SAARLAND UNIVERSITY

SAARBRÜCKEN GRADUATE SCHOOL OF COMPUTER SCIENCE

Latency- and Resilience-Aware Cyber-Physical Networks

Thesis Proposal Colloquium

Andreas Schmidt, MSc
Telecommunications Lab
Saarland Informatics Campus - Saarbrücken

May 17, 2017

Being Cyber-Physical

SAARLAND UNIVERSITY
SAARBRÜCKEN GRADUATE SCHOOL OF COMPUTER SCIENCE

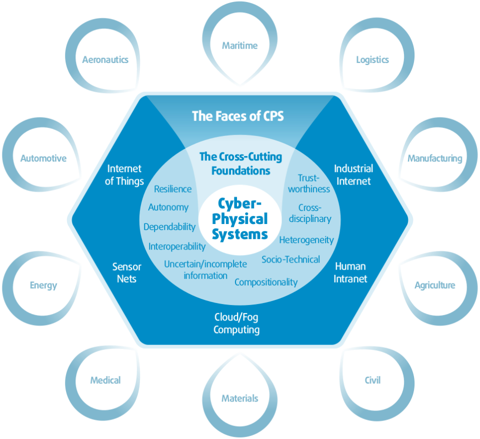
Cyber	**Physical**
digital	analog
timeless	temporal
discrete	continuous
information	weight, size, energy, force, power, temperature, ...
clean	dirty
intangible	tangible

Being Cyber-Physical

Cyber	**Physical**
digital	analog
timeless	temporal
discrete	continuous
information	weight, size, energy, force, power, temperature, ...
clean	dirty
intangible	tangible

Cyber-Physical := Bridging the gap, bringing the two worlds together.

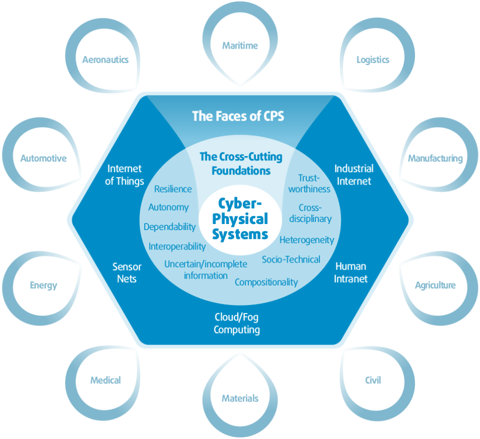
Cyber-Physical Applications



Source: CPS Summit Action Plan 2016

Cyber-Physical Applications

SAARLAND UNIVERSITY
SAARBRÜCKEN GRADUATE SCHOOL OF COMPUTER SCIENCE



Source: CPS Summit Action Plan 2016

All technologies are about **networking** and **communication**.

Problems and Questions

Latency

- How long does an operation / a transmission take? (in the best / average / worst case)
- (How likely) will it finish on time? Is an extra millisecond enough?

Problems and Questions

Latency

- How long does an operation / a transmission take? (in the best / average / worst case)
- (How likely) will it finish on time? Is an extra millisecond enough?

Resilience

- (How likely) will my message arrive?
- How can I deal with faults?
- How can I increase the success rate of my applied measures?

SAARLAND UNIVERSITY
SAARBRÜCKEN GRADUATE SCHOOL OF COMPUTER SCIENCE

Latency

- How long does an operation / a transmission take? (in the best / average / worst case)
- (How likely) will it finish on time? Is an extra millisecond enough?

Resilience

- (How likely) will my message arrive?
- How can I deal with faults?
- How can I increase the success rate of my applied measures?

System Design

- How to ensure proper (temporal and functional) operation?
- How to cross system layers to improve performance?

Network Edge

- Improved Network Applications
- Advanced Protocols
- ...

Approaches

Network Edge

- Improved Network Applications
- Advanced Protocols
- ...

Network Core

- Virtual Network Functions
- Specialized Network Equipment (Routers, Access Points, ...)
- ...

Network Edge

- Improved Network Applications
- Advanced Protocols
- ...

Network Core

- Virtual Network Functions
- Specialized Network Equipment (Routers, Access Points, ...)
- ...

Cross-Layer Design

- Co-design operating system and network stack.
- Reduce latencies and increase resilience by exposing the “right” aspects of hardware, operating and network system to the application.

Existing Solutions

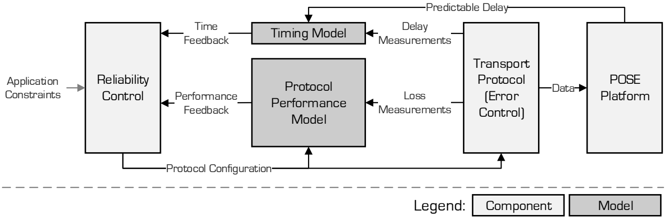
- TCP: Fully reliable, ordered byte-stream. Vulnerable to loss, no time bounds.
- UDP: Best effort, hardly any robustness or timing. (post cards)

Existing Solutions

- TCP: Fully reliable, ordered byte-stream. Vulnerable to loss, no time bounds.
- UDP: Best effort, hardly any robustness or timing. (post cards)

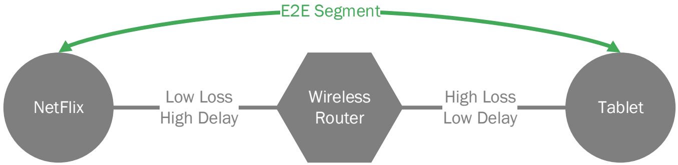
Problem: No time- and resilience-awareness.

