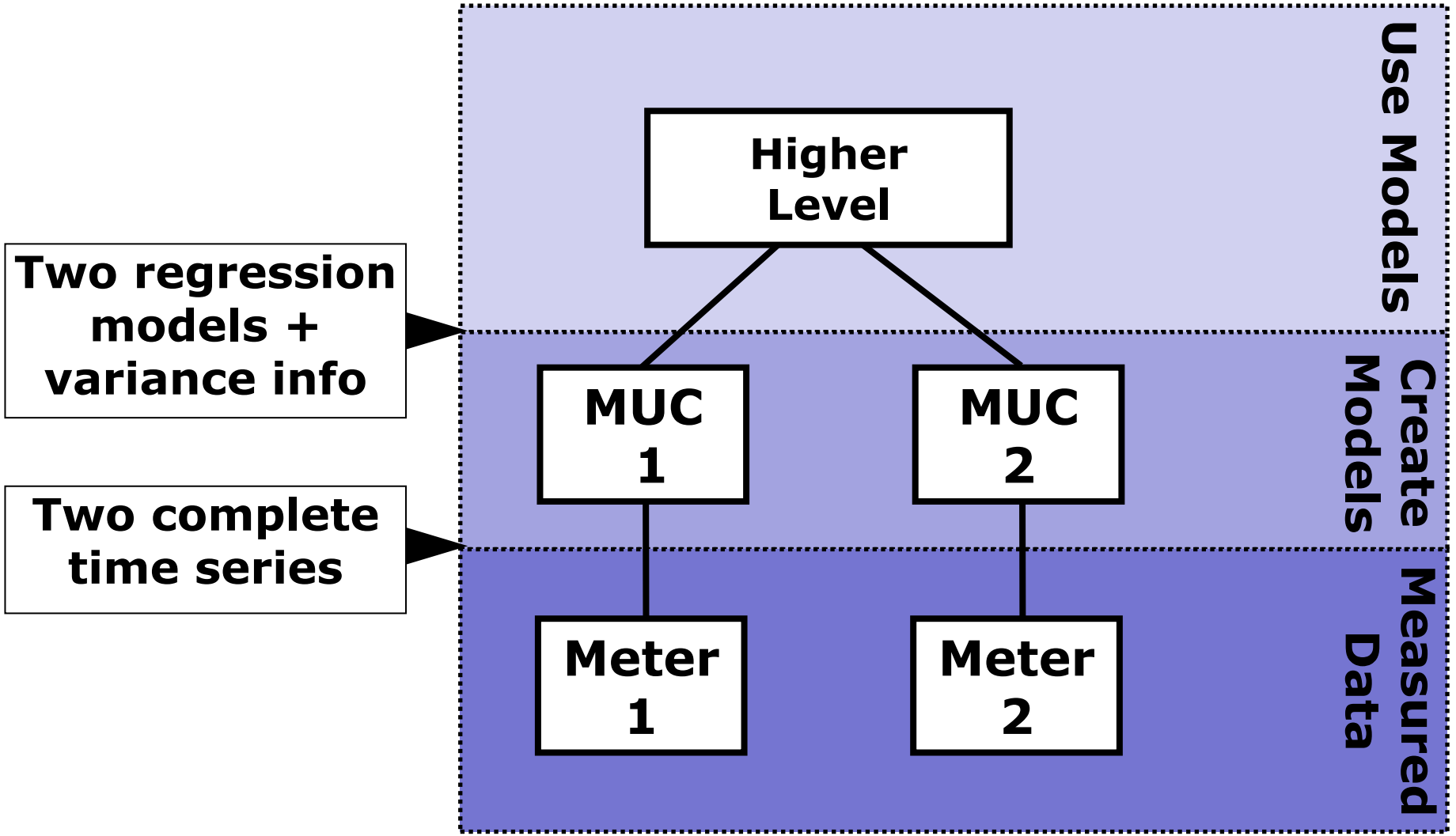
Model Parameter Estimation

- Regression model has to be defined in advance
  - MUCs and higher levels have to know the model
  - Necessary for merging parameters
- Straightforward combination of regression model parameters
  - Parameters merge like original data
  - Good for hierarchical system models (Smart Grid)
  - Low computational effort for merging
- Estimation of merged noise (variance) is more difficult
  - Solved by heuristic estimation of cross correlation based on model cross correlation and variance information

