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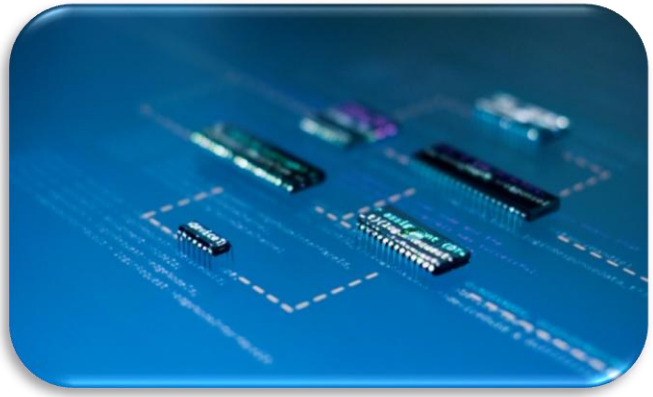

CHROMOSOME

A Modular Middleware for Cyber-physical Systems

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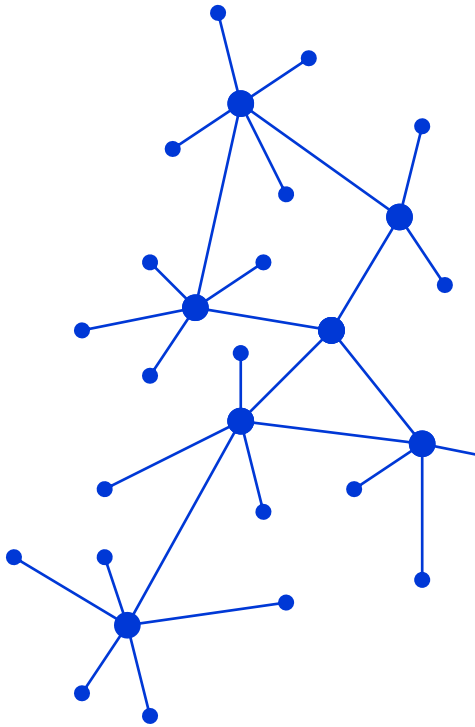
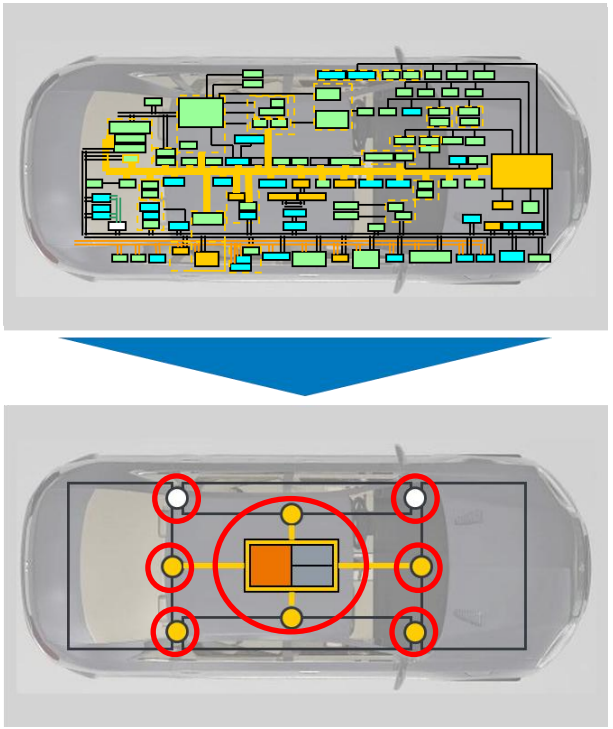


Observation

- Technical systems consist of more and more individual controllers
- *Example:* Modern cars
  - Up to 70 electronic control units (ECU) in a premium segment car
- Challenges:
  1. How to reduce the complexity of such systems w.r.t. hardware?
  2. How to design software for such systems independent of the concrete hardware?



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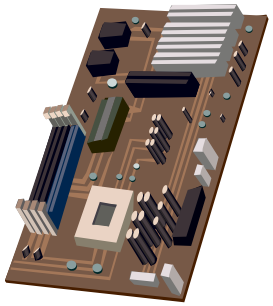
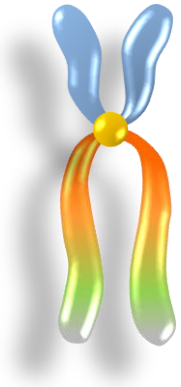
Facing the Challenges

- **Hardware:** Modular hardware platform
  - *Not* focus of this talk
  - For more information, see for example RACE project: http://www.projekt-race.de/



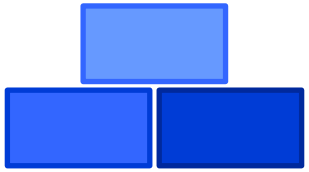
- **Software:** Modular middleware platform
  - Focus of this talk
  - Middleware must satisfy various requirements
  - For more information, see CHROMOSOME project: http://chromosome.fortiss.org/



