Towards Trustworthy Data in Networked Control Systems: A Hardware-Based Approach

Thomas Ulz, Thomas Pieber, Christian Steger[1]
Rainer Matischek, Holger Bock[2]

[1]Graz University of Technology
[2]Infineon Austria AG

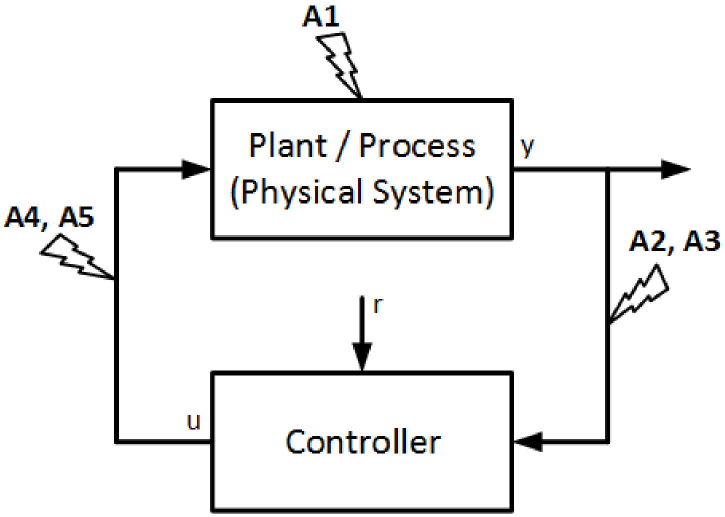
Outline

1. Introduction
2. State-of-the-Art
3. Approach Securing NCSs
4. Conclusion and future work

Introduction

- Networked Control Systems (NCS) are gaining popularity
  - E.g. Smart Factories and “Industrial Internet of Things”
- Increase in popularity entails higher interest of attackers
  - Attacks targeting NCS become more frequent
- Proper functionality of the NCS must be ensured
  - Malfunctioning NCS might have severe consequences for the system or the controlled process
  - Or even threaten human lives

Introduction



- By introducing network interfaces between sensor, controller, and actuator
- Also new potential attacking points introduced
- → Network communication must be secured!

– **A1**: Attacks directly targeting physical process

– **A2**: *Deception attacks*, attacker injects false information $\tilde{y} \neq y$

– **A3**: Denial-of-Service Attacks

– **A4**: Attacker induces false control commands $\tilde{u} \neq u$

– **A5**: Denial-of-Service Attacks

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    1. Authenticated encryption
    2. Joint encryption and error correction
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State-of-the-Art

- There are several research challenges for NCS
  - Network delays
  - Packet loss
  - Information security
- Regarding information security, the following properties must be protected for data transferred in an NCS
  - Confidentiality
  - Integrity
  - Availability
  - Authenticity

State-of-the-Art

- No current work aims to protect all 4 of these properties
- Most often, DoS attacks are mitigated (Availability)
  - By considering the ensuing packet loss in the NCS
- To protect data confidentiality, encryption is applied
  - However, data integrity and authenticity not considered
  - We will show in this presentation why applying plain encryption in an NCS is not a good idea

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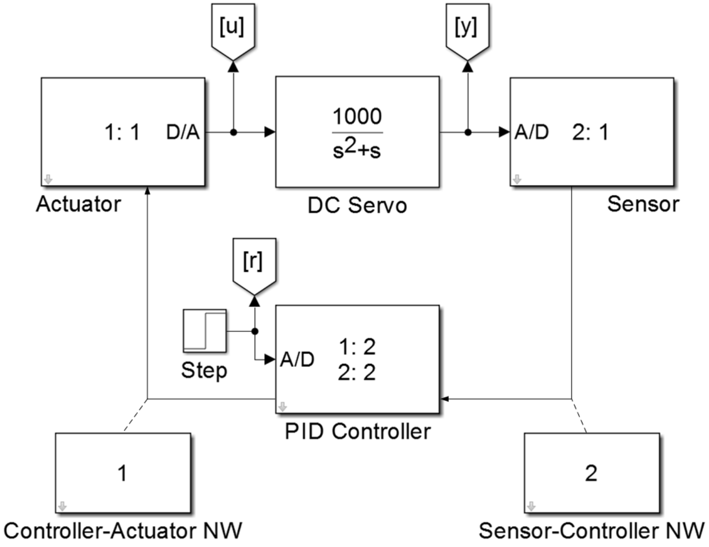
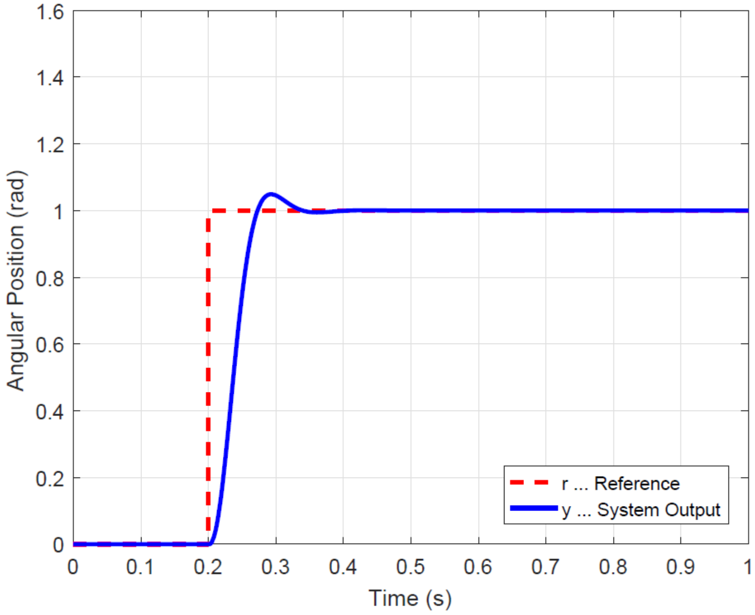
Securing NCSs – Simulation Model

