Wireless Control: Opportunities and Challenges

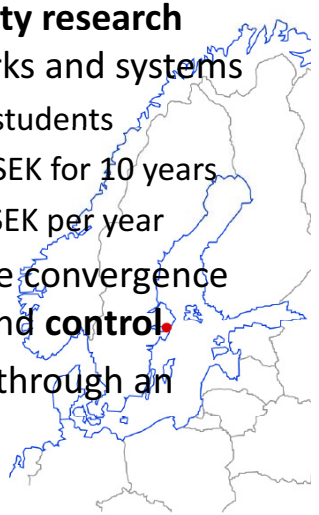
Karl Henrik Johansson
ACCESS Linnaeus Centre, School of Electrical Engineering
Royal Institute of Technology, Stockholm, Sweden

Joint work with Carlo Fischione, Mikael Johansson, Henrik Sandberg
Dimos Dimarogonas, Maben Rabi, Alexander Seuret
Jose Araujo, Piergiuseppe Di Marco, Erik Henriksson
Magnus Lindhé, Pan Gun Park, Chithrupa Ramesh, Per Sahlholm

Automationsdagarna, Stockholm, 4-5 Feb, 2009

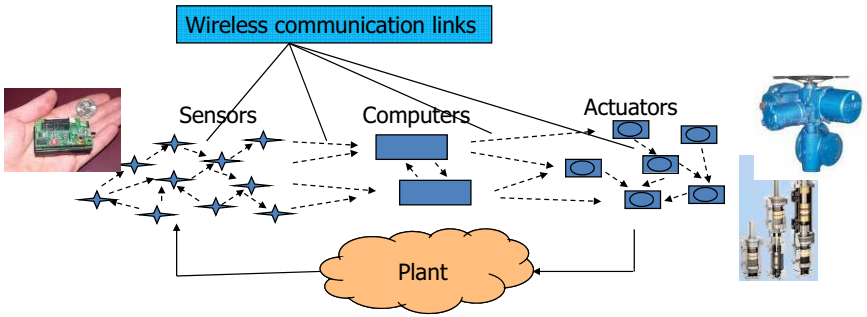
ACCESS Linnaeus Centre

- One of Europes's largest **university research center** in communication networks and systems
  - 35 senior researchers and 80 PhD students
  - Basic funding from VR on 111.5 MSEK for 10 years
  - Total research budget about 50 MSEK per year
- Cross-disciplinary research on the convergence of **computing**, **communication** and **control**
- Strong **industrial collaborations** through an industrial partnership program

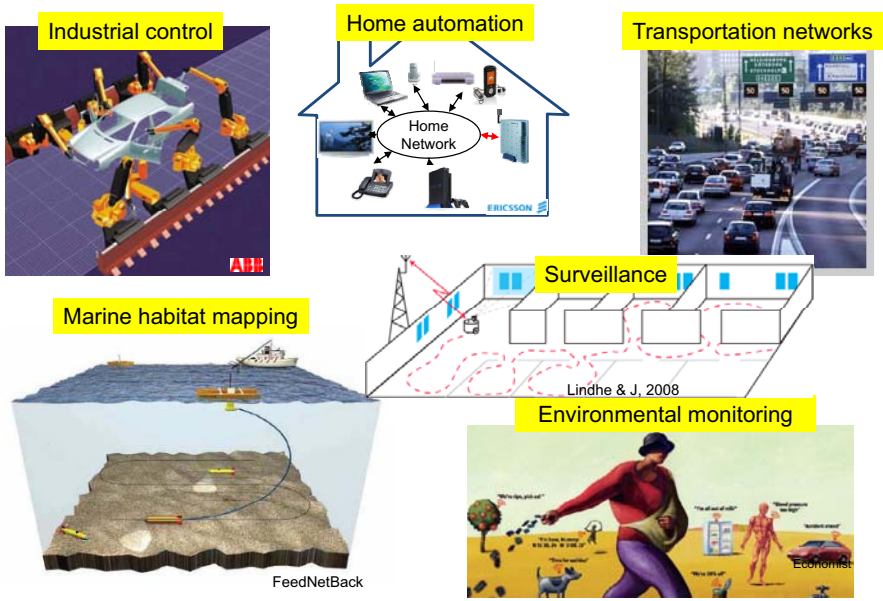


Wireless feedback control system

- A wireless network of computer devices able to monitor and control a physical plant