Software Design Requirements (1/4)

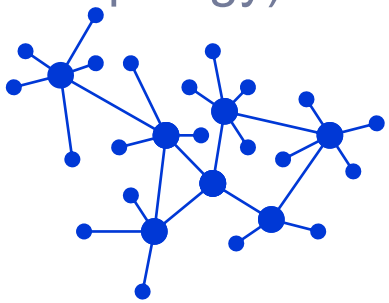
1. Individual parts should be able to be exchanged without touching the other parts of the system (e.g., software update, addition of new functionality)

   → *Component-based design*



2. Sending data to a component on the other end of the system should “feel” the same than sending data to a “nearby” component (i.e., developers don’t want to care about the concrete topology)

   → *Abstraction of communication*



Software Design Requirements (2/4)

3. It must be possible to state the maximum latency of data transmission between components (e.g., airbag triggering)

   → *Real-time capability*

4. Critical components (e.g., ABS in a car) must execute next to uncritical components (e.g., infotainment) without influencing each other

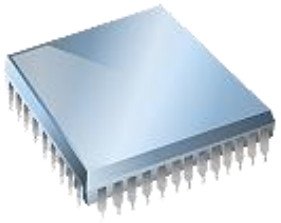
   → *Mixed criticality support, isolation*

Software Design Requirements (3/4)

5. It must be possible to execute the components on many different target platforms with different operating systems (OS) (e.g., microcontrollers / PCs with real-time OS / embedded OS)

   → *Target platform abstraction*

   → *Support for cyber-physical systems (CPS)**



- *From Wikipedia [1]: “A cyber-physical system (CPS) is a system of ***collaborating computational elements controlling physical entities***. […] Unlike more traditional embedded systems, a full-fledged CPS is typically designed as a ***network of interacting elements*** with ***physical input and output*** instead of as standalone devices.”

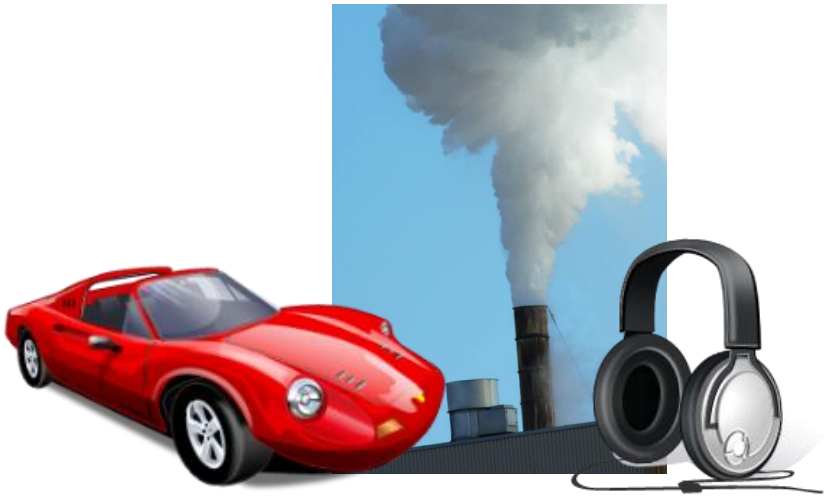
[1] http://en.wikipedia.org/wiki/Cyber-physical_system

Software Design Requirements (4/4)

6. For maximum use, the system should be applicable to different domains such that devices of these domains can cooperate (e.g., automotive, automation, multimedia, …)

   → *Multi-domain support*

(automotive domain is just an example here)



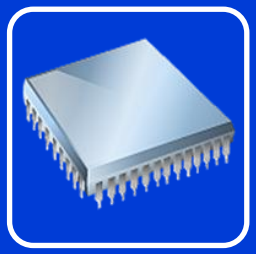
Software Stack for Realization of Requirements

Application(s)

- *Component-based design*
- → Platform-independent implementation based on middleware abstraction

Middleware (XME runtime system)

- *Abstraction of communication*
- *Real-time capability*
- *Mixed criticality support*
- *Multi-domain support*
- *Target platform abstraction*



Target platform(s)

- *Operating system*
- Target hardware
- → Platform-specific functionality and features

What is a Middleware?

