Workpackage 4:
Network-aware control and estimation

Maurice Heemels

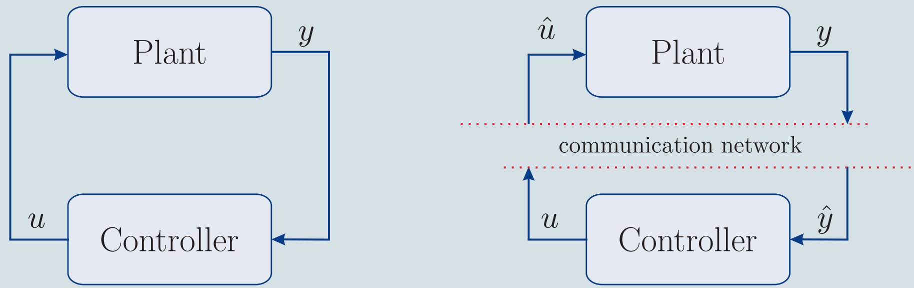
June 2010, End-user panel meeting

Overview Workpackage 4

Main tasks:

- **Task 4.1** Analysis methods of closed-loop systems operating over wireless networks
- **Task 4.2** Design methods for centralized and distributed network-aware MPC and estimation
- **Task 4.3** Prototype tools for network-aware and distributed control and estimation design

Networked control systems



(i) Varying sampling/transmission interval

(ii) Varying communication delays

(iii) Packet loss

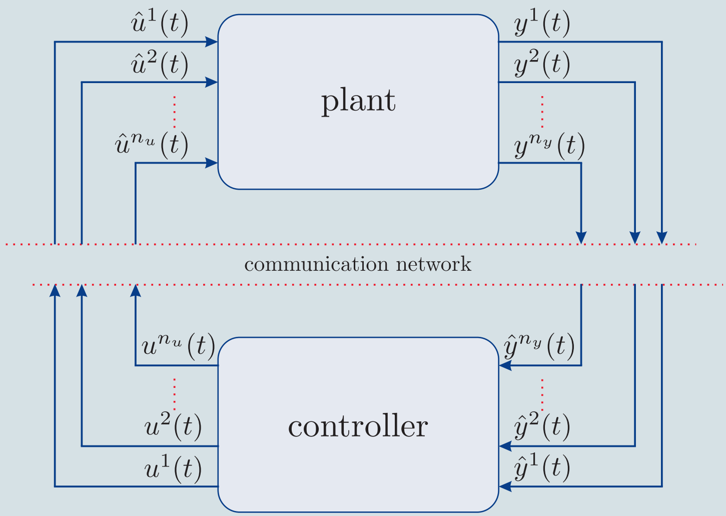
(iv) Communication constraints through shared network

(v) Quantization

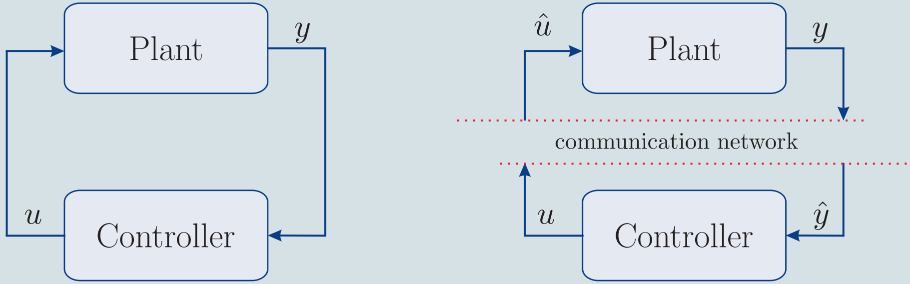
These (uncertain) effects influence stability and performance

Networked control systems

- Communication constraints:
  - Network is divided into sensor and actuator nodes
  - Only one node can access the network simultaneously
  - This gives rise to the problem of scheduling: protocols (RR/TOD)



Networked Control Systems



(i) Varying sampling/transmission interval

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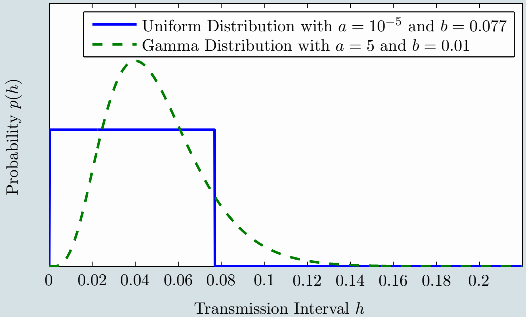
Task 4.1: Quantitative understanding effects on stability & performance
Task 4.2: Design methods for network-aware MPC and estimation