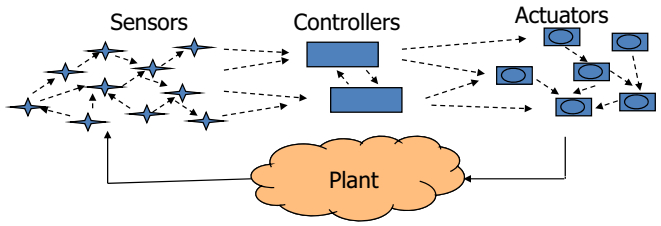


Wireless control applications



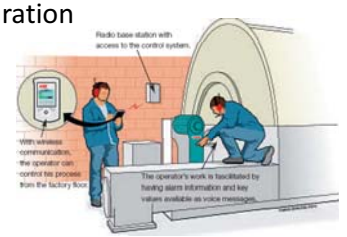
Key questions

- How communicate sensor and control data?
- How compute control actions?

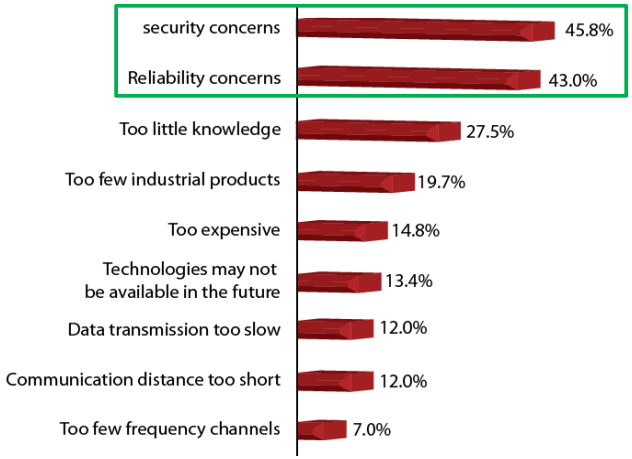


Benefits of wireless networking in industrial control

- **Cost**
  - Reduced wiring
  - Reduced installation work
- **Flexibility**
  - Less physical design limitations
  - More mobile equipment
  - Faster commissioning and reconfiguration
- **Robustness**
  - No cable wear and tear
  - No connector failure