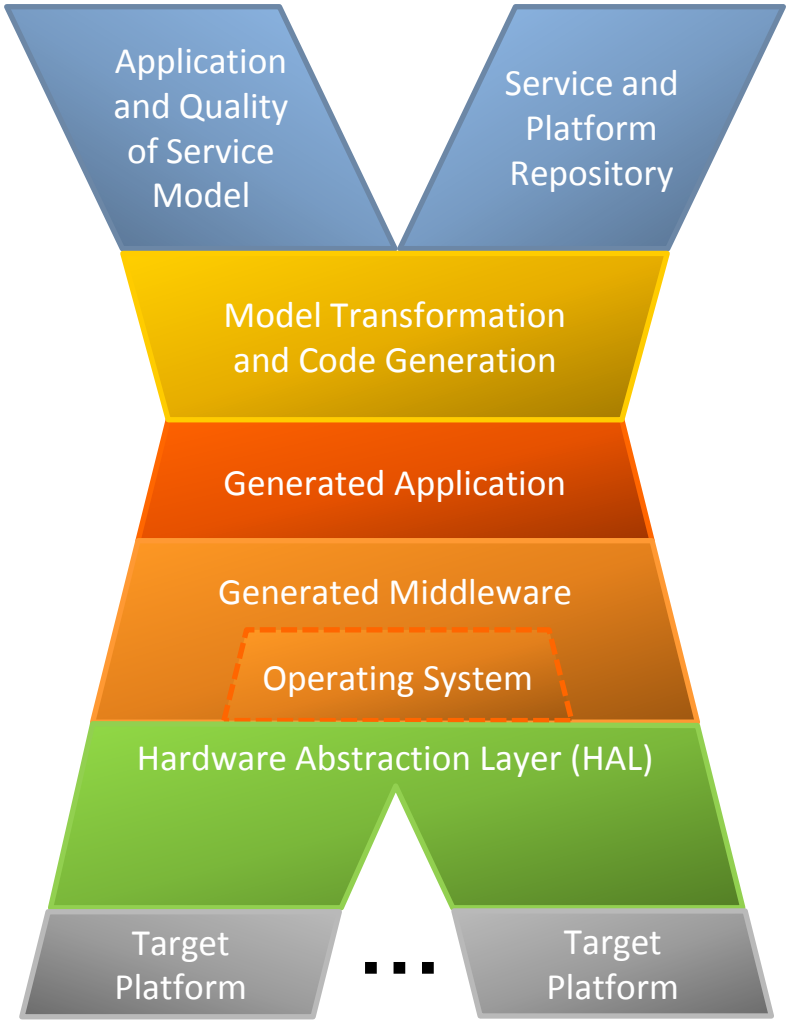
- From Wikipedia [2]:
  "Middleware is computer software that ***provides services*** to software applications beyond those available from the operating system. […] The term is most commonly used for software that ***enables communication*** and ***management of data*** in distributed applications."

→ Basically an "add-on" to a system to provide a higher level of (programming) abstraction for software developers

→ Located in between the application and the operating system (hence the name "middleware")

[2] http://en.wikipedia.org/wiki/Middleware

CHROMOSOME Architecture



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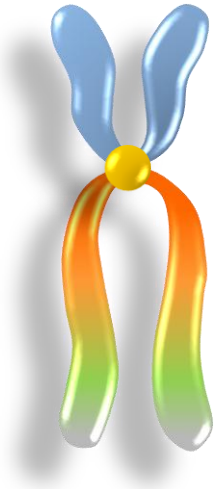
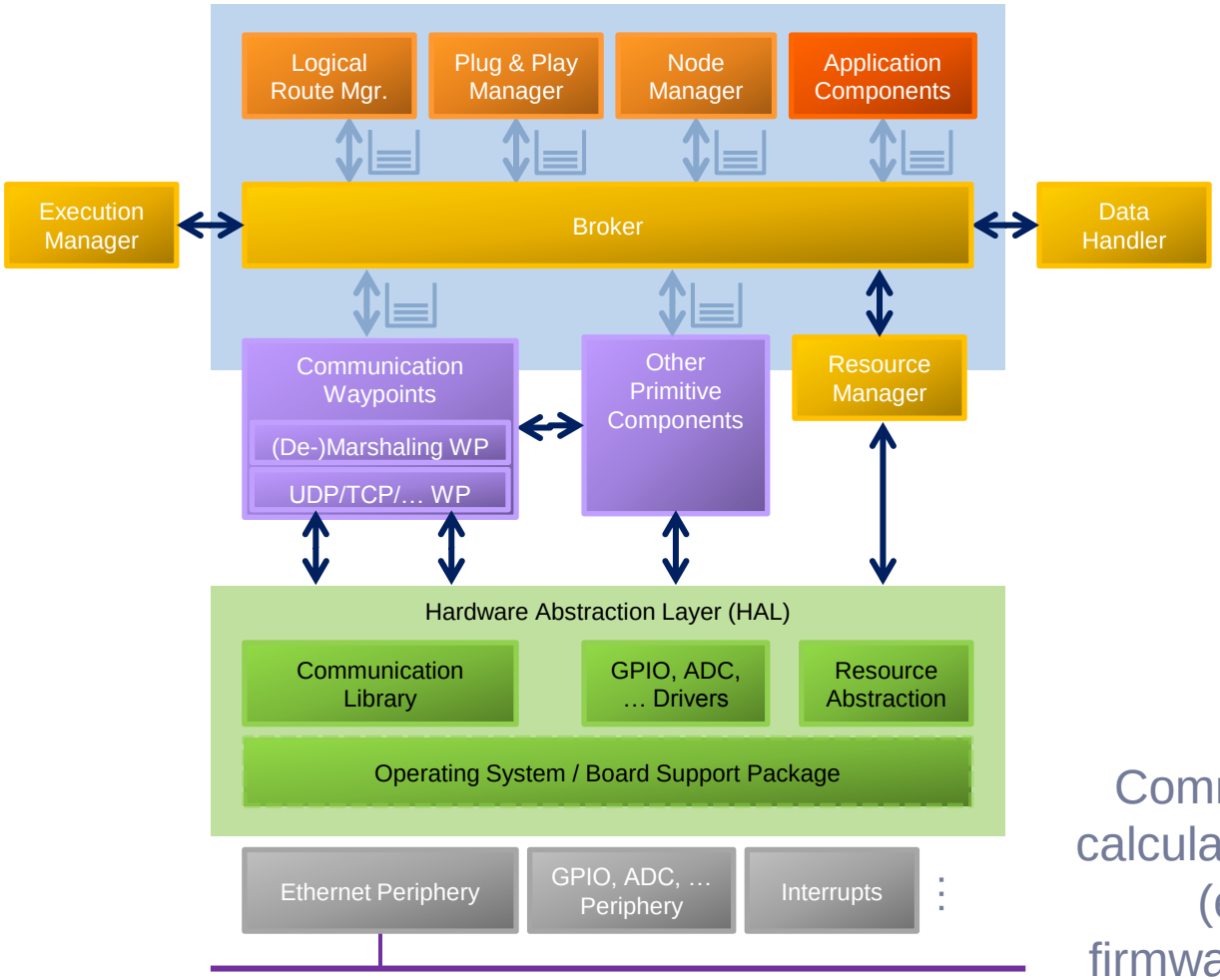


