Towards Real-time Wireless Cyber-physical Systems

Cyber-physical Systems District Romain Jacob [±] , Morce Zimmerling ² , Pengcheng Huang [±] , Jan Beutel [±] and Lathar Thiele [±]	
Wired industrial installations ar costly budy restricted erestrict	Ange effective wireless Dyber-physical Systems is challenging characteristics of the system of the system of the system end starting of the system of the system of the system effective field of the system of the system of the system field of the system of th
We address this challenge by Distributing global responsibilities to local components	Applications exchange packets via flows Flow F = (source, destination, T, D) • T = minimal interpacted relation • D = end to end deatline
Our solution is based on three building blocks: Node level Basec on IGM, a processor interconnect Oecopies Application and Communication sals Network level Wireless real (three protocol	Bell decaujus processon in time, powr and clock domain, while supporting predictable inter-communication
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200

Installation cost (\$) per meter of cable



http://cat5-wiring-hq.com

Sensors Actuators Controllers

Let's try to go wireless!

Developing effective wireless Cyber-physical Systems is challenging

Design Real-time guarantees goals

> End-to-end deadlines are met

Resource reservation

> No buffer overflow



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There is hope for Real-Time Wireless Cyber-Physical Systems!

```
We tackle the wireless CPS
challenge by combining...
Wireless real-time
                              Reliable
                   [1]
protocol
                             Adaptive | Communication
                              Real-Time
Dual-processor
                             Decouples Application
                   [2]
architecture
Distributed real-time
                              Ensures deadlines
protocol (DRP)
                              Prevents overflows
```

- [1] Zimmerling M. et al., *Adaptive Real-time Communication for Wireless Cyber-physical Systems* Tech. Rep., ETH Zurich, **2016**
- [2] Sutton F. et al., Bolt: A Stateful Processor Interconnect, SenSys'15, 2015

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DRP is based on *contracts,* which distribute responsibilities between components

DRP



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The challenging task is to *formalize* the contracts

Given sporadic "read" and "write" operations periodic wireless communication protocol

Requires to Define the local schedule constraints

- Perform a global worst-case analysis
 Delays Buffers
- Distribute the responsibilities

The simulated system correlates closely with the analysis

Simulated end-to-end delay compared to the analytic bound



[%]

Physical implementation of the protocol

Extensive testing on Flocklab public WSN testbed

Dependability evaluation and optimization

Probability of failure Retransmission scheme

Reaching meaningful performances

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ETT zürich Towards Real-time Wireless Cyber-physical Systems ETT LEMMISCHE UMWERSTAT Ramain Jacob [±] , Marce Zimmerling ² , Pengcheng Huang [±] , Jan Beutel [±] and Lathar Thilele [±]	
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Real-time guarantees System level DRP Distributed Real-time Protocol Ensures global guarantees • End to end decodince are met, • Buffer overflows are orevented. }	$\begin{array}{c} \text{Grave} \\ 0, \\ 0, \\ 0, \\ 0, \\ 0, \\ 0, \\ 0, \\ 0$
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