Main approaches

- Discrete-time modeling approaches
- Continuous-time modeling approaches

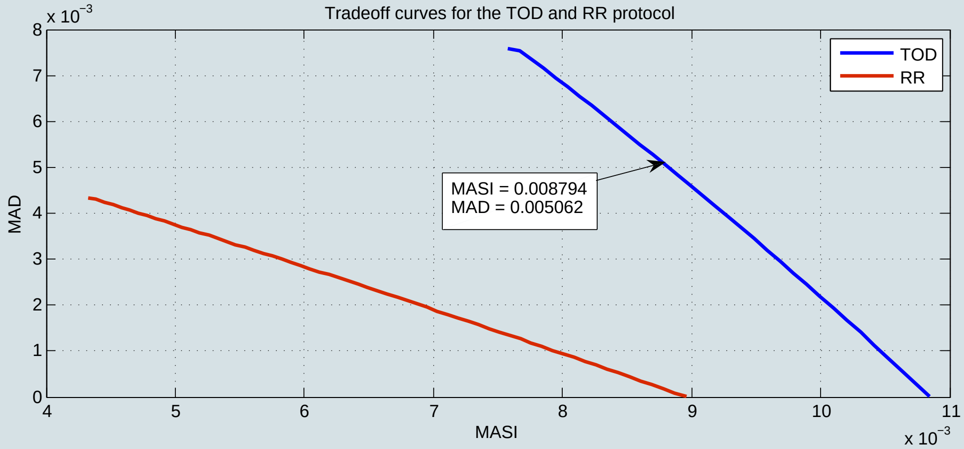
Models for network-induced imperfections:

- Deterministic bounds. E.g.
  - Delays $\tau_k \in [\tau_{min}, \tau_{max}]$
  - Sampling intervals $h_k \in [h_{min}, h_{max}]$
  - Maximal number of subsequent dropouts $\bar{\delta}$
- Stochastic models: Probability distribution function (PDF)



Stability and Performance analysis given network characteristics

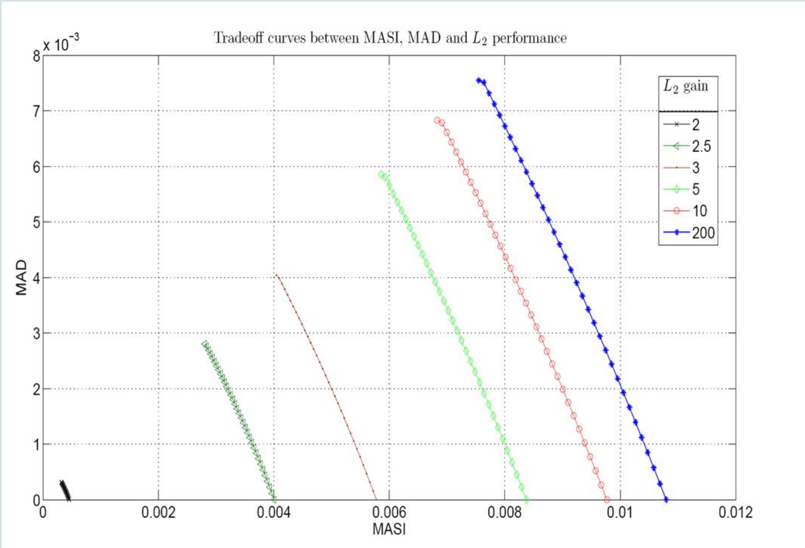
Benchmark example of batch reactor



Tradeoffs between

- MATI and MAD
- Protocols

Numerical results: including L_2 performance



Tradeoffs between

- MATI, MAD & performance: control and network properties!
- Protocols

WP 4 activities

Task 4.1 :

(i) Comparison of different methods (LKF vs LMI, different overapproximations) (CDC'09, HSCC'10)

(ii) Comparison how to "optimally" model packet dropouts in NCSs (ACC'10)

(iii) Inclusion communication constraints in discrete-time approach (HSCC'09):

(iv) Included delays and quantization in continuous-time approach (ECC'09, CDC'09):

(v) Stochastic models of WSN (WP2!) with true continuous PDF (ACC'10)

(vi) Improved methods

WP 4 activities

Task 4.2:

- Controller design of state feedback and observer-based decentralized “linear” controllers (CDC’09, ACC’10 initial results)
- Robust Model Predictive Control (MPC) algorithms that achieve a profitable trade-off between transmission rate (battery energy savings) and loss of closed-loop system performance (ECC’09)
- Experimental and initial testing of hybrid MPC algorithms in closed-loop with wireless sensors is described (NECSYS’09)
- Decentralized MPC over lossy communication channels
- Stochastic MPC schemes with guaranteed mean-square convergence (submitted)
- (Centralized and distributed) Kalman filters for “networked” measurements (delays, packet loss, etc)
- Simple frequency-domain methods for NCS (submitted)

Task 4.3:

- Initial implementations discrete-time and continuous-time approaches in MATLAB toolbox (in progress)

Outlook Workpackage 4

Central theme: Integration of the distributed MPC controllers, the distributed (Kalman) filters and the net-aware controllers.

Time separation: distributed MPC (slow sampling) combined with local wireless loops (fast sampling)

- Initial results available (see before).
- Compensation-based techniques (using time-stamping and sending larger control packets), observer-based control and dynamic output feedback controllers (e.g PID) for lower-level (local) feedback loops.

In particular,

- Complete the analysis/design framework to handle all 5 networked-induced phenomena
- Further development of MATLAB toolbox to spur academic and industrial usage
- Applying and verifying the ideas on the Barcelona water net and other test cases: PROOF-OF-CONCEPTS