CHROMOSOME:
Cross-domain open modular operating system or middleware

Architecture of a CHROMOSOME Node



Node:
Communication participant with calculation and storage capabilities (e.g., software process, firmware on embedded controller)

Basic Functions

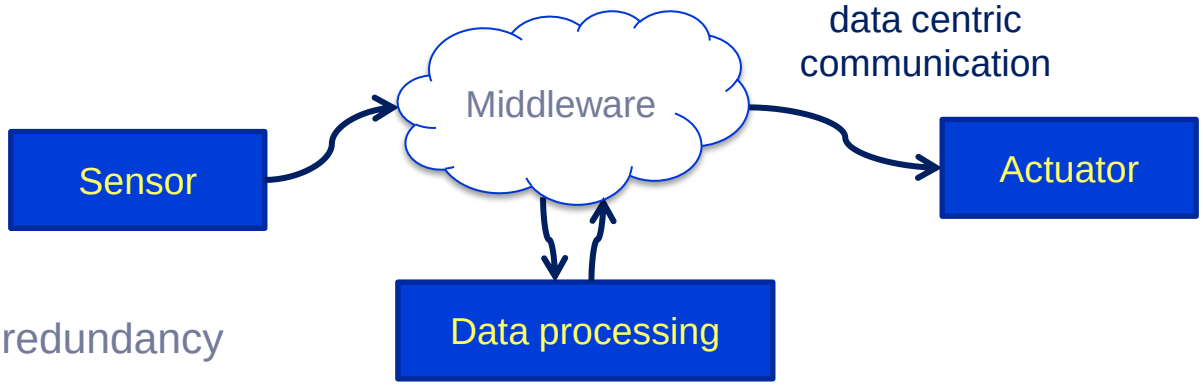
- *Data centric communication:* Decoupling of sender and receiver
- *Modeling:* Model-driven design of the application
- *Platform support:* Customizable support for various platforms
- *Plug & Play:* Dynamic reconfiguration at runtime
- *Real-time capability:* Event or time driven model of execution
- *Open source:* Free licensing model (Apache License Version 2.0)

↳ http://chromosome.fortiss.org/

Data Centric Communication

Goal:

- Make all data available to all components



Rationale:

- Avoid costs by unneeded redundancy

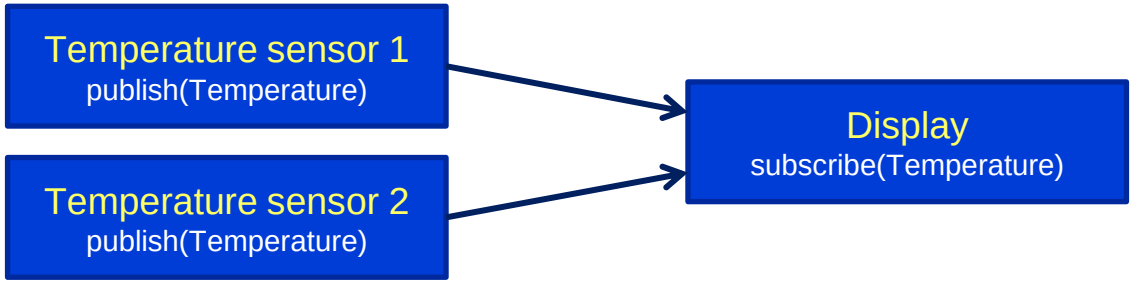
Realization:

