

Monitoring environment-parameters for research towards energy-efficient buildings

Speaker's Intro

Speaker

Bart Voet

Day Job

Practice Lead Java Development at AXA

Evening and weekend

Family

Programming and hacking

Learning electronics

Skateboarding and snowboarding

...

Stakeholders

Primary stakeholder

Division of Building Physics KUL

(Department Civil Engineering)

System capturing data from digital sensors

Scalable to different scenario's

Research facility

Educational environment

External research

Stakeholders

Stakeholder

Groep T

Evolution

Smart sensors

Digital interfaces

Sensor networking

New devices (and open source)

Raspberry Pi, BeagleBoard, Cubieboard

AVR, Arduino, ...

...

Stakeholders

Stakeholder

Author (and other hobbyist)

Learning platform

Experienced Java Developer

Learning embedded development

Open source platform

Scalable to different devices

Focused on monitoring

Integrable in different scenario's

Startup requirements

Context

Department of Building Physics KUL
performing

research on energy **efficient buildings**

Startup requirements

Demand

System(s) for continuous measurement
that is

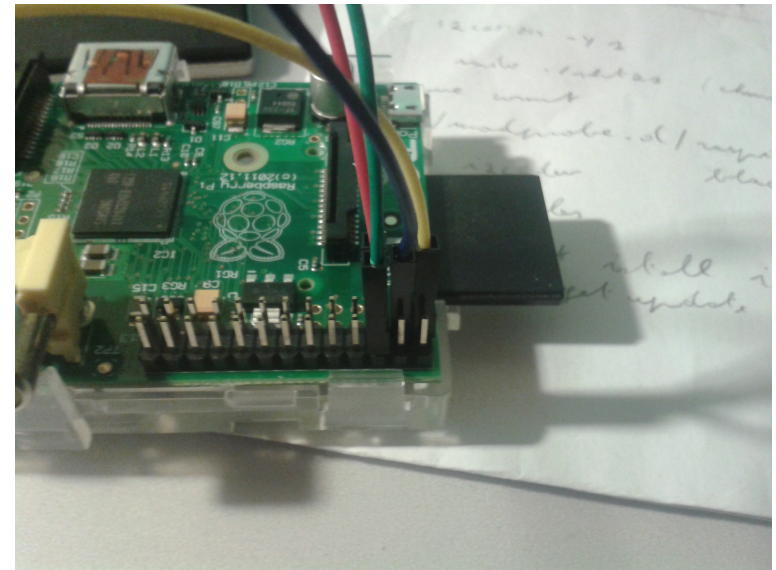
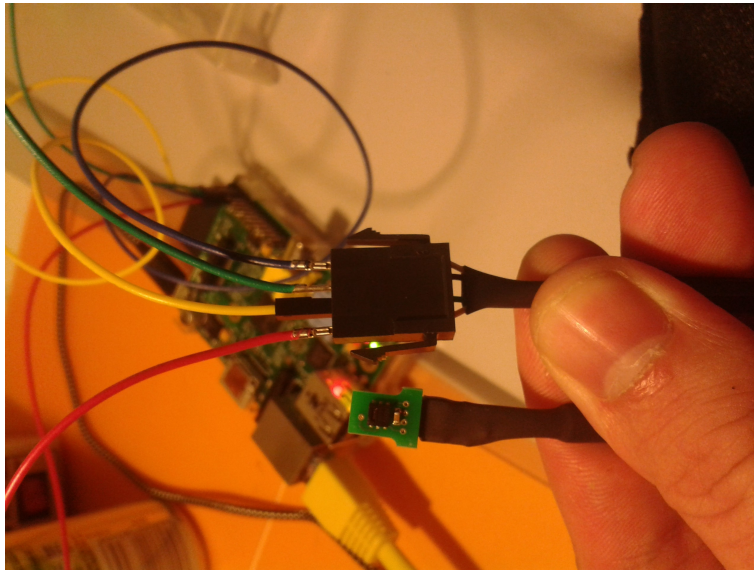
Reliable

Inexpensive system(s)

Continuous measurement

Startup requirements

Use **Raspberry Pi** as a device for **sensing**



Startup requirements

Use Raspberry Pi as a device for **sensing**
environment **parameters**

Important for

Indoor climate

Energy consumption

Example given

Relative humidity

Temperature

Differential pressure

... and **other** measurements in the future

Startup requirements

More specifically, use Raspberry Pi as a device to

Control and **configure** sensors

Collect data

Store sensor measurements

(for later evaluation and analysis)

Correlate stored measurements

configuration

timing

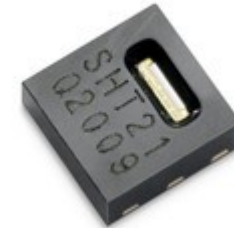
Startup requirements

Using sensors (Sensirion)

SHT21 (STS21-SHT25)

temperature

relative humidity



SDP600 (later phase)

differential pressure

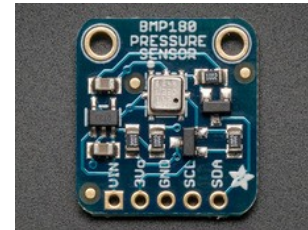


Startup requirements

Later on

BMP180 (Bosh)

Barometric pressure



DHT11

Temperature



Startup requirements

Taking into account profile of the users

- Students

- Researchers

Assuming only basic knowledge of

- Electronics

- Command line

- High level programming construct

(but not advanced)

Scope and position

Scope limited to **digital (smart)** sensors

Digital interface (i2c, spi or custom)

Integrated MCU performing

Calibration

Linearization

No focus on **classic sensors**

Manual calibration

Precision resistors

...

Scope and position

Consequence

Focus on **system** (not hardware design)

Integration

Extensibility

Ease of use

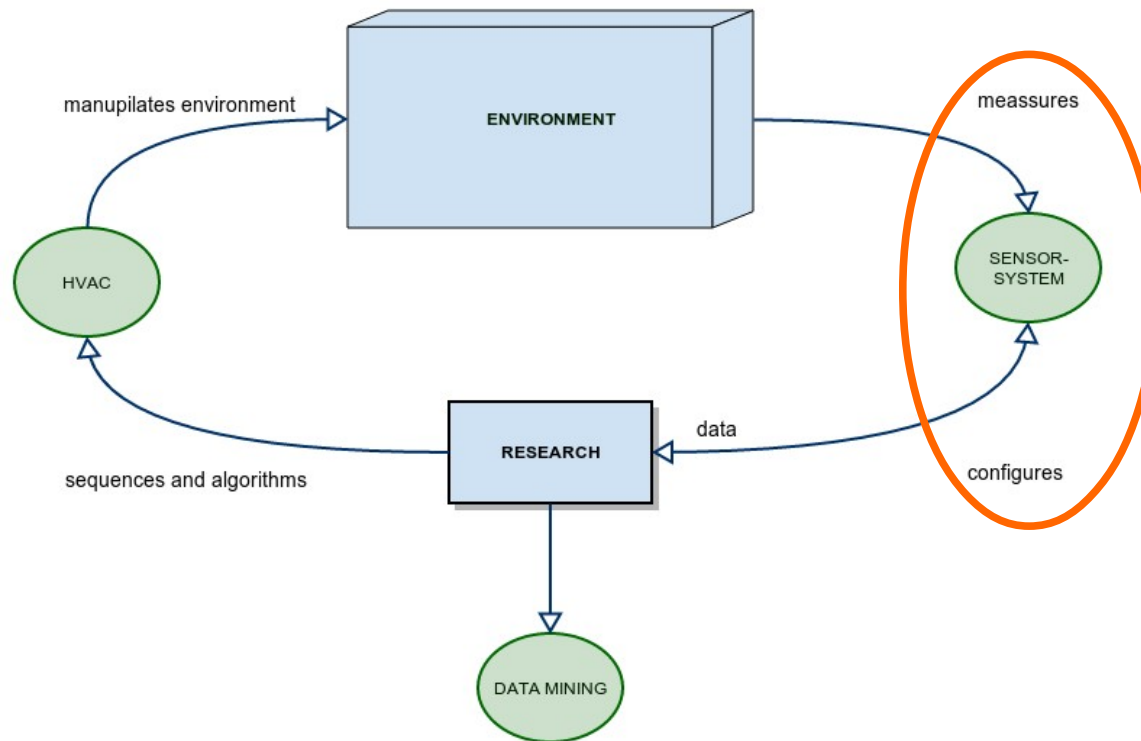
Reliability

Documentation

...