- To evaluate the presented approaches, a DC Servo with a transfer function $G(s) = \frac{1000}{s\,(s+1)}$ was used.
- The model was simulated in Matlab/Simulink and the TrueTime toolbox



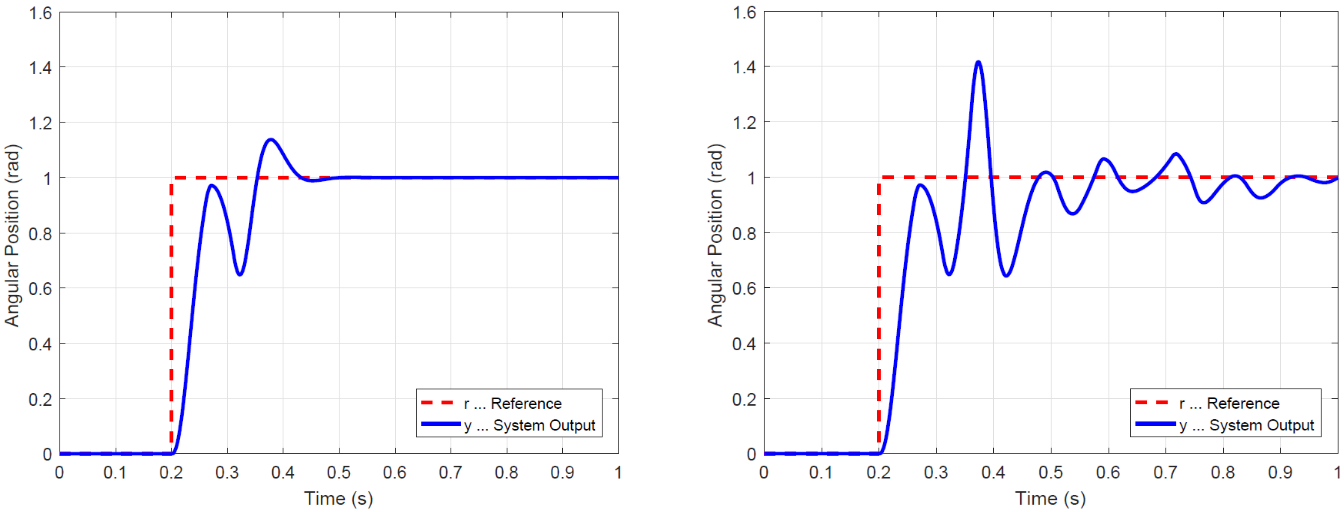
Securing NCSs – Simulation Model

- For this model, we applied a simple PD-controller
- This leads to the following step response for a system without any network delays or errors