- Decoupling of sender and receiver
  → *Data centric communication*

Concepts:

- *Topic:* Data type with assigned semantics and fixed structure (e.g., temperature, velocity, voltage, pressure)
- *Publication:* Intent to send data of a given *topic*
- *Subscription:* Request to receive data of a given *topic*

Data Centric Communication
Example



Attribute Support for Topics (1)

Goal:

- Allow selective filtering of data at the transport layer

Realization:

- Annotation of data with additional properties
  → *Attributes* (a.k.a. meta data)
- Definition of a simple ontology for attributes

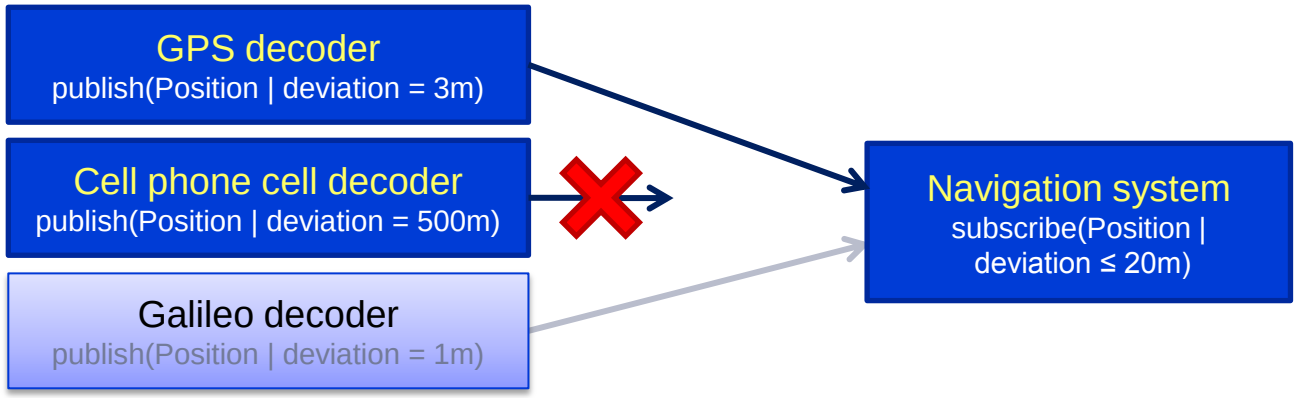
Concepts:

- *Attributes:* Key/value pairs for exact specification of data properties (e.g., timestamp, accuracy, confidence, source)
- *Annotation*: Specification of meta data for a *publication*
- *Filtering*: Specification of data acceptance criteria for *subscriptions*

Attribute Support for Topics (2)

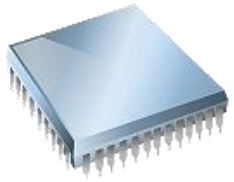
Example:

- *deviation* is an attribute of topic *Position*



Static and Dynamic Systems

- On resource constrained systems, the middleware can be statically configured and only contains predefined functions
  → Suitable for “small” target systems



- On less resource constrained systems, aspects like plug & play allow dynamic reconfiguration at runtime
  → Flexibility

- Model-driven tooling allows to select the appropriate variant:
  → CHROMOSOME Modeling Tool

CHROMOSOME Modeling Tool

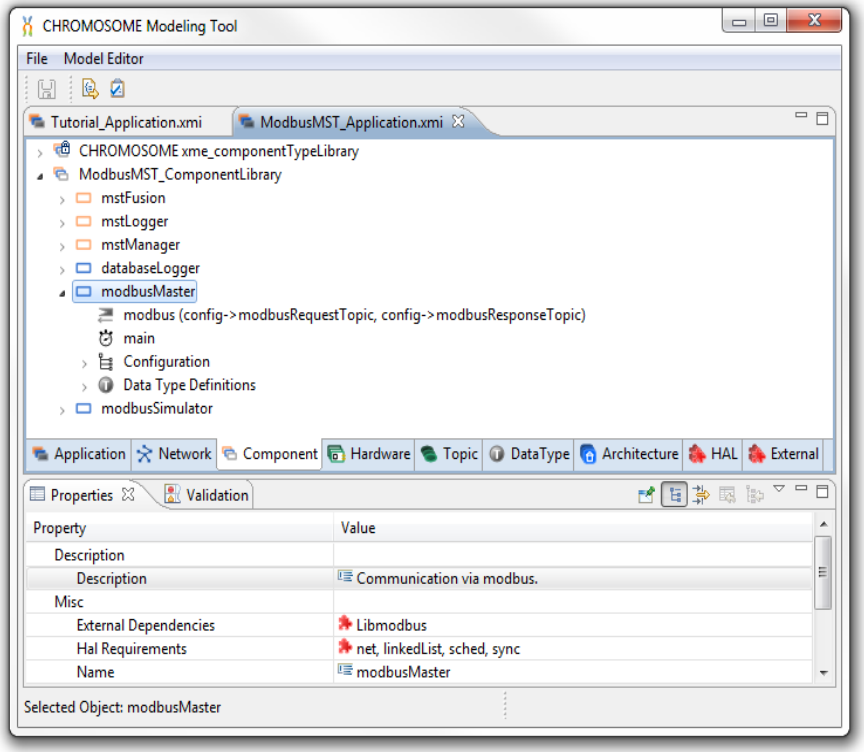
Goal:

