NICCI

Network-Informed Control – Control-Informed network

Meeting in Aachen 2017

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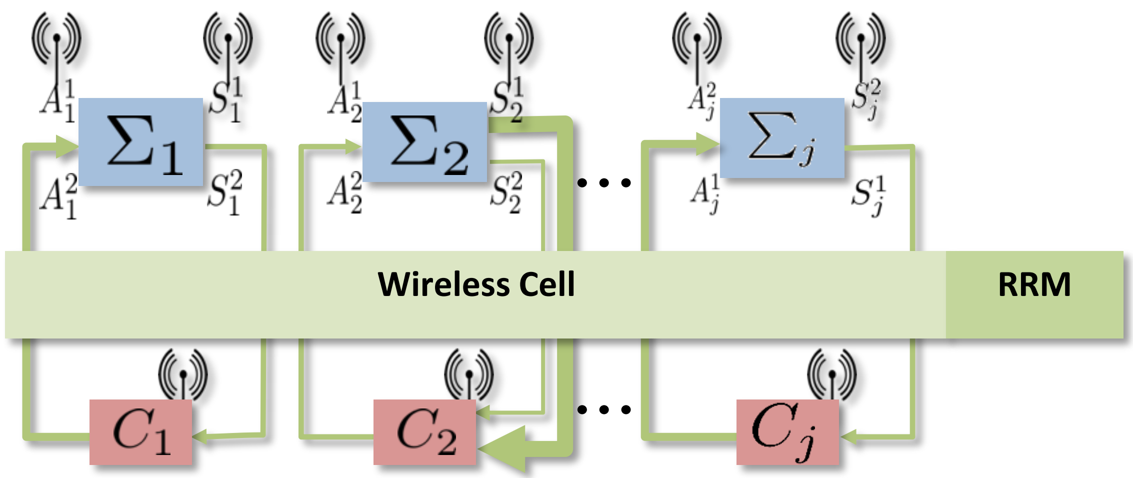
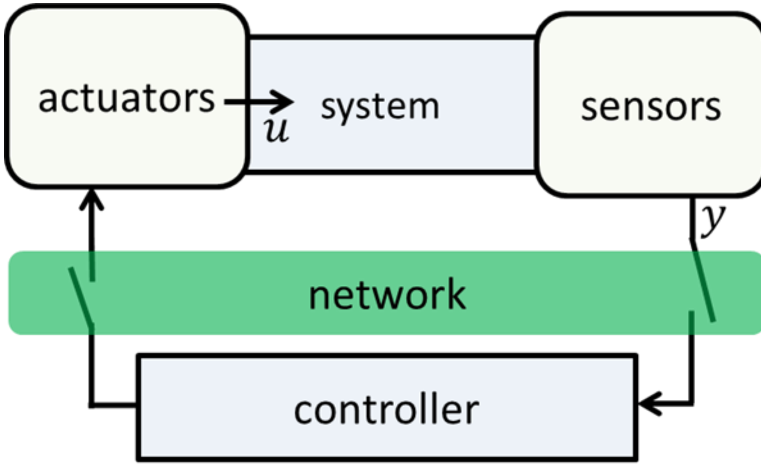


Network aware control
Evaluating limits of achievable performance (MD group)

Question – controller optimizes communication for performance
▶ determine when/what/where to send for optimal performance



Setup

- **dynamics**
  - **unknown, but bounded uncertainties**
  - **discrete, time linear dynamics**
  - noisy measurements
- **network**
  - **ideal communication** no loss/no (significant) delay
    (or compensated – data sent arrives before next time instant)
  - here: **one link to sensors/actuators** (extension straightforward)

Core idea: exploit **robust output feedback MPC**

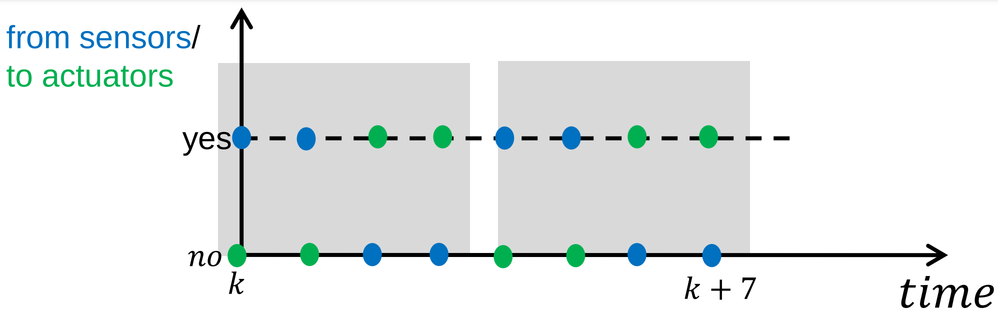
Challenge: when/what/where to send to optimize control performance

