– MLCCA –
Multi-Level Composability Check Architecture for Dependable Communication over Heterogeneous Networks

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Outline

Motivation

Industrial Automation: Communication Demands

- Real-Time, reliable communication
- Heterogeneous systems
- Wireless networks gaining popularity
- Plethora of platforms and protocols

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Main Question

How to ensure end-to-end application communication requirements?

- Latency, jitter, omission degree, data throughput
- Scalability, portability (sensors . . . servers)

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$\Rightarrow$ Growing demand in industrial and other scenarios

MLCCA Approach

Multi-Level Composability Check Architecture

- Automated component composability checking
  - Application requirements
  - System (network stack, OS) properties
- Functional as well as non-functional attributes
- Integration into a common (communication) middleware

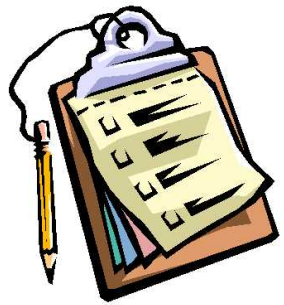
- Detection of mismatches as early as possible
- Multi-Level checking
  - Design Time
  - Compile Time
  - Run Time

Design-Time Checking

- System Design Tool
- Component Descriptions
  - Properties, requirements, ...
  - Machine processable; e.g. in XML

- What checks are possible on system compositions?
  - Completeness of specification
  - Correctness

Design-Time Checking



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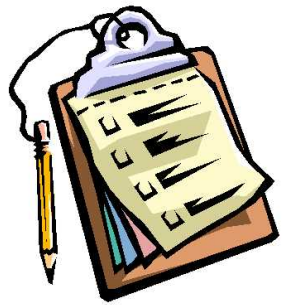

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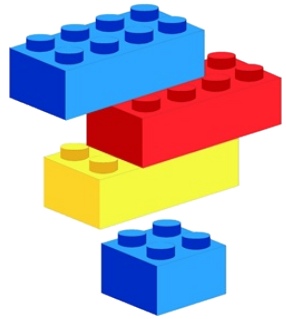
Compile-Time Checking

Why is the second stage necessary?

- Refactoring without design tool support
- Writing applications from scratch



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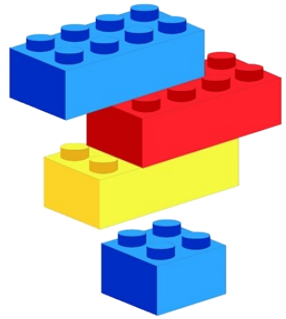

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- Generation of compile-time errors . . .
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  - . . . with expressive messages

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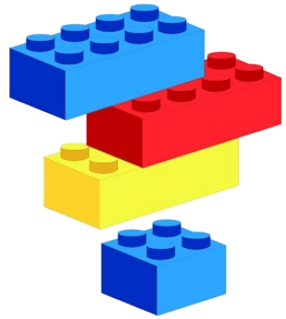

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The solution

- Template Meta-Programming (TMP)

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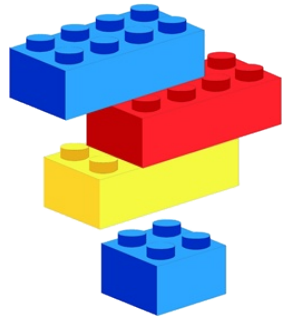

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The solution

- Template Meta-Programming (TMP)
- Generation of machine-readable composability information

Compile-Time Checking: Implementation

How is it performed?

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struct EmergencySwitchSpec {
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```

Compiler output:

```
CheckAttributeAgainstAttributeList.h:60: error: no matching
    function for call to assertion_failed(*** (
    TestAttributes<Omission<5u>, deref<l_iter<list1<
    Omission<2u> > > > >::ATTRIBUTES_MISMATCH::***)(
    Omission<5u>, Omission<2u>))
```

Run-Time Checking

Typical Run-Time Checks

- Service discovery (UPnP, Jini, . . .)
- Matching of functional attributes (CORBA)
- Requirement of Composability Checks?