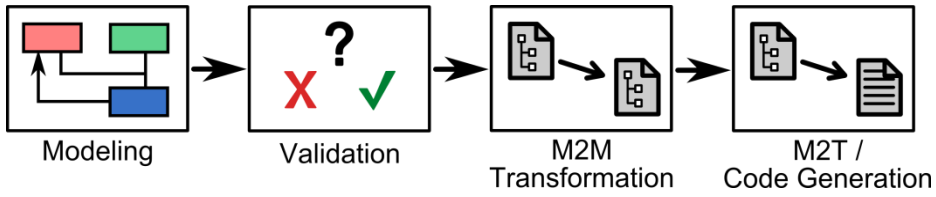
- Describe applications via models
- Reusable models for component types, data types (topics), …
- Generate stub code
- Configure application
- Generate build system

Realization:

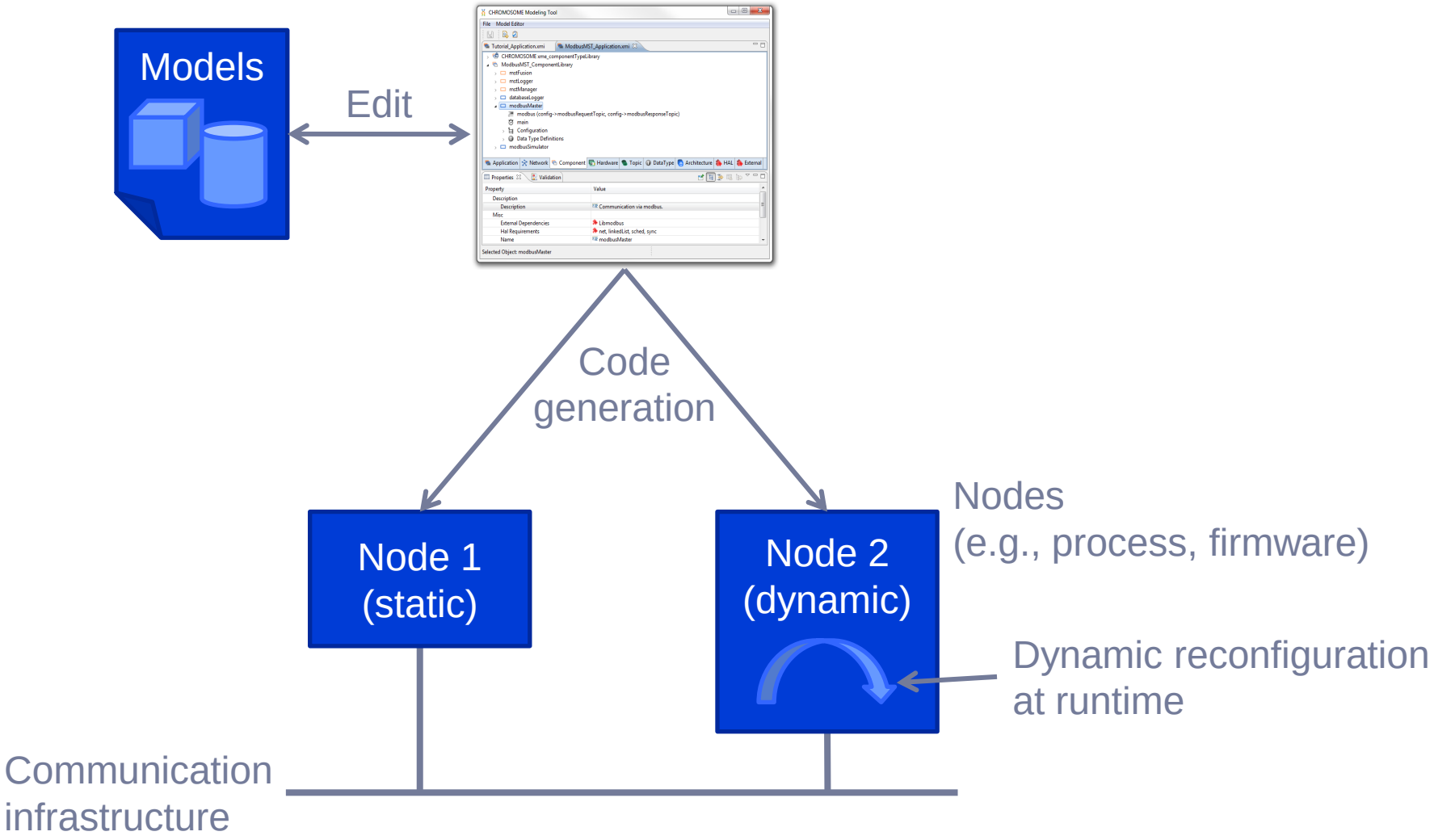
- Eclipse Modeling Framework based rich client application