Context

Research-process and its components



Scenario's

Primary scenario: Research-facility in Gent

HVAC-infrastructure deployed

Electricity and ethernet



Deploy, install and configure sensors

Aggregate data

Scenario's

Scenario: Educational environment (students)

Class-room environment

Labo



Experiment and learn

Explore sensors

Scenario's

Scenario: Large buildings

Mobile scenario

No HVAC

No assumptions on

Electricity

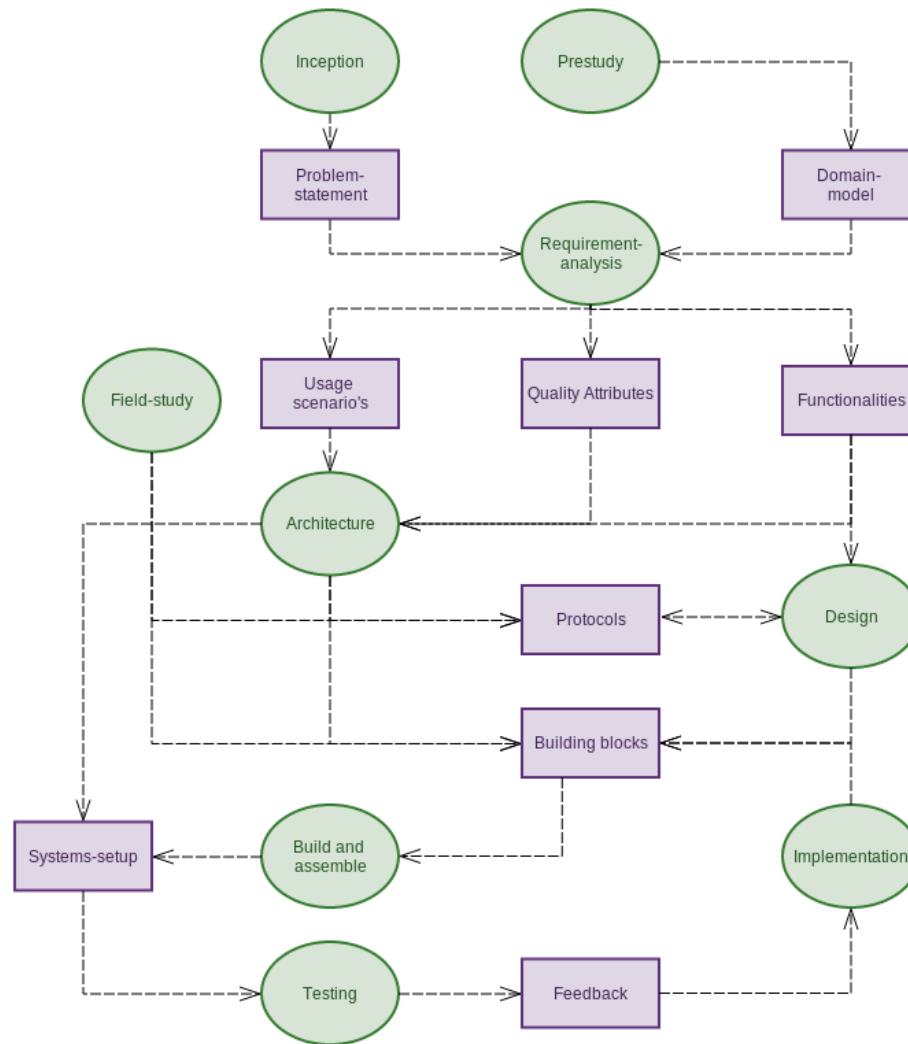
Network



Similar to primary scenario

More constrained environment

Approach

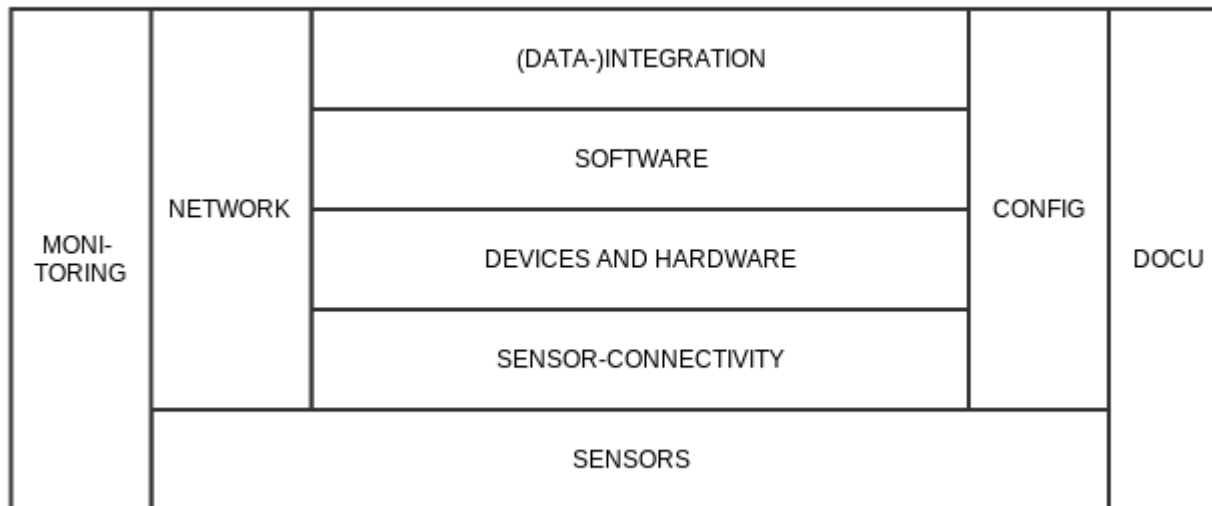


Approach

Category of building blocks (solutions)

Hardware, software, documentation

Serve as annotation in thesis



Approach

Category of solutions

Hardware, software, documentation

Serve as annotation in thesis

STORAGE	INTEGRATION	TOOLS FRAMEWORKS
APPLICATION		
LIBRARY		
DRIVER		

System Challenges

TOP 5 Challenges

Multiple sensors

Concurrent access

e.g. Sensirion-sensors having
same i2c-adress (40)

Large area's

i2c and spi not developed
for long distance
(even if you lower the clock)

System Challenges

TOP 5 Challenges

Reliability, durability and **resilience**

Ability to recover from

Power interruption

Network incidents ...

Alerting-capability

Sensor goes down

Errors coming from sensors

Processing device not working

Heating ...