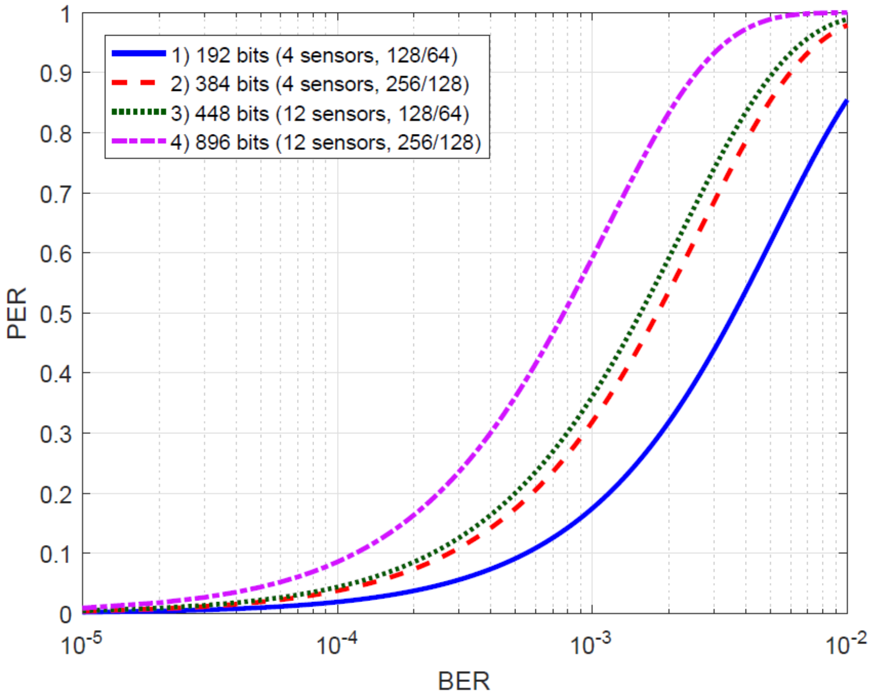
Securing NCSs – Authenticated Encryption

- Instead of currently used basic encryption
- Applying “Authenticated Encryption” (AE), where data “Confidentiality, Integrity, and Authenticity” can be provided
- But, a single bit-error renders the data packet useless!
- The following step responses were simulated for bit-errors of 25% and 50% respectively



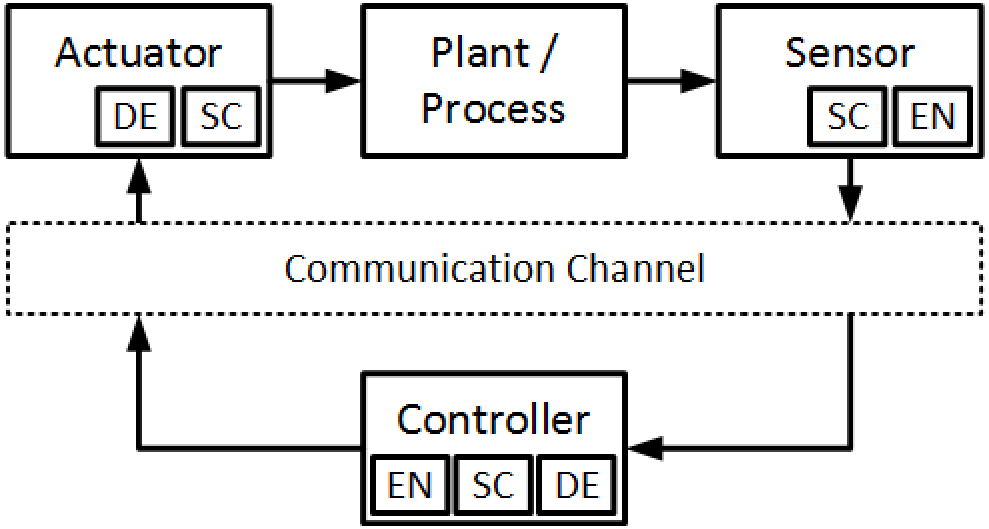
Securing NCSs – Authenticated Encryption

- Low bit-error rates already lead to high packet-error rates
- Suddenly, DoS attacks are easier to perform for attackers!



Securing NCSs – JEEC

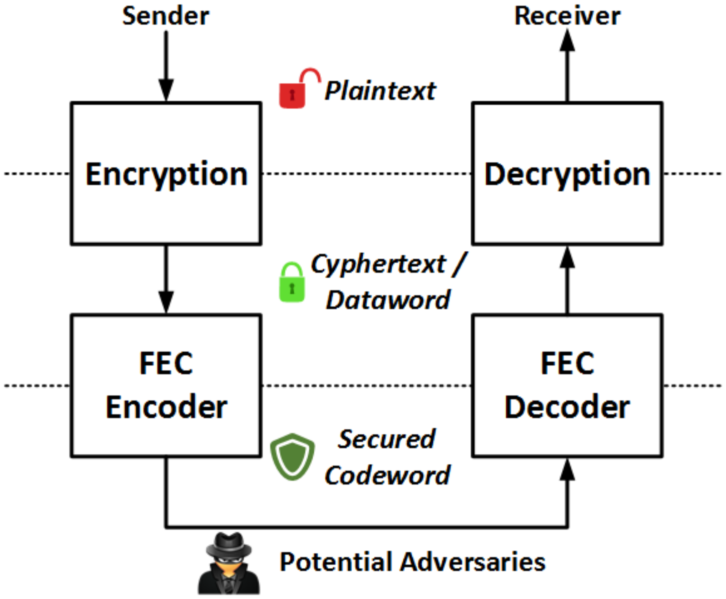
- To mitigate this self-induced problem, we apply “Joint encryption and error correction” (JEEC)
  - Well established principle from satellite communication
- Additionally combine with HW-Security-Controllers (SC)