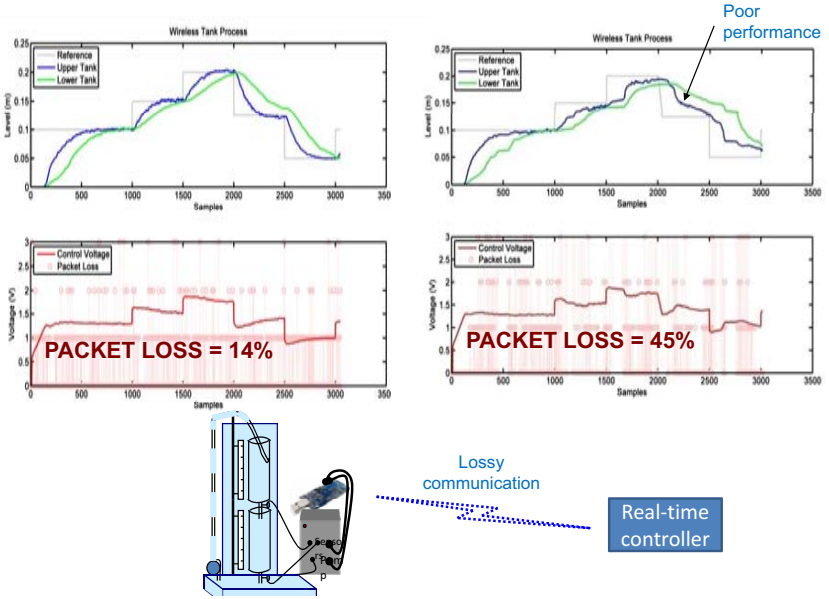


Concerns about wireless networking in industrial control

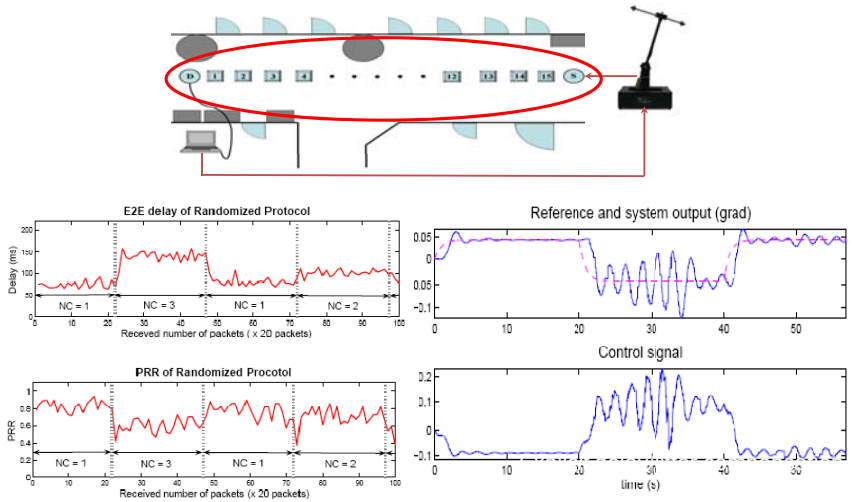


"Market pulse: Wireless in industrial systems: cautious enthusiasm", Industrial Embedded Systems, Winter 2006

Packet loss influence on feedback control



Multi-hop network **delay** influence on feedback control

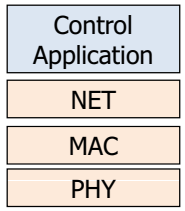


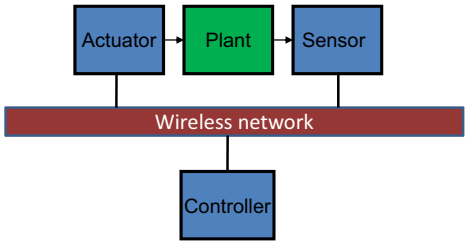
Witrant et al., *IEEE CCA,* 2007

A communication or a control problem?

Approaches to control over wireless networks

1. Communication protocol suitable for control
2. Control application that compensates for communication imperfections
3. Cross-layer solution with integrated design of application and communication layers





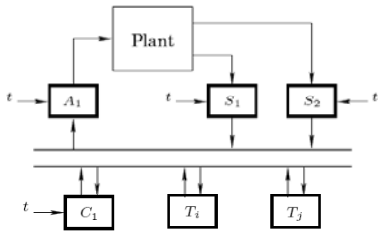
A fundamental challenge in wireless control

A traditional conflict between

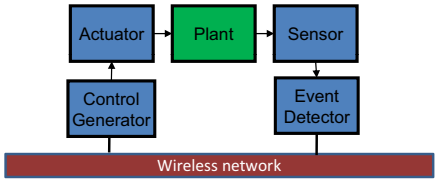
- time-driven, synchronous, sampled data **control engineering**

and

- event-driven, asynchronous, ad hoc **wireless networking**



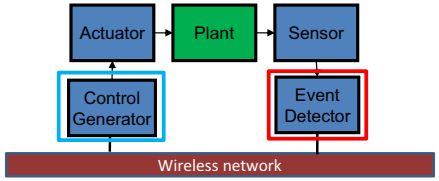
A new architecture for wireless control



Rabi and J., *WICON, 2008*

When to transmit?

- Medium access control mechanism at sensor
  - E.g., threshold crossing



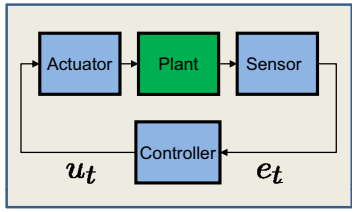
How to control?

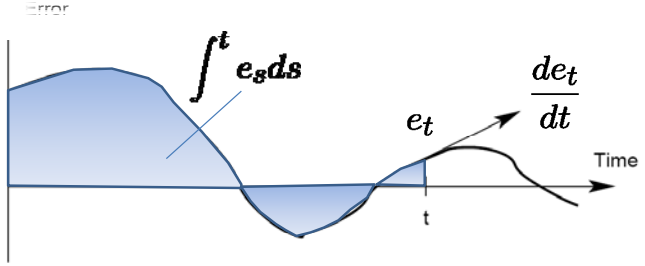
- Execute control law on fixed control alphabet
  - E.g., piecewise constant controls

Rabi et al., *2008*

Proportion-Integral-Derivative control

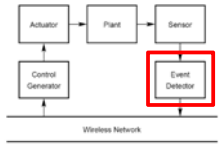
$$u_t = K_P e_t + K_I \int^t e_s ds + K_D \frac{de_t}{dt}$$

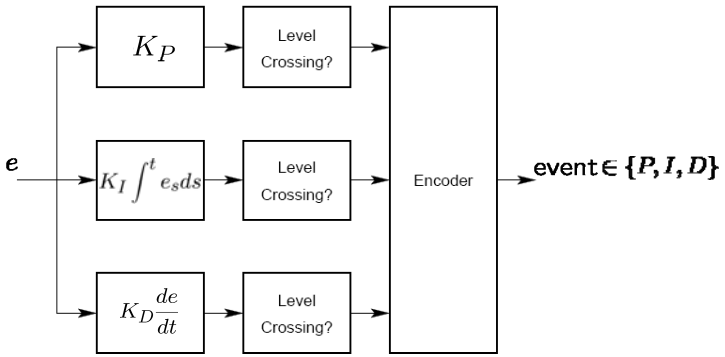




How extend PID control to event-based control?