Outline

- System Model Description
- **Example**
- Open Questions

Example Model

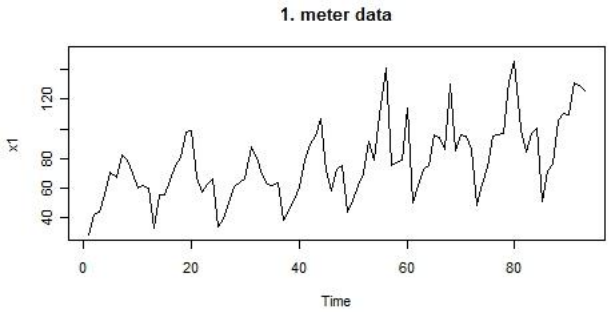


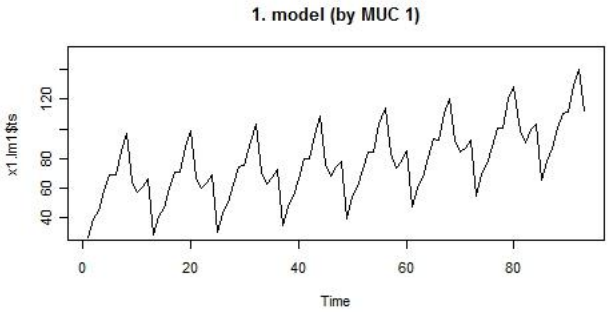
Regression Model

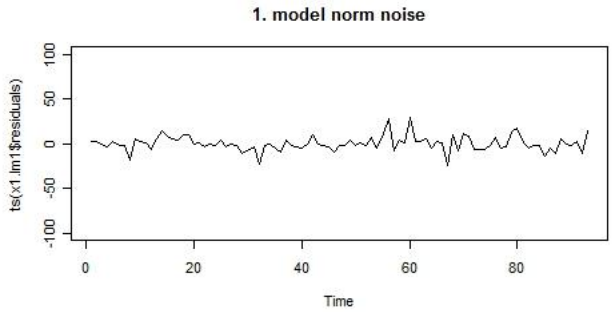
- Linear model with additive seasonal variables
  - Just as an example!
  - b_i, s_i, c_i (slopes) & f (period frequency) are model parameters
  - Time is the only modeled influence
    - Other predictor variables can be integrated
  - w_t noise information

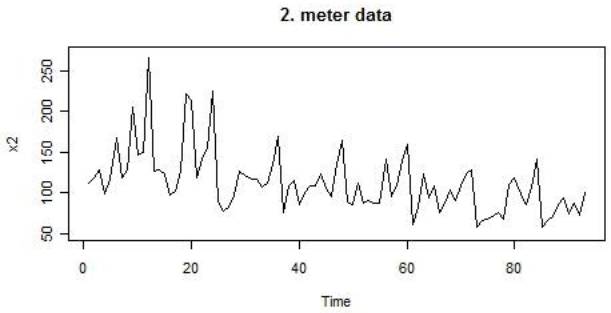
$$x_t = b_0 + b_1 t + b_2 t^2 + \sum_{i=1}^{[f/2]} \left\{ s_i \sin\left(\frac{2\pi i t}{f}\right) + c_i \cos\left(\frac{2\pi i t}{f}\right) \right\} + w_t$$