System Challenges

TOP 5 Challenges

Usability

- Scalable to different scenario's

- Users are no software- or hardware-engineers

- Need an interface that's

 - Easy to integrate with other systems

 - Easy to integrate in personal computing
(structured txt-files)

System Challenges

TOP 5 Challenges

Extensibility

Adding new sensors and configure

Adding new sensor-type without changing the system (open-closed-system)

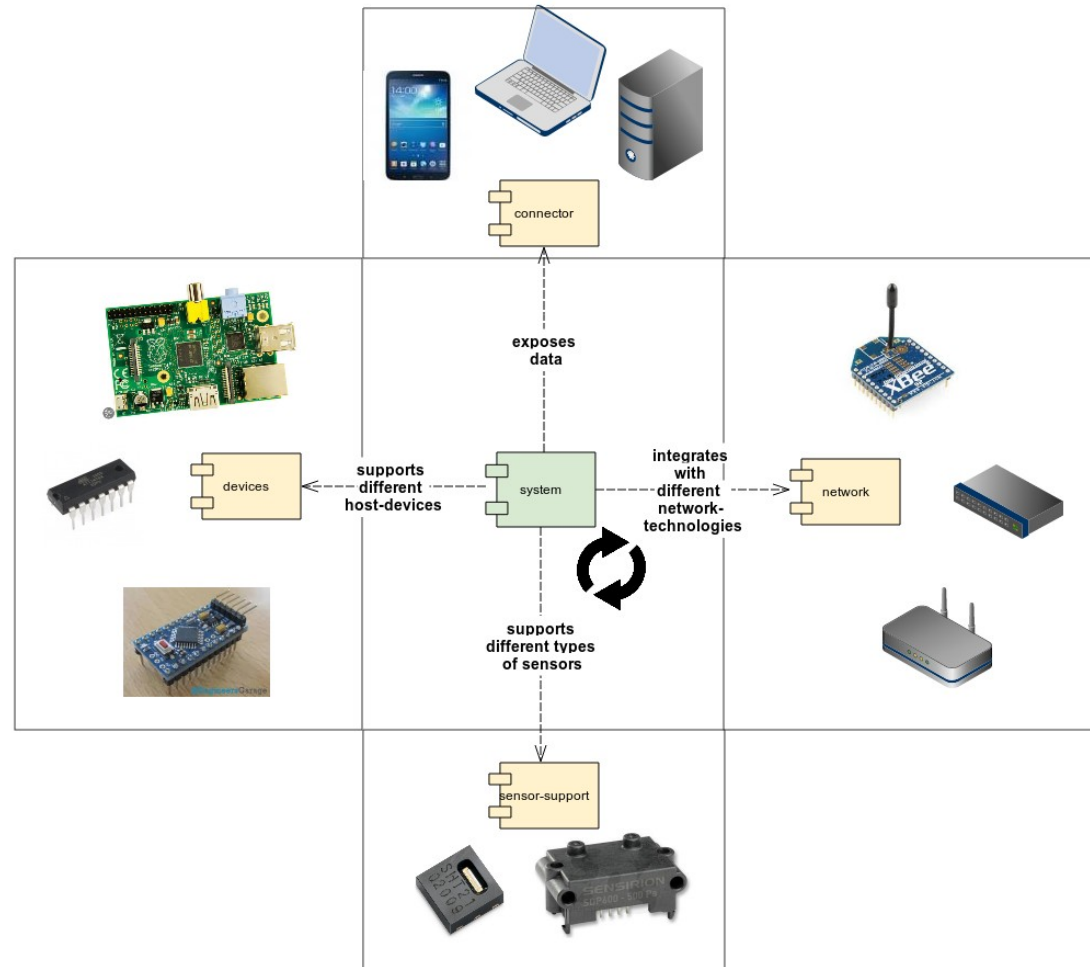
Configurability

Changing sensor-parameters

Changing scheduling

System Architecture

System-concept: **runtime and dependencies**



System Architecture

System-concept **Runtime**

Scheduling measurements

Relying on system abstractions

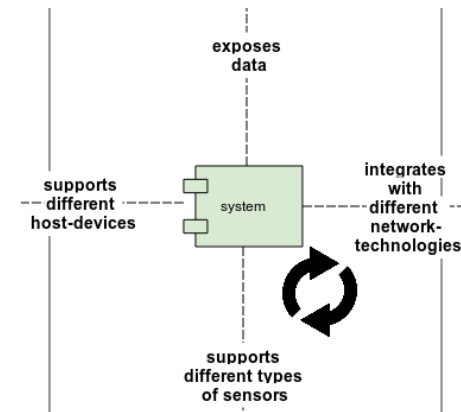
Integration

Storage

Device-abstractions

More sensors

Of different types



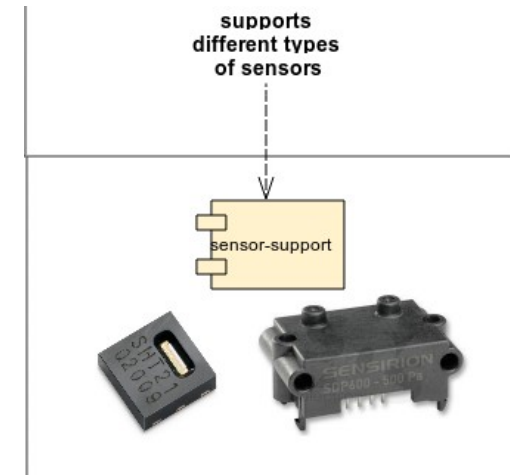
System Architecture

System-concept: **Support different sensors**

System supports

Extracting data from
multiple Sensors

Multiple types via
Sensor-abstraction



System Architecture

System-concept: **Support different devices**

Isolate system-dependencies

Scheduling

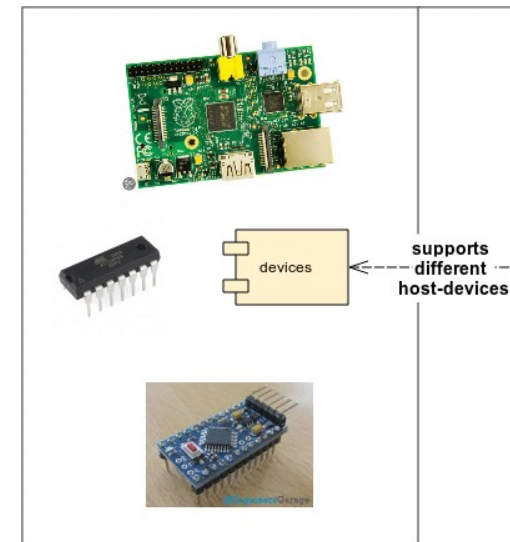
Digital interfaces

...

Support for

Low level (c-api)

High level (java)



System Architecture

System-concept: **Network independence**

Integration-capability isolated

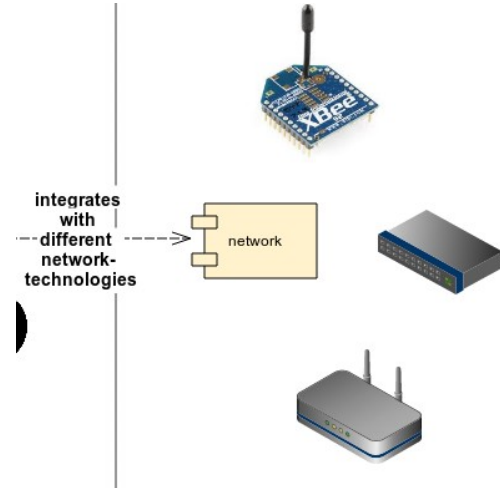
Local integration

Zigbee

WIFI

MQTT

...



!! System provides abstraction and pluggability to adapt, not all implementations exists !!