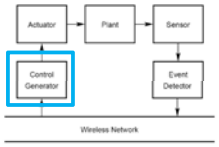
Event-detector for PID control

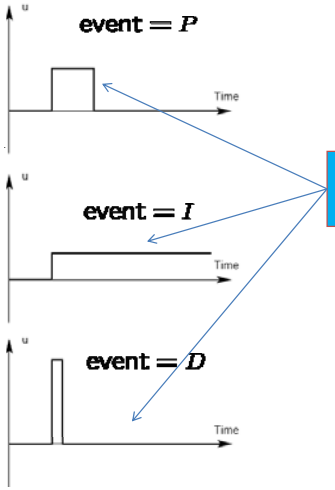




Rabi and J., *WICON, 2008*

Control generator for PID control

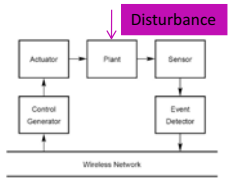


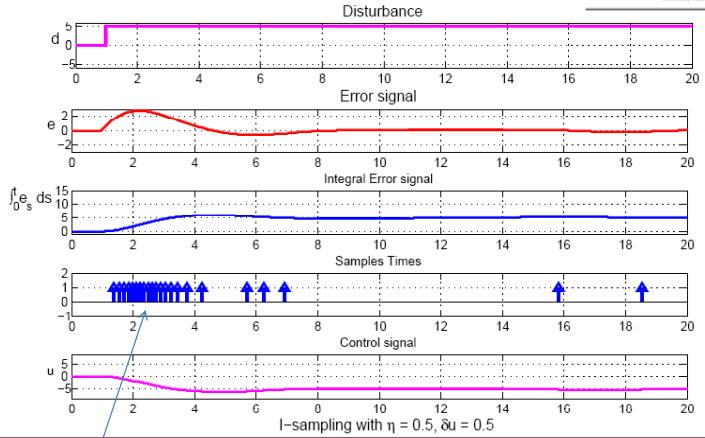


Control alphabet consists of three symbols, which are activated depending on the event

Rabi and J., *WICON, 2008*

Example: Integral control

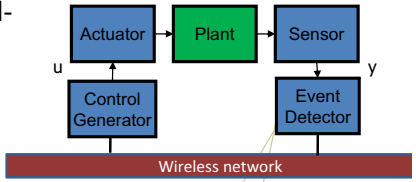


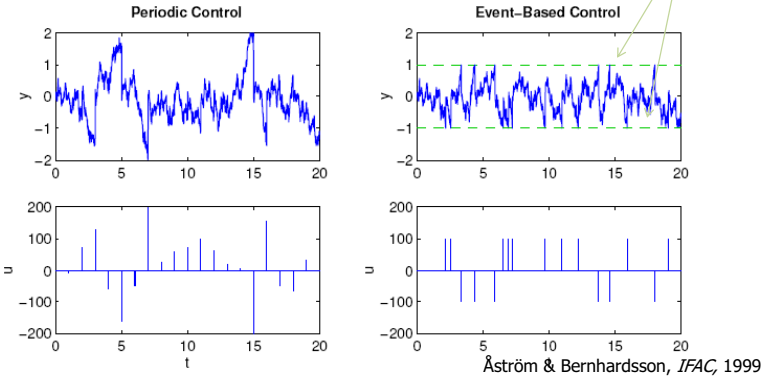


- Communicate only when integral error triggers events

Example: Impulse control

- Event-detector implemented as fixed-level threshold at sensor
- Better control performance than periodic control

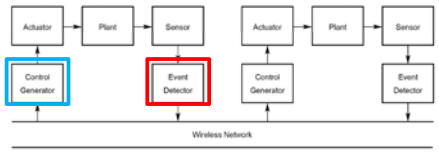




Åström & Bernhardsson, *IFAC,* 1999

Conclusions

- Wireless control and monitoring will be everywhere
- Potential **challenges** due to data loss, radio interference, delay variations and system complexity
- **Solutions** are being developed based on an integrated view of control and wireless networking:
  - Communication: new protocols suitable for feedback control
  - Control: new control architectures and methods



Slides and more information available at http://www.ee.kth.se/~kallej