Securing NCSs – JEEC

- By applying forward error correction (FEC), also DoS attacks are harder to perform for potential adversaries (“Availability” aspect)

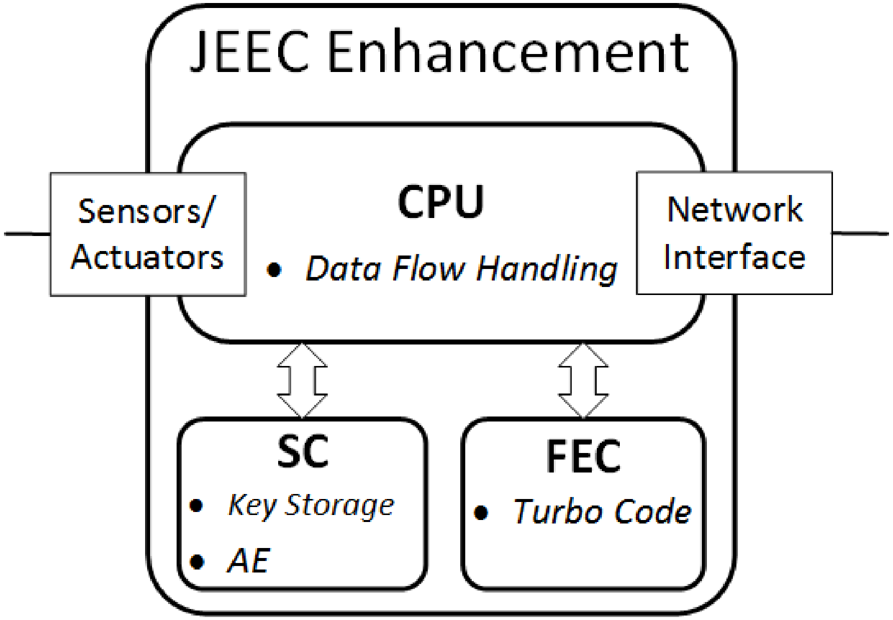
- The encrypted information with additional error correction data is transferred



- In addition, JEEC can be used for anomaly detection in the NCS

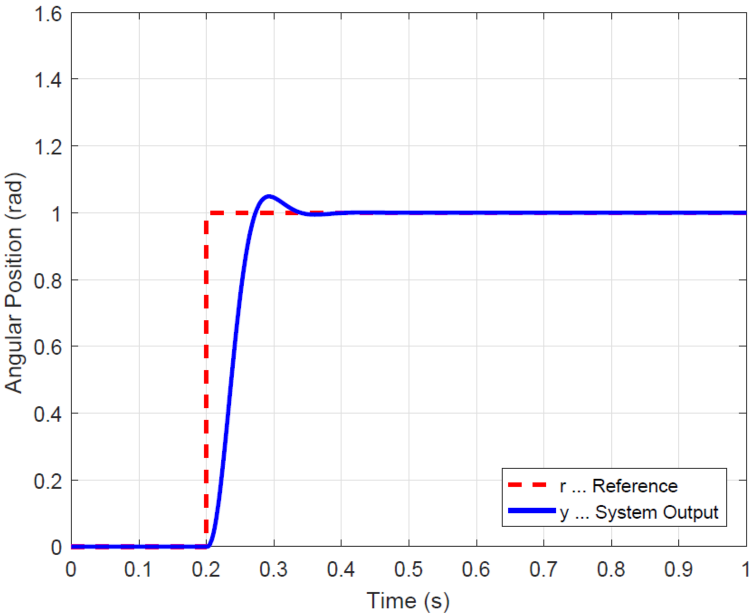
Securing NCSs – JEEC System Design

- In order to guarantee low additional delays due to the applied JEEC principle, and to be robust against potential SW-Attacks
- We propose a system design using dedicated hardware components (SC) to perform security related operations



Securing NCSs – Evaluation

- Using a low-delay JEEC enhancement, the initial step response for our simulation model can be achieved



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Conclusion

- In this paper, we highlight the security risks of NCSs
- We show, why simply applying pure encryption or authenticated encryption is not sufficient to provide confidentiality, integrity, authenticity, and availability for the system
- We propose to use JEEC to mitigate the problems induced by (authenticated) encryption
- To induce only minimal overheads, we propose a dedicated hardware enhancement for NCSs

Future work

- In our approach, we applied sequential JEEC
- However, there is also research aiming to combine (authenticated) encryption and forward error correction into one step
- In theory, this should allow to build smaller and faster hardware extensions to perform this step
- Currently, we are investigating such algorithms in SystemC simulation models

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Questions?

Thank you!

For detailed questions please contact main author:
Thomas Ulz <thomas.ulz@tugraz.at>