Live Demo



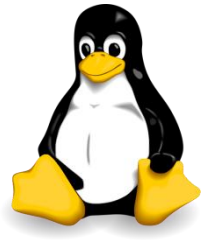


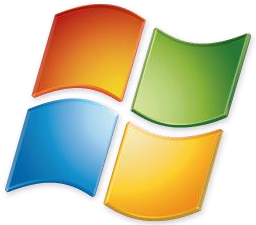
Complete Workflow



Platform Support

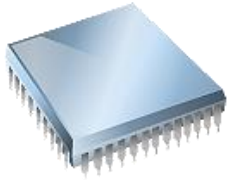
- Linux (PC 32bit/64bit): primary, released
- Windows (PC 32bit): secondary, released
- FreeRTOS (ARM 16/32bit): not yet released
- Contiki (AVR 8bit): experimental
- PikeOS: internal only



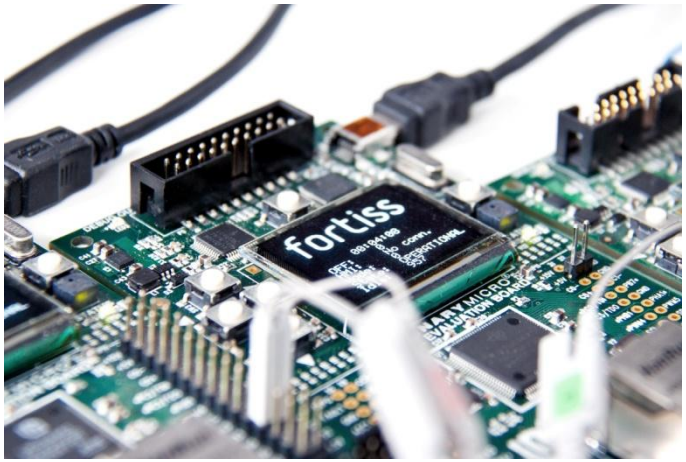


Contiki

Embedded Target Support



- Platforms:
  - Texas Instruments ARM Cortex M3 (Stellaris LM3S8962)
  - ST Microelectronics ARM Cortex M3 (STM32F10xxx)
- Operating system: FreeRTOS



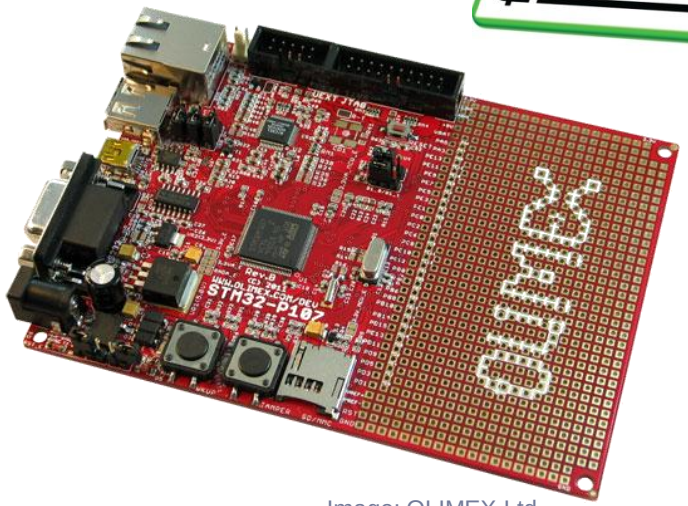


Image: OLIMEX Ltd.

Plug & Play

Goal:

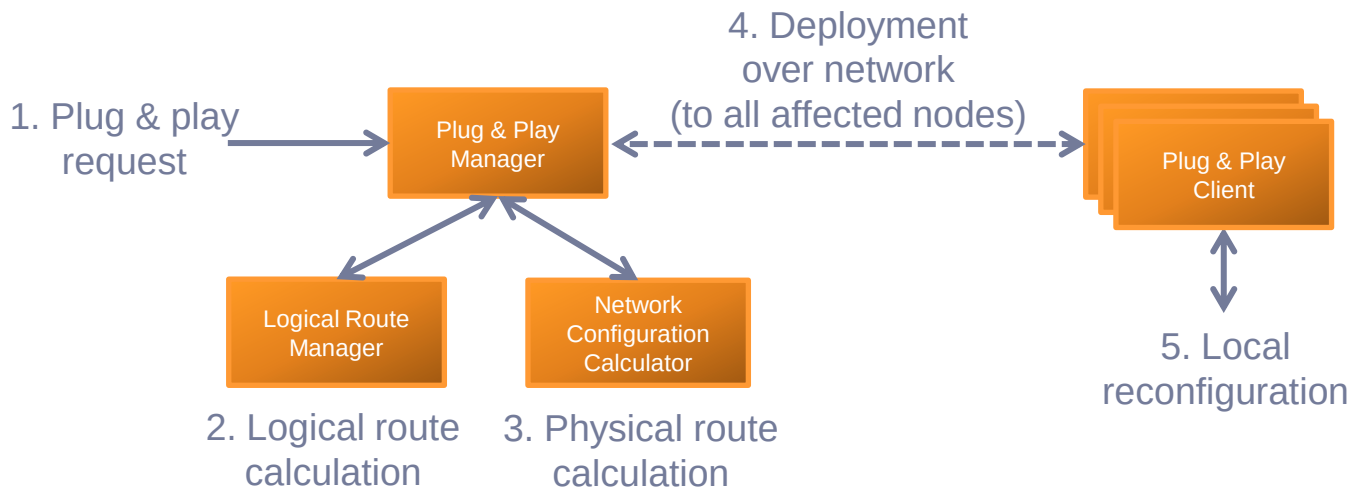
- Dynamic addition/removal of components at runtime