System Architecture

System-concept: **Data exposure**

Connectors for clients

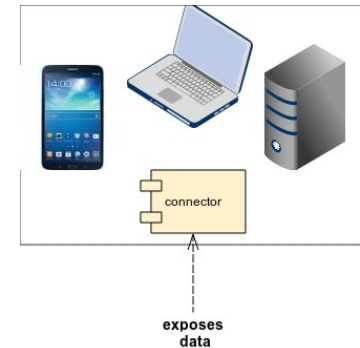
Open protocols to integrate
with various kind of devices

Current provided protocol

REST exposing

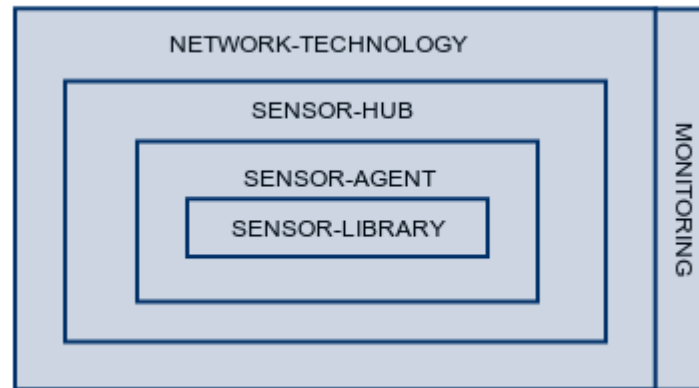
JSON

CSV (under construction)



System Architecture

Design-concept: **Layering**



Different building blocks

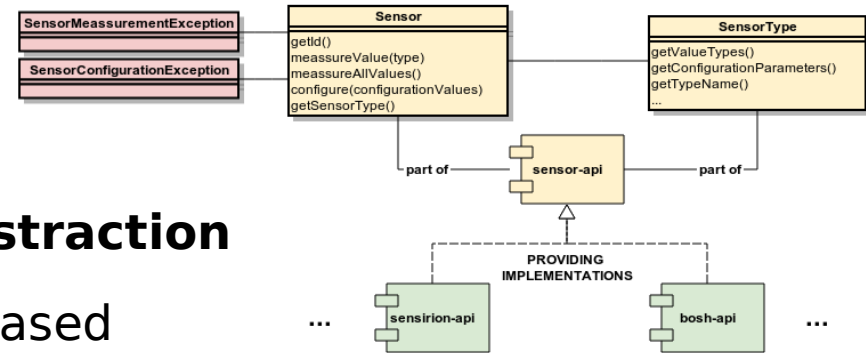
Built on top

Inner layers can be used independently

Segregation by interface

System Architecture

Layer: **Sensor-API**



Sensor- and SensorType-abstraction

Interfaces key-value pair based

Modules containing concrete implementations

Standardized exceptions

Goal

Provide a repository for reuse (Github-project)

Isolate the processing logic

Provide an abstraction layer for Sensor-agent

Translate the datasheet behind an abstraction

System Architecture

Layer: **Sensor-API**

System-abstraction of

Digital interfaces
(i2c, spi, uart)

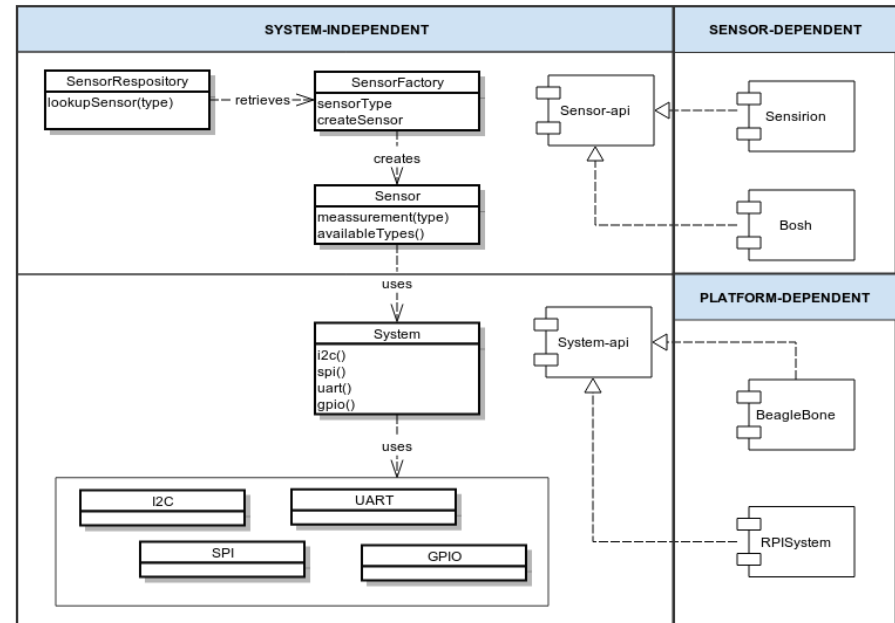
Pin-access

Timing

Goal

Portability (vs scenario's)

Choice of libraries (e.g. RPi can work JME or Pi4j)



System Architecture

Layer: **Sensor-Agent**

Runtime or application

Captures data at interval

Manages sensors via sensor-api-abstraction

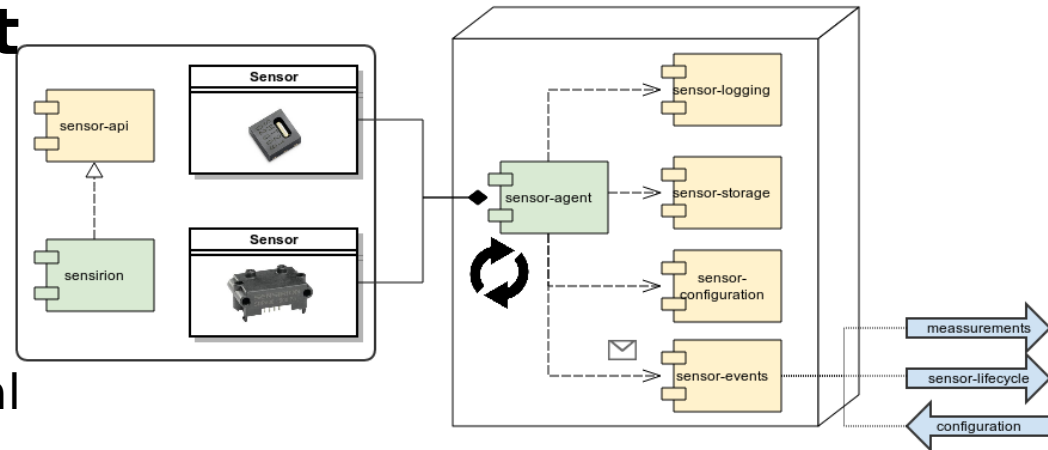
Notifies and communicates via sensor-events

Goal

Use the sensor-api without low-level coding

Set up a measurement system based on configuration

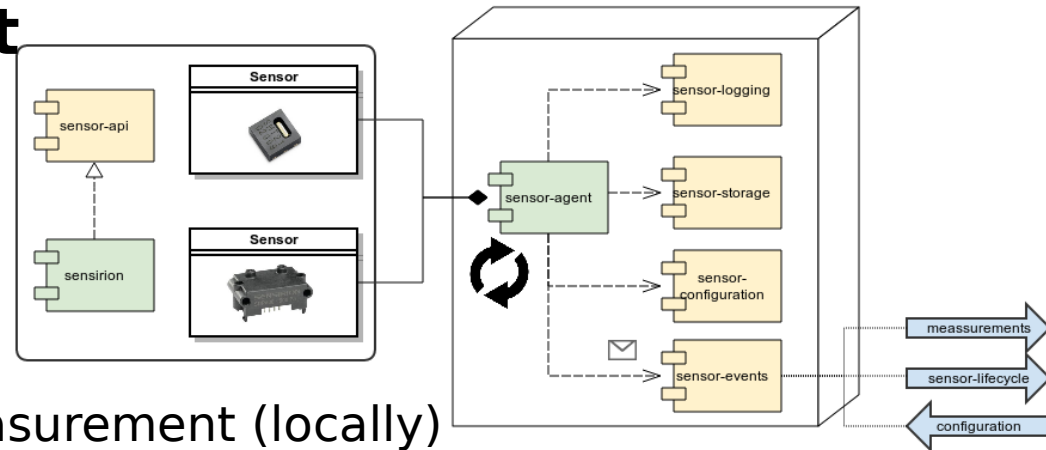
Plug-in architecture for cross-cutting-concerns