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Run-Time Composability Checking

- Automatic evaluation of component attributes
- Matching of application vs. network layer(s)
- Consideration of routing information

$\Rightarrow$ No service $>$ unreliable service

Middleware Integration

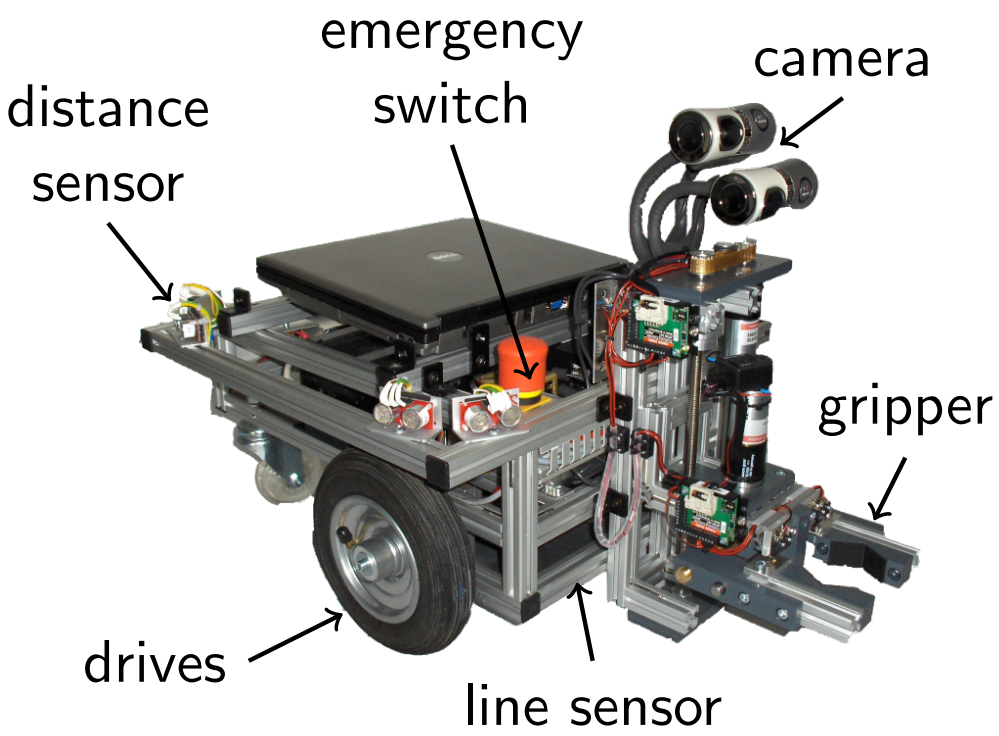
MLCCA integration in communication middleware

- Design-Time, Compile-Time, Run-Time checking
- Transparency for applications
- Portability (100% standard C++98)
- Scalability (8-bit μC ... 64-bit server)

Implementation in FAMOUSO

- event-based pub/sub communication middleware
- Support for C++, Python, Matlab, ...
- Integration of CAN, WMN, UDP/MC, ...
- `http://famouso.sourceforge.net/`