Rationale:

- Applications need to be updated or extended while in use

Realization:

- Plug & Play Manager and related components in the middleware



Real Time Capability

Goal (initial implementation):

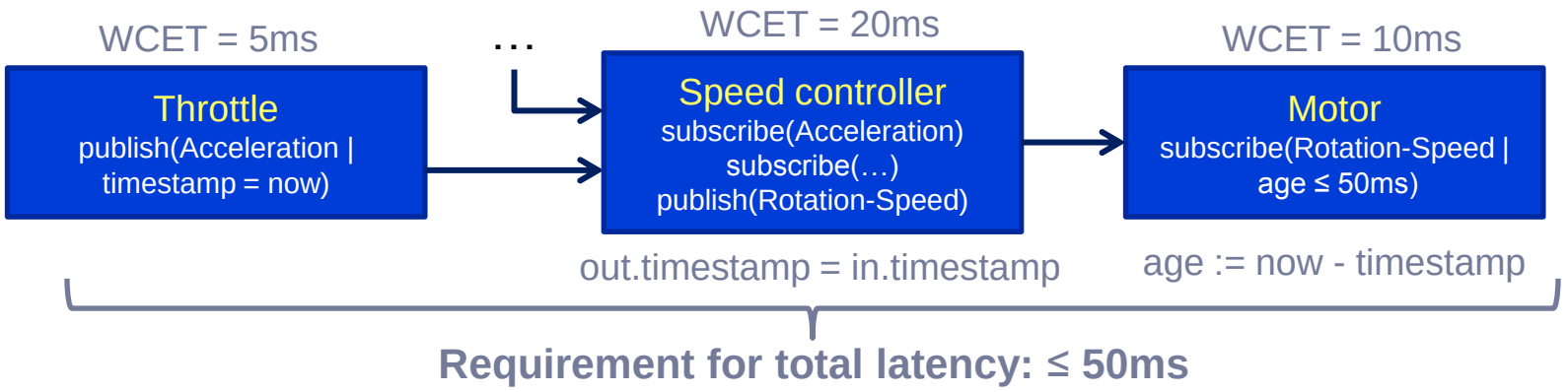
- Realization of specified end-to-end latency by real-time scheduling on a real-time capable platform (e.g., PikeOS or FreeRTOS)

Rationale:

- Prototype for real-time critical implementations

Realization:

- Specification of real time requirements via attributes



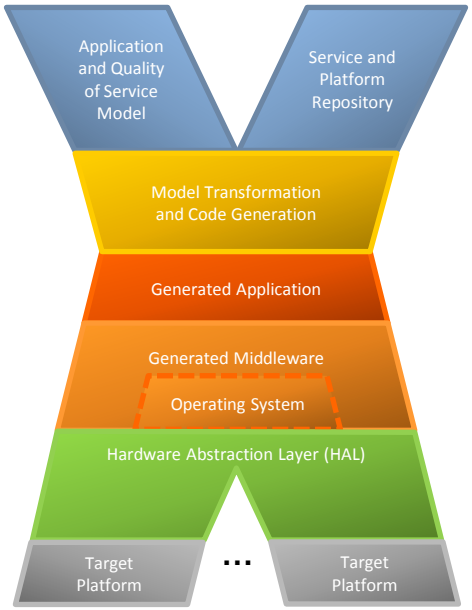
Availability of CHROMOSOME

CHROMOSOME is open source software

- Download at
  ↳ http://chromosome.fortiss.org/

Current release (v0.3) as of May 29, 2013

- Model-driven static configuration of runtime system
- Platform abstraction for Linux and Windows
- 40-page introduction and tutorial included
- Installation instructions: see tutorial
- Next release planned for end of June



Evolution of CHROMOSOME

Image: Kigoo Images / pixelio.de

- CHROMOSOME is still in development; new features are added over time
- By providing an open platform, we expect community contributions
- Community extension can deliver additional benefits to existing applications when combined with each other (compare Smartphone apps)
- If you are interested, you are welcome to try it out!

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