System Architecture

Layer: **Sensor-Agent**

Depends on abstractions



Logging

Storing the sensor-measurement (locally)

Storing the sensor-**configuration**
(might be another storage-medium than measurement)

Integrates with the outside-world via sensor-**events**

New measurement (out)

Sensor activated or reconfigured (out)

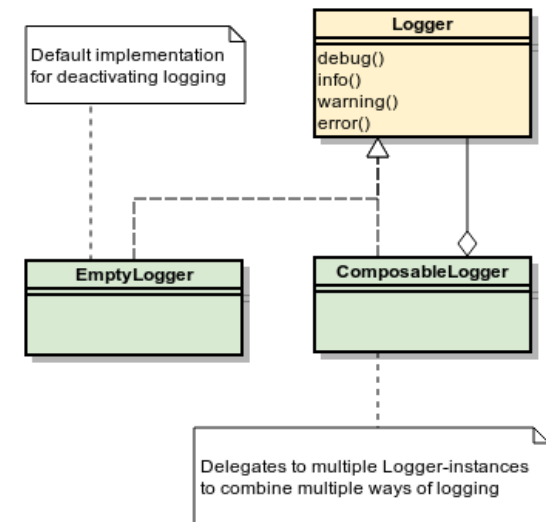
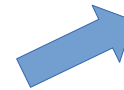
Instructions for reconfiguration (in)

System Architecture

Layer: **Sensor-Agent**

Abstractions

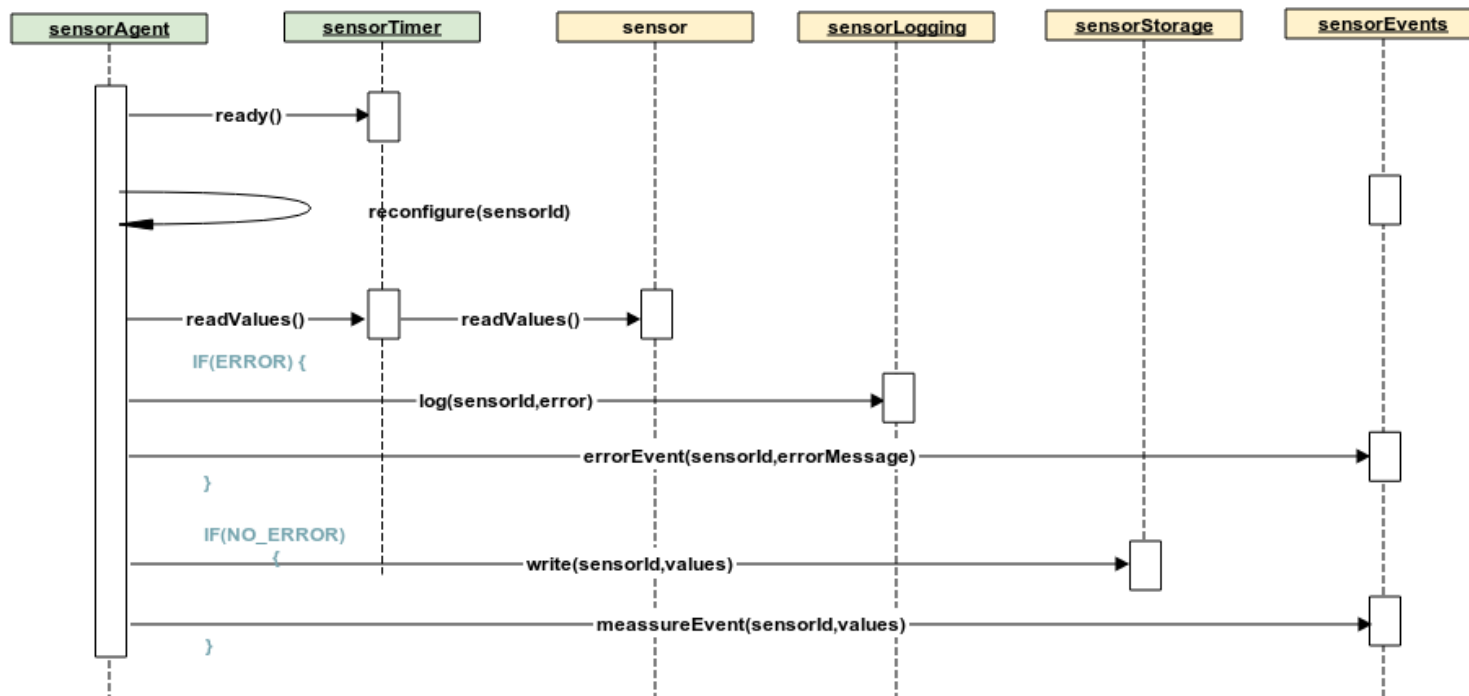
are interchangeable
interface segregation
dependency injection
can be combined (or composed)
are deactivated by default
by default empty implementations