Application Example: Emergency Switch



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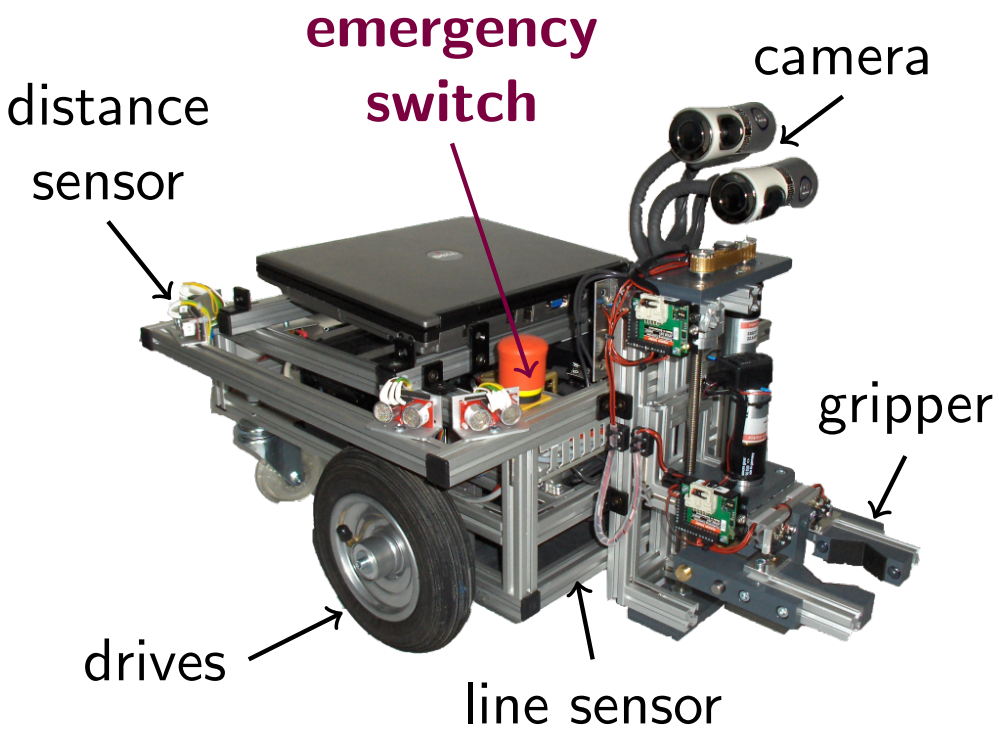

Emergency Switch (ES)

- periodic "okay" messages
- absence $\Rightarrow$ emergency

Component Requirements:

- period: $50ms$
- max. two omissions

Emergency Switch: System Configuration CAN

- Emergency switch on local CAN bus

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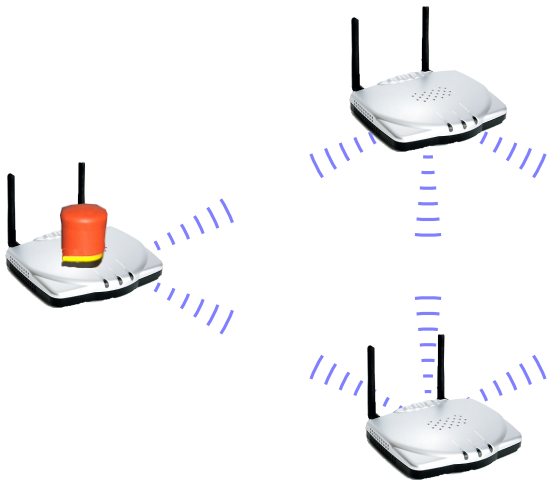
MLCCA:

✓ Design Time | ✓ Compile Time | ✓ Run Time

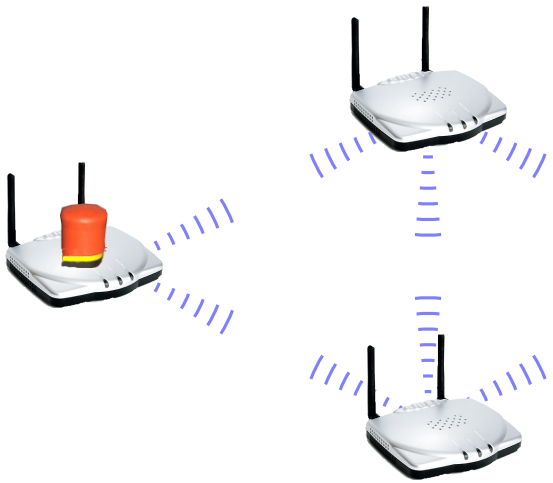
Emergency Switch: System Configuration WMN