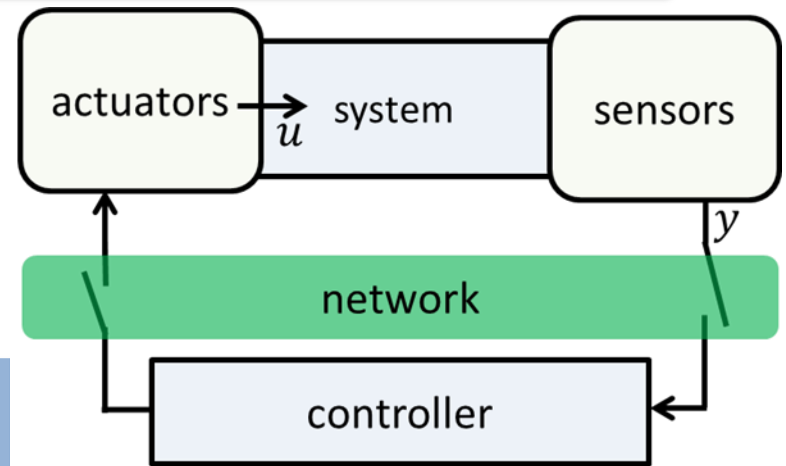
Trade-offs: (example) less latency or more data

Different communication choices possible (given by RRM)

Possible when/where to communicate formulations

- **each time instant one communication** from sensors or to actuators
- on **average 0.75 communications** each time instant





what to communicate (how much data):

naïve choice: sensors send y_k and controller u_k

actuators use backup $u_k = 0, u_k = u_{k-1}$ if nothing new is received

general case: multiple measurements/commands in each packet

a) piggy back old measurements, e.g. send y_k & y_{k-1} at k

b) send input sequences, e.g. send u_k & u_{k+1} at k

Solution approach to optimize communication

- **consider fixed communication schedule tube**
- **simple performance evaluation necessary + avoid influence of tuning**

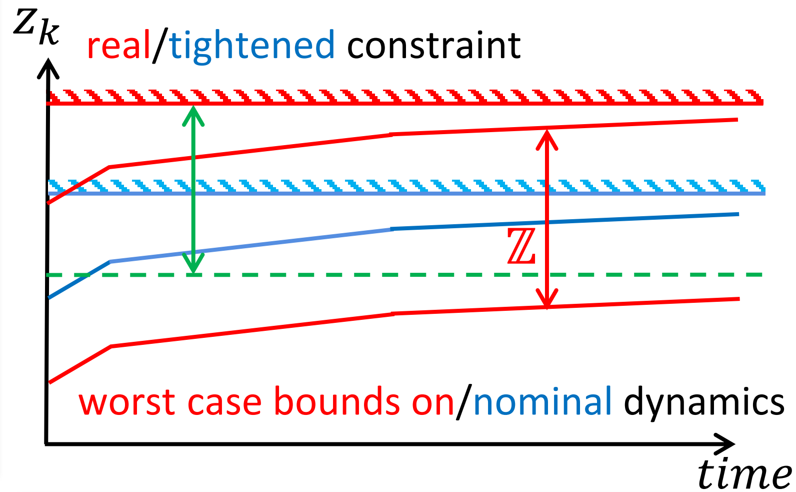
Combination with robust output feedback MPC: basics

Framework

- LTI system with bounded process noise
  $x_{k+1} = Ax_k + Bu_k + w_k, w_k \in \mathbb{W}$
- constraints on state x_k and input u_k
  $x_k \in \mathbb{X}, u_k \in \mathbb{U}$
- sensor measurements, bounded noise
  $y_k = Cx_k + v_k,\ v_k \in \mathbb{V}$

"economic" performance

$z_k = Fx_k + Gu_k$



Robust output feedback MPC:

tube approach: decompose dynamics into

1. **nominal system** (no noise) + MPC
2. **error systems** + **fixed, linear controller**

Control objective:

worst case optimal set-point tracking

- minimize back off from constraints (set $\mathbb{Z}$) – tune "tube controller"

Contribution:

automated "optimal" controller design (for given communication schedule)

- **allows to compare different communication schedules**
- **guarantees on closed loop behavior** (constraint satisfaction, robust stability)
- **computationally efficient**