System Architecture

Layer: **Sensor-Agent**

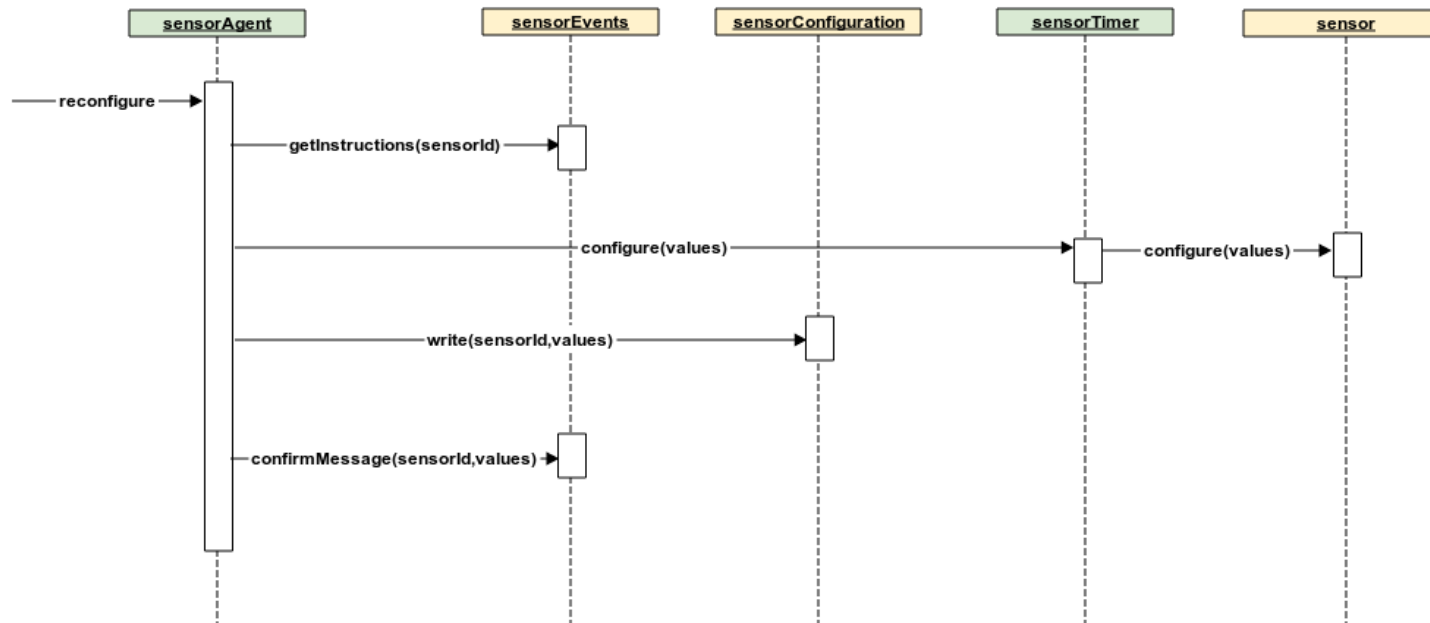
Runtime sequence



System Architecture

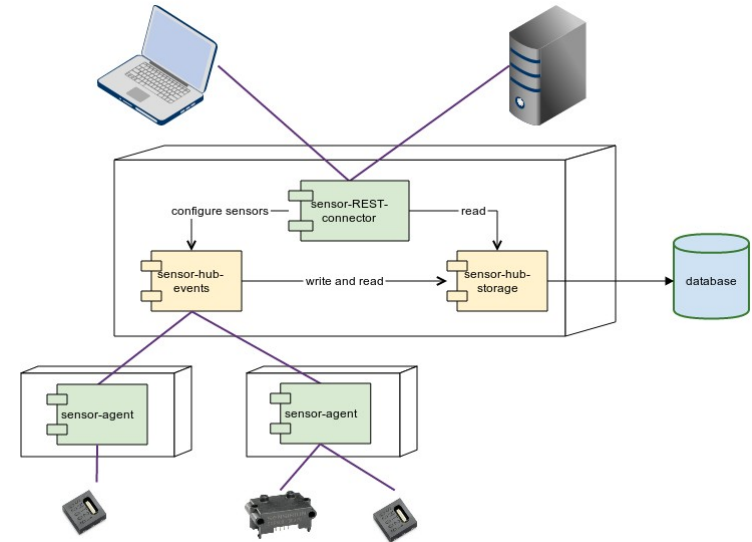
Layer: **Sensor-Agent**

Configuration sequence



System Architecture

Layer: **Sensor-Hub**



Runtime or (web-)application

Communicating with agents

Centralizing data-storage

Exposing data to users (and other devices/servers)

Goal

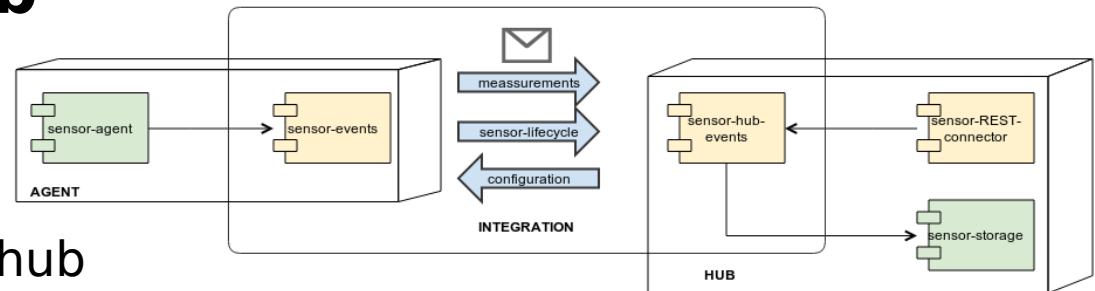
Collecting and storing data from different sensors