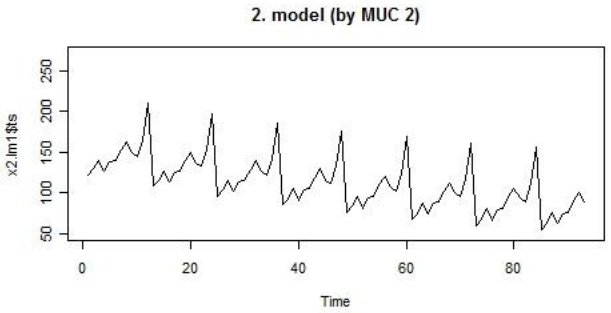
Merging Process of Example

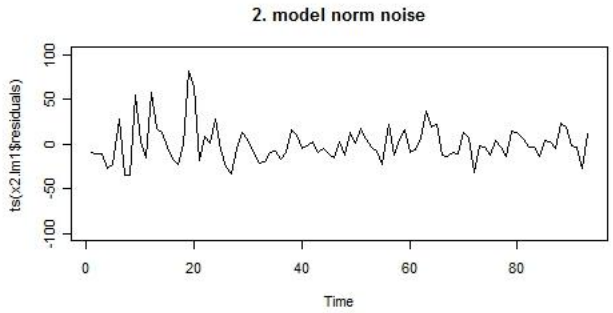


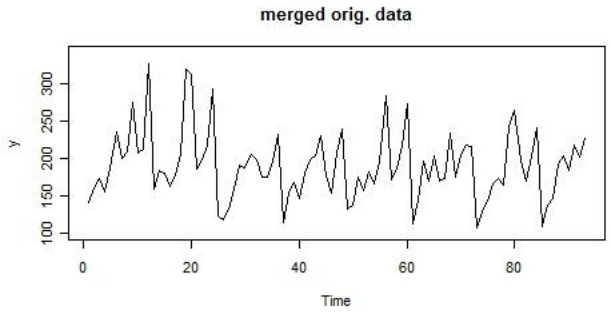


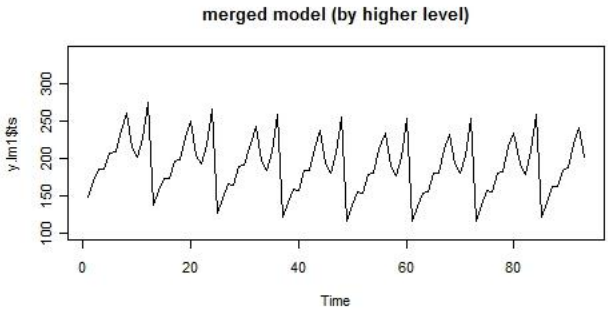


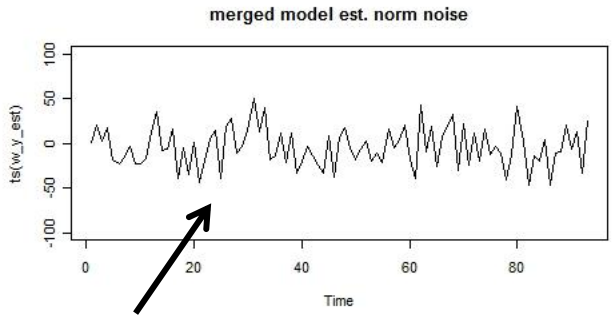












random process with distribution type and variance estimated based on model cross correlation and variance of 1st and 2nd model