- Emergency switch over WMN



Emergency Switch: System Configuration WMN

- Emergency switch over WMN



MLCCA:

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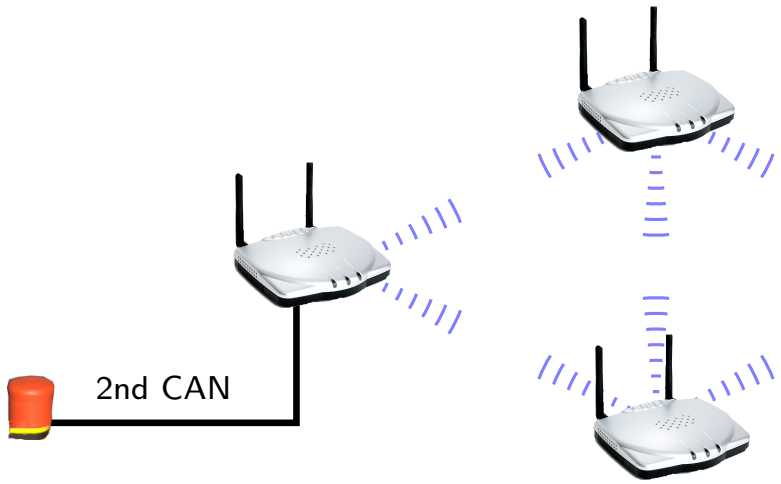
Emergency Switch: System Configuration WMN/CAN

- Emergency switch on CAN, via WMN gateways



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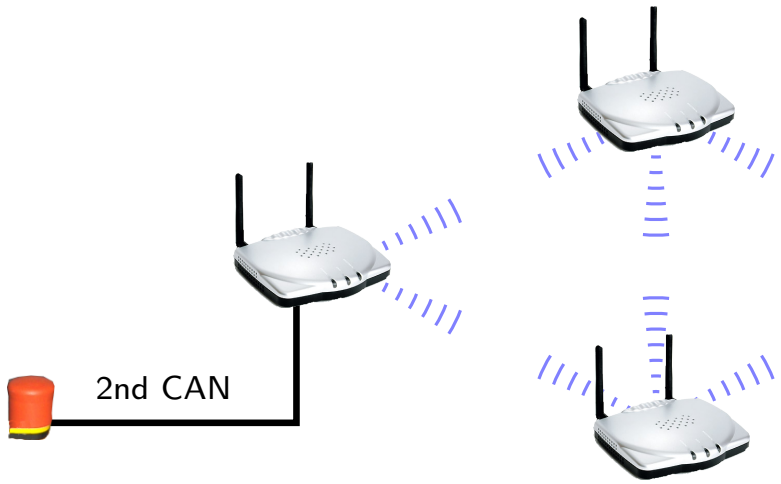

MLCCA:

× Design Time | ✓ Compile Time | × Run Time

Emergency Switch: Summary

- No automatic way to make wireless networks 100% reliable
- Prevention of unreliable setups ...
  - ... as early as possible
  - ... reliably
  - ... over network/protocol borders

Conclusion

Initial Question

How to ensure end-to-end application communication requirements?

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2. Extension of Design Tool checks
3. Novel Compiler-based Checks
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- Implementation in FAMOUSO communication middleware
- Applicability for Industrial Automation scenarios