Enable user to query the data

Interface for configuring remotely the sensors

System Architecture

Layer: **Sensor-Hub**



Link between agent and hub

Measurements are pushed

Instructions are forwarded to

Events

Confirmation of configuration

Errors

Sensor-hub-events and sensor-events

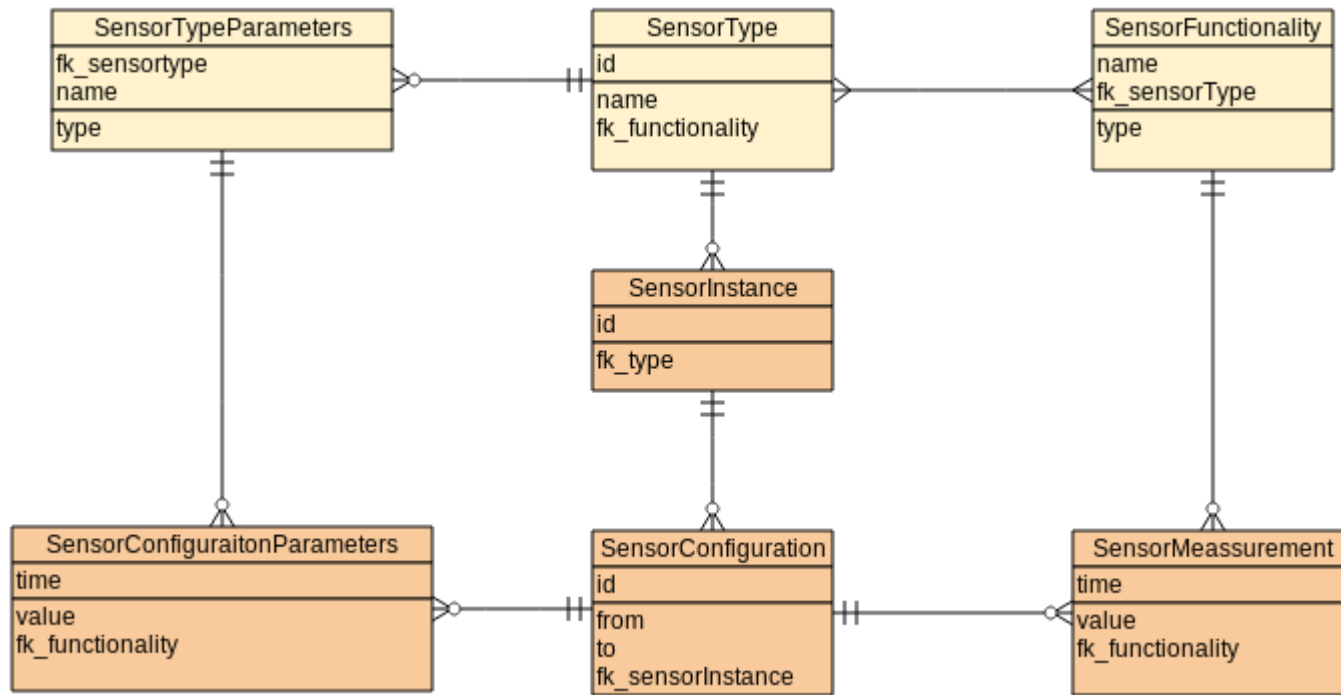
Should integrate with same protocol

Code is message based

System Architecture

Layer: **Sensor-Hub**

Datamodel



System Architecture

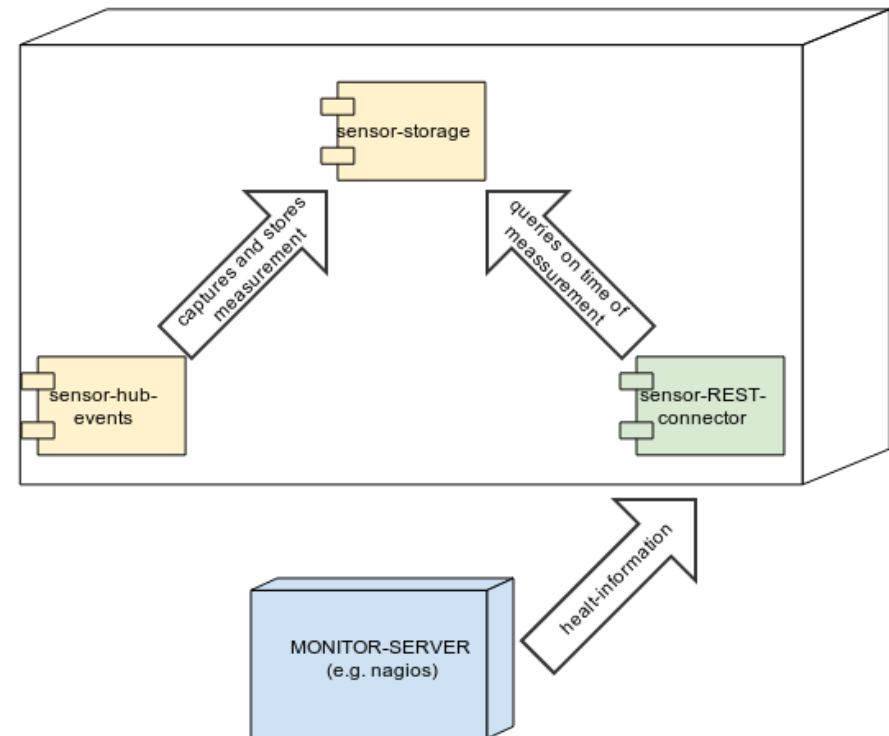
Layer: **Monitoring**

Monitor tool can query for

Error events

Deactivated agents
or sensors
(activity-monitoring)

REST-interface



Development principles

S

Single Responsibility Principle

O

Open Closed Principle

L

Liskov Substitution Principle

I

Interface Segregation Principle

D

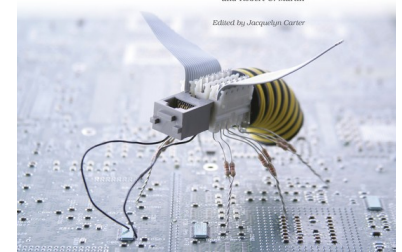
Dependency Inversion Principle

The Pragmatic
Programmers

Test-Driven Development
for Embedded C

James W. Grenning
Forewords by Jack Ganssle
and Robert C. Martin

Edited by Jacques-Louis Carrier



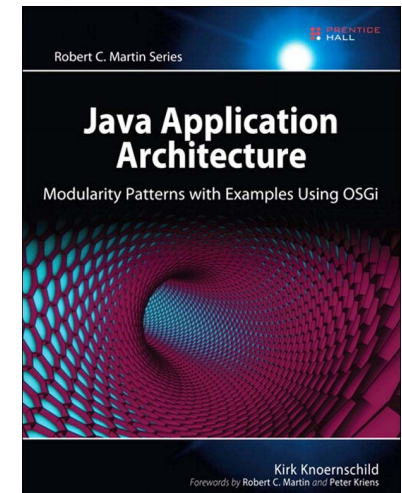
Robert C. Martin Series

PRENTICE
HALL

Java Application
Architecture

Modularity Patterns with Examples Using OSGi

Kirk Knoernschild
Forewords by Robert C. Martin and Peter Kriens



Development principles

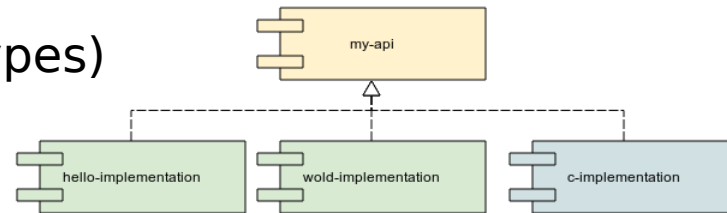
Modularity

Package code and classes
into reusable and composable
package

Provide

api-components
(interfaces and types)

concrete
implementations



Code needs to be **SOLID**

Development principles

Test Driven Development (**TDD**)

Drive your code through tests

Just enough code

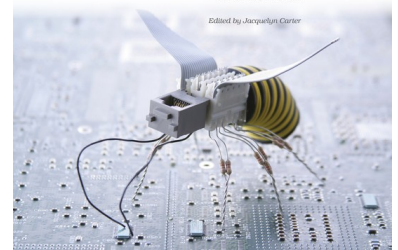
Isolate dependencies

The Pragmatic Programmers

Test-Driven Development for Embedded C

James W. Grenning
Forewords by Jack Ganssle
and Robert C. Martin

Edited by Jacquelyn Carter



Robert C. Martin Series

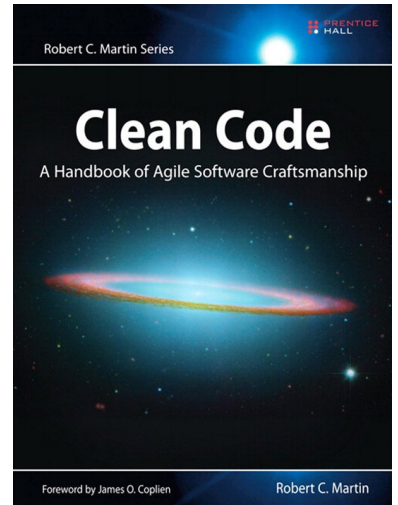
PRENTICE
HALL

Clean Code

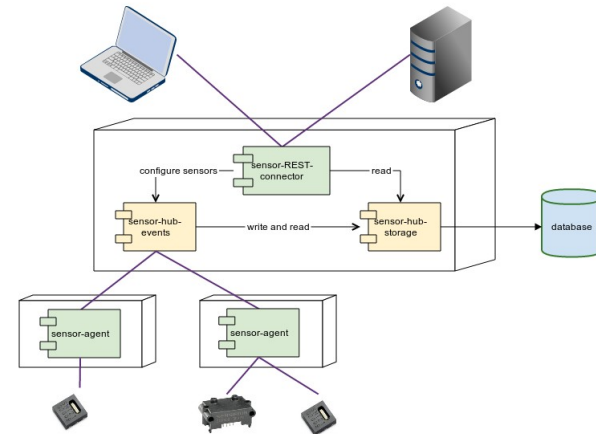
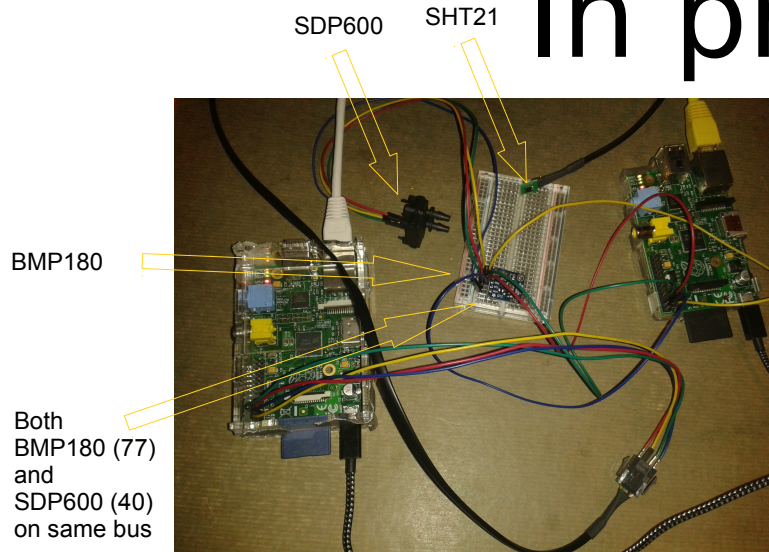
A Handbook of Agile Software Craftsmanship