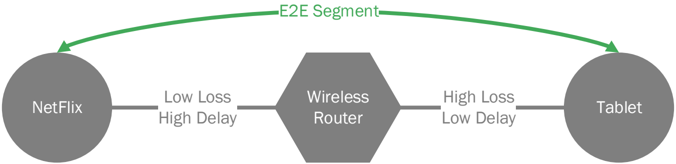
SAARLAND UNIVERSITY
SAARBRÜCKEN GRADUATE SCHOOL OF COMPUTER SCIENCE



Predictably Reliable Real-time Transport (PRRT)

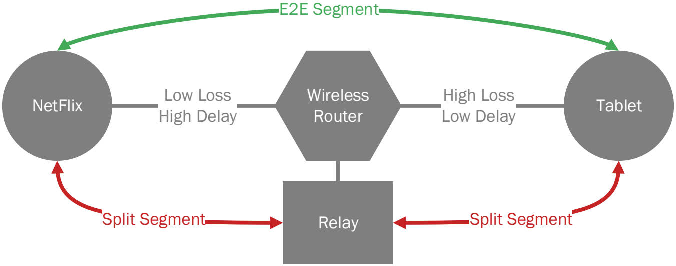
- We build a **predictable, reliable network protocol** that takes **application constraints** and the **channel** into account.
- We combine it with **reliable operating systems stacks**.


E2E Segment
NetFlix
Low Loss
High Delay
Wireless
Router
High Loss
Low Delay
Tablet



End-to-End (E2E)

- Important functions (e.g. reliable transport) **must be implemented E2E**.
- E2E ignores differences on intermediate links (one **virtual connection**).
- **Treating links differently** can be more **optimal** (fine-tune error control).
- Important for **everyone** (content- and access-providers as well as users).



Transparent Transmission Segmentation (TTS)

- Segment the network with respect to **domains** (loss, data rate, congestions).
- Improve performance of **network functions** (congestion, error, and flow control).
- Achieve **better performance** (throughput, resilience, latency).
- Segment in a **transparent** manner (end-host do not change).

Proof-of-Concept [ICCE-Berlin'16, NetCPS'16, ICCC'16]

- Formulated requirements, evaluation methodology and the **general concept**.
- First tests showed that **TTS** with TCP can **outperform E2E**.
- With a 3% loss probability on the last hop, ...
  - **mean RTT** with TTS **reduced by 4%** and **RTT jitter is reduced by 16%** and
  - TTS is faster in **91.7%** of the cases.

TTS: Results

Proof-of-Concept [ICCE-Berlin'16, NetCPS'16, ICCC'16]

- Formulated requirements, evaluation methodology and the **general concept**.
- First tests showed that **TTS** with TCP can **outperform E2E**.
- With a 3% loss probability on the last hop, ...
  - **mean RTT** with TTS **reduced by 4%** and **RTT jitter is reduced by 16%** and
  - TTS is faster in **91.7%** of the cases.

Detailed Investigations and Network Implementation [NetSoft'17]

- Identified relevant **network domains** and affected **network functions**.
- Implemented a **relay** within SDNs, to be automatically deployed and integrated into the communication.
- Proof that used abstractions and virtualization techniques induce **small footprint** and can effectively **improve performance**.

Project Work

LARN

Latency- and Resilience-Aware Networking

DFG Priority Programme 1914 "Cyber-Physical Networking"

- **Goal:** Cross-layer design of a **Reliable Networking Atom** (RNA).
- Developed **X-Lap**, a cross-layer, inter-host timing and jitter analysis tool. [RTN2017]
- Plan to improve **PRRT** based on X-Lap results.
  - Improved inter-process communication (lower latency and less jitter).
  - Incorporate measurements to provide bounds on processing delay.
  - Adapt API and internal functions to provide better performance.

Transparent Transmission Segmentation (TTS)

- Precisely quantify the **effects of segmentation** on performance.
- Develop **models for** predicting the **segmentation gains**.
- Compare **implementation and deployment aspects** with different protocols (TCP, RTP, PRRT) within modern network infrastructures.

Thesis Work

SAARLAND UNIVERSITY
SAARBRÜCKEN GRADUATE SCHOOL OF COMPUTER SCIENCE

Transparent Transmission Segmentation (TTS)

- Precisely quantify the **effects of segmentation** on performance.
- Develop **models for** predicting the **segmentation gains**.
- Compare **implementation and deployment aspects** with different protocols (TCP, RTP, PRRT) within modern network infrastructures.

Data Science for TTS

- **Research Question:** Where to put how many relays for good performance?
- Answer depends on network measurements and is complex to calculate.
- Data science approaches have raised interest of network engineers. [SIGCOMM'17 WS]
- Invited Talk "Towards (More) Data Science in Communication Networks" [NetSys'17]

Latency- And Resilience-aware Cyber-Physical Networks

- **Cyber-Physical Networks** require new approaches to provide **resilience- and latency-awareness** in communication.
- Many challenges **cannot be tackled with existing solutions**.
- **Predictably reliable real-time transport protocols** improve the situation at the network edge, making transmissions more efficient.
- **Intelligent segmentation solutions** to allow fine-grained network function operation in the network core.
- **Data Science** is essential for making educated decisions.

Latency- And Resilience-aware Cyber-Physical Networks

- **Cyber-Physical Networks** require new approaches to provide **resilience- and latency-awareness** in communication.
- Many challenges **cannot be tackled with existing solutions**.
- **Predictably reliable real-time transport protocols** improve the situation at the network edge, making transmissions more efficient.
- **Intelligent segmentation solutions** to allow fine-grained network function operation in the network core.
- **Data Science** is essential for making educated decisions.

Thank you for your attention. Questions?