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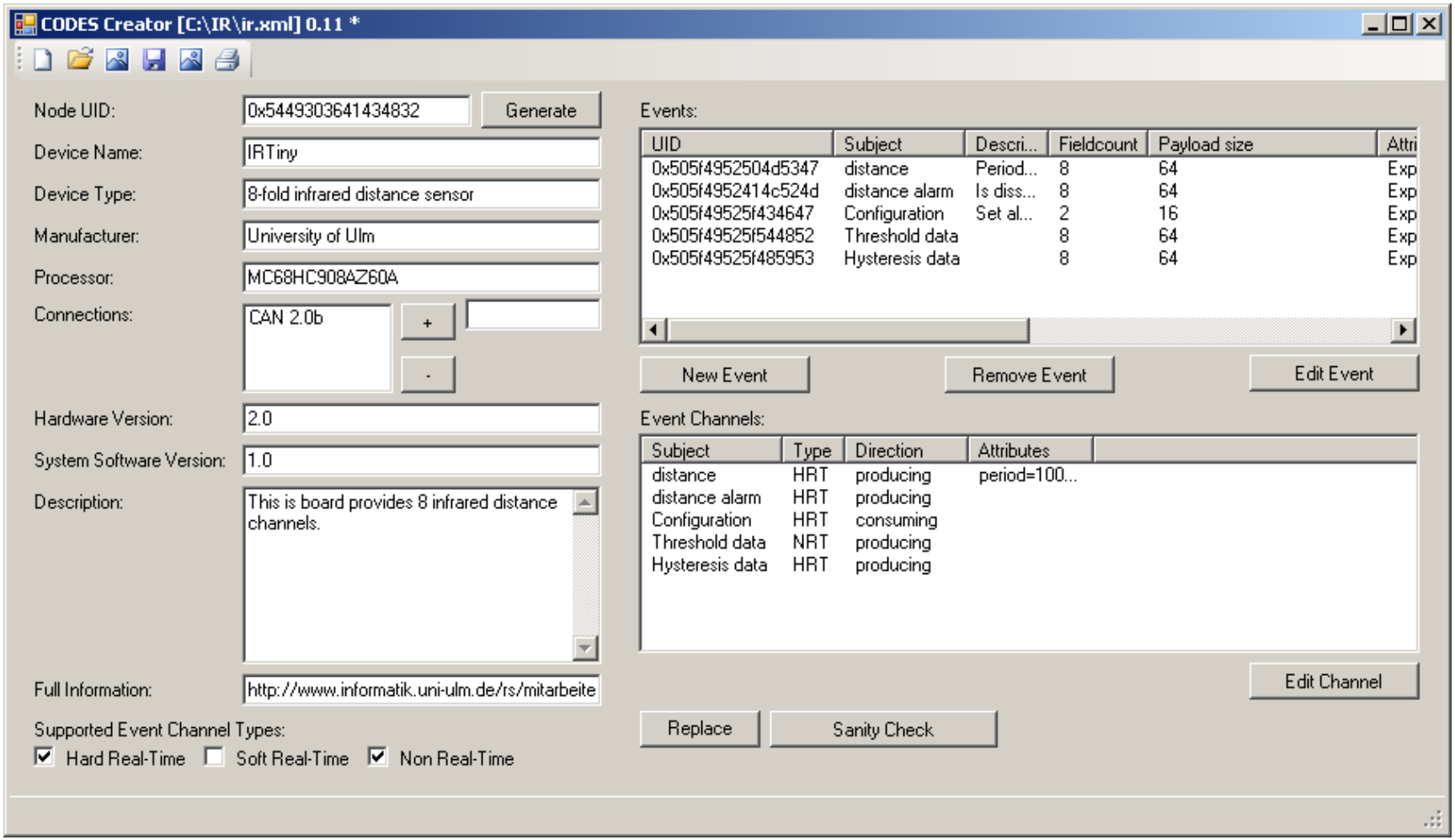
CODES Creator



Middleware Overview

Attribute-Based Composability Checks

	Design-Time	Compile-Time	Run-Time
WSDL*	✗	–	✓
UPNP*	✗	–	✓
Jini*	✗	–	✓
CANopen*	✓	–	–
IEEE 1451*	✓	–	–
CORBA	✗	–	✓
MLCCA	✓	✓	✓

*) no support for QoS attribute descriptions

FAMOUSO Middleware