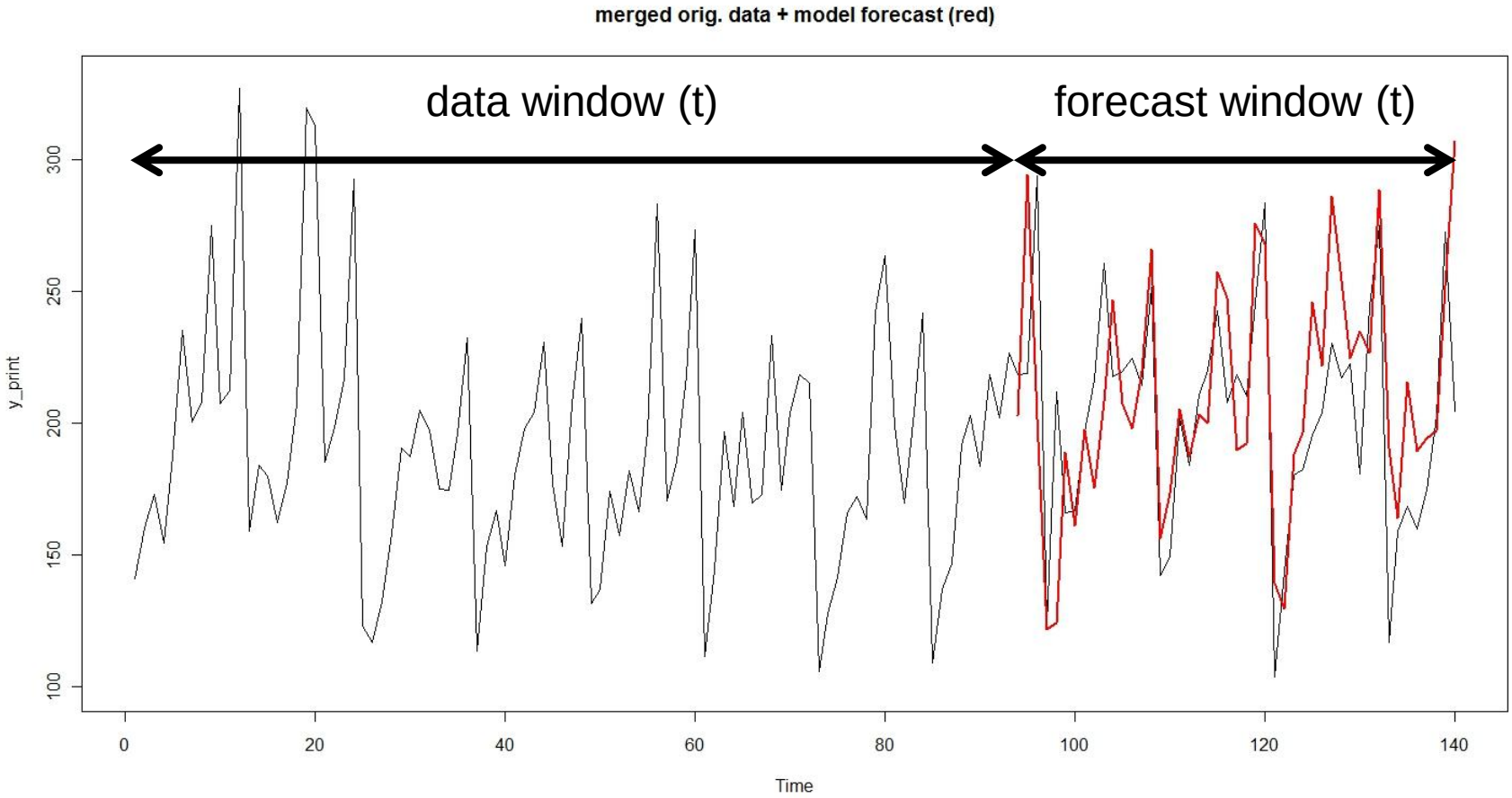
Comparision of Models for Merged Data

- Parameter match of merged model and model of original merged data

Parameter	Difference
b0	-2.842171e-14
b1	-2.220446e-16
b2	1.734723e-18
c1	7.105427e-15
s1	-3.552714e-15
c2	7.105427e-15
s2	-4.440892e-16
c3	7.105427e-15

Parameter	Difference
s3	-1.776357e-15
c4	1.776357e-15
s4	-1.776357e-15
c5	0.000000e+00
s5	2.331468e-15
c6	1.776357e-15
s6	1.562500e-02

Model Forecast for Example Data at Higher Level



- This forecast window has half the size of the data window
  - Forecast window should be shorter than data window
  - Relation depends on allowed uncertainty (to be investigated)

Evaluation of Example

- Comparison of mean and variance in data window (t)

Parameter	Merged original data	Merged Model
Mean	189.7	189.7
Variance (incl. noise)	2075.4	1949.6
Variance of noise	591.6*	465.82+

(*) based on regression model residuals (+) estimated

- Comparison of mean and variance in forecast window (t)

Parameter	Merged original data	Model forecast
Mean	203.3	211.2
Variance (incl. noise)	1810.7	1949.6
Variance of noise	n/a	465.82

Evaluation of Example (II)

- Merged model fits well in data window
- Forecast is reasonable but has to be improved
  - Different regression model
    - Additional/other influencing variables (predictors)
  - Shorter forecast window
  - Different heuristic for variance estimation
- Original load time series needed to continue this work

Outline

- System Model Description
- Example
- **Open Questions**

Open Questions

- What kind of short term forecast models are already in use?
  - Time horizon: seconds, minutes or hours
  - Level: per household or per village
- What are the important parameters?
  - How important is variance information?
  - What are the important influences (e.g. sunshine level, wind, temperature…)?
- Is it possible to get original load time series?
  - Measured data at meters, at MUCs and at higher levels to derive a well fitting regression model