Handover of Autonomous Driving Functions: From Theory to Practice

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Joint work with D. van Dooren, S. Schiessl, K. Johansson
Machine-Type Communications: Origins

**Autonomous monitoring & metering purpose**
- End of 90s: First conceptual research on “sensor networks”
- Mid 2000: First standards (802.15.4, 6LowPAN)
- ~2010: Picked up by cellular networking industry (M2M business)
Closing the Loop …

- Closed-loop control (driven by autonomy trend)
- Dependability becomes the focus: Latency & reliability ➔ Critical machine-to-machine communications!
Dawn of New Application Class?

Local Computation

Virtualized Control

Sensor

Actuators

Local Fusion / Control

Global Fusion / Processing / Control

Dynamic, interactive mapping

Local Computation

Mobile Network / Edge Resource

Backbone / Internet

Cloud Centre

Processing Environment
Handover - Motivation

- Control-type of application run over cellular network
- Handover of the application required due to mobility
- Example: Platoon-control for autonomous driving
Model & Problem Statement

• Given infrastructure (base stations, mobile nodes, links)
• Leader-follower scenario, control of distance and speed
• Control strategy executed at base station
• Samples/commands transmitted over time-varying links

• Given a safety region, can we compute instantaneous safety level?
• Can we derive from that a switching policy for handover?
Model & Problem Statement II

2 handover types considered:
Break-before-make vs. Make-before-break
Safety Analysis

- Linear stochastic plant model, regularly sampled
- Analysis by hybrid system approach:
  - Control system traverses through different states
  - System might be in open loop for a certain period!

- Probabilistic reachability analysis performed [Abate, 2008]
Example Numerical Results

• Two base stations, links characterized by PER
• Simple two-car scenario assumed
• Disturbance to the plant by leading vehicle
• Linear quadratic regulator applied

• Sampling time of 100 ms
• Choice of safety region, target safety level of $1 \times 10^{-4}$
• Transient safety analysis over the next $\sim 4$ s
Example Numerical Results

Safety violation probability analysis

Plant in equilibrium, $p_{c2} = 0.1$
And now to practise: CMA Stockholm

- 5G Cloud services
  - demand prediction
  - management of fleet
  - traffic information

- Service platform
  - accurate, tailored information

- Mixed travel modes and fleets
Conclusions

• Ubiquitous control as new application class?
• Open problems with respect to control and communication system design:
  • Here: How to characterize safety violations at run-time in the presence of a handover?
• State of the plant matters a lot in the management of the communication system
• But: Many effects not taken into account yet …
• How good do the models describe reality?