Foreword by James O. Coplien

Robert C. Martin



In practice



```

Guake Terminal
The system is going down for system halt NOW!
pi@raspberrypi ~ $ Connection to 192.168.1.114 closed by remote host.
Connection to 192.168.1.114 closed.
bart@bvpers2:~$ ssh pi@192.168.1.114
ssh connect to host 192.168.1.114 port 22: No route to host
bart@bvpers2:~$ ssh pi@192.168.1.114
pi@192.168.1.114's password:
Permission denied, please try again.
pi@192.168.1.114's password:
Linux raspberrypi 3.10.25+ #622 PREEMPT Fri Jan 3 18:41:00 GMT 2014 armv6l

The programs included with the Debian GNU/Linux system are free software;
the exact distribution terms for each program are described in the
individual files in /usr/share/doc/*/copyright.

Debian GNU/Linux comes with ABSOLUTELY NO WARRANTY, to the extent
permitted by applicable law.
Last login: Tue Jun 3 22:45:12 2014 from bvpers2.home
pi@raspberrypi ~ $ sudo i2cdetect -y 1
0: 1 2 3 4 5 6 7 8 9 a b c d e f
10: . . . . . . . . . . . . . .
20: . . . . . . . . . . . . . .
30: . . . . . . . . . . . . . .
40: . . . . . . . . . . . . . .
50: . . . . . . . . . . . . . .
60: . . . . . . . . . . . . . .
70: . . . . . . . . . . . . . .
pi@raspberrypi ~ $
  
```

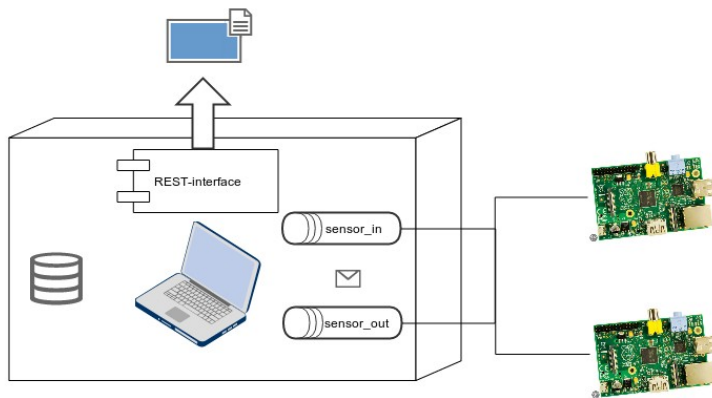
```

Guake Terminal
pi@raspberrypi ~ $ sudo shutdown -h now
Broadcast message from root@raspberrypi (pts/0) (Tue Jun 3 21:59:04 2014):
The system is going down for system halt NOW!
Connection to 192.168.1.137 closed by remote host.
pi@raspberrypi ~ $ Connection to 192.168.1.137 closed.
bart@bvpers2:~$ ssh pi@192.168.1.137
pi@192.168.1.137's password:
Linux raspberrypi 3.6.11+ #538 PREEMPT Fri Aug 30 20:42:08 BST 2013 armv6l

The programs included with the Debian GNU/Linux system are free software;
the exact distribution terms for each program are described in the
individual files in /usr/share/doc/*/copyright.

Debian GNU/Linux comes with ABSOLUTELY NO WARRANTY, to the extent
permitted by applicable law.
Last login: Tue Jun 3 21:58:52 2014 from bvpers2.home
-bash: rt: opdracht niet gevonden
pi@raspberrypi ~ $ sudo i2cdetect -y 1
0: 1 2 3 4 5 6 7 8 9 a b c d e f
10: . . . . . . . . . . . . . .
20: . . . . . . . . . . . . . .
30: . . . . . . . . . . . . . .
40: . . . . . . . . . . . . . .
50: . . . . . . . . . . . . . .
60: . . . . . . . . . . . . . .
70: . . . . . . . . . . . . . .
pi@raspberrypi ~ $
  
```


In practice



The screenshot shows the ActiveMQ web console interface. The browser address bar displays 'localhost:8161/admin/queues.jsp'. The page header includes the ActiveMQ logo and the Apache Software Foundation logo. The navigation bar contains links: Home, Queues, Topics, Subscribers, Connections, Network, Scheduled, Send, and Support. Below the navigation bar, there is a 'Queue Name' input field and a 'Create' button. The main content area displays a table of queues.

Name ↑	Number Of Pending Messages	Number Of Consumers	Messages Enqueued	Messages Dequeued	Views	Operations
sensor_in	0	0	0	0	Browse Active Consumers atom rss	Send To Purge Delete
sensor_out	0	0	0	0	Browse Active Consumers atom rss	Send To Purge Delete

The footer of the page includes the copyright notice: 'Copyright 2005-2013 The Apache Software Foundation. (printable version)' and the URL 'activemq.apache.org'.

Conclusion

Mobile (devices)

Reliable

Reuse?

Status and roadmap

Java

Sensor-API

SHT21 and SDP600 done

STS21, BMP118

Sensor-HUB (activemq)

READY TO BE TESTED !!!

DEPLOYMENT-refinements (configuration)

C

Sensor-API (SHT21)

Sensor-Agent (ongoing)

Status and roadmap

Documentation

Deployment-guide

Mini-training on Raspberry Pi

Structured documentation on supported sensors **ongoing**

Code and documentation on <https://github.com/bartvoet/>

https://github.com/bartvoet/sensors_documentation

g... deredactie.be: ... Google YouTube · Broa... groept Functies zoeken Google scala fp Nieuw tabblad Come Home · A... Save to Men

PUBLIC bartvoet / sensors_documentation Unwatch 1 Star 0 Fork 0

Documentation for the sensor-hub-project — Edit

10 commits 1 branch 0 releases 1 contributor

branch: master sensors_documentation / +

Practical example as pdf

bartvoet authored 2 hours ago latest commit 6e2edec43

setup Adding setup-documents 7 hours ago

thesis Practical example as pdf 2 hours ago

README.md Initial commit 10 days ago

README.md

sensors_documentation

<https://github.com/bartvoet/sensors/commits/master>

g... deredactie.be: ... Google YouTube · Broa... groept Functies zoeken Google scala fp Nieuw tabblad Come Home · A... Save to Men

PUBLIC bartvoet / sensors Unwatch 1 Star 0 Fork 0

branch: master sensors / Commits

Jun 05, 2014

Adding support for activemq as interaction to enable the sensor-agent 44d9d6d32
bartvoet authored a minute ago Browse code

Adapted SensorEvents interface 4bd03c3d17
bartvoet authored an hour ago Browse code

Added SensorValue to indicate the type of the returned value d73aa0412a
bartvoet authored an hour ago Browse code

Jun 04, 2014

Test b6fe4bf2bf
bartvoet authored 2 hours ago Browse code

Cleanup SensorAgent 5e28df1e81
bartvoet authored 2 hours ago Browse code

Cleanup of SensorType-interface e929c4e837
bartvoet authored 2 hours ago Browse code

Refactoring abstractions d271ea3c5f
bartvoet authored 3 hours ago Browse code

Feb 28, 2014

Add support for SDP600 9e967c2e8a
bartvoet authored 1h 28 min Browse code

Cleanup e93d9efc43
bartvoet authored on 28 feb. Browse code

Added dependency to sensor-api 8740173892
bartvoet authored on 28 feb. Browse code

Jan 31, 2014

Clean up, removed original POC bc87240c83
bartvoet authored on 31 jan. Browse code

removal of module, not yes necessary e653df3578
bartvoet authored on 31 jan. Browse code