

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

...

Intro

What is the content of this thesis?

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

Requirements and scope

What is expected?

Startup requirements

Context

Department of Building Physics KUL
performing

research on energy **efficient buildings**

Startup requirements

Demand

System(s) for continuous measurement
that is

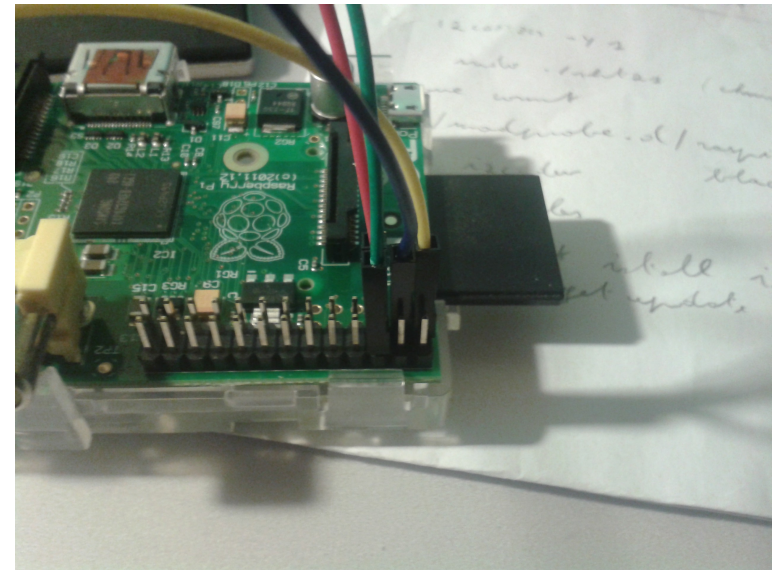
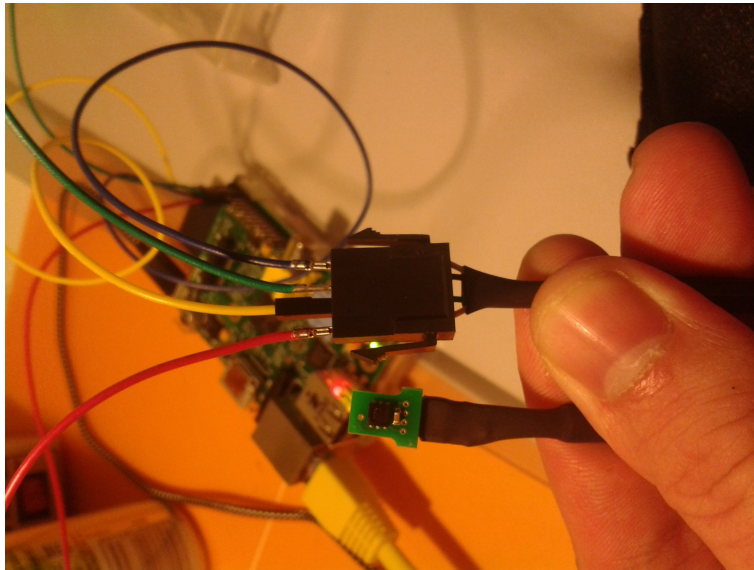
Reliable

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

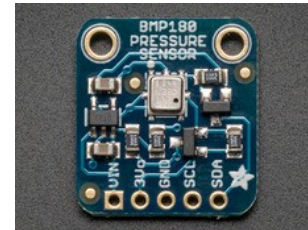


Startup requirements

(Not requested by stakeholder)

BMP180 (Bosh)

Barometric pressure



DHT11

Temperature



User profile

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 focus

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

...

(although not excluded)

Scope and focus

Consequence

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

Integration

Extensibility

Ease of use

Reliability

Documentation

...

Scope and position

Consequence

Focus on a **pluggability** and **portability**

Different hardware

Different systems (OS or not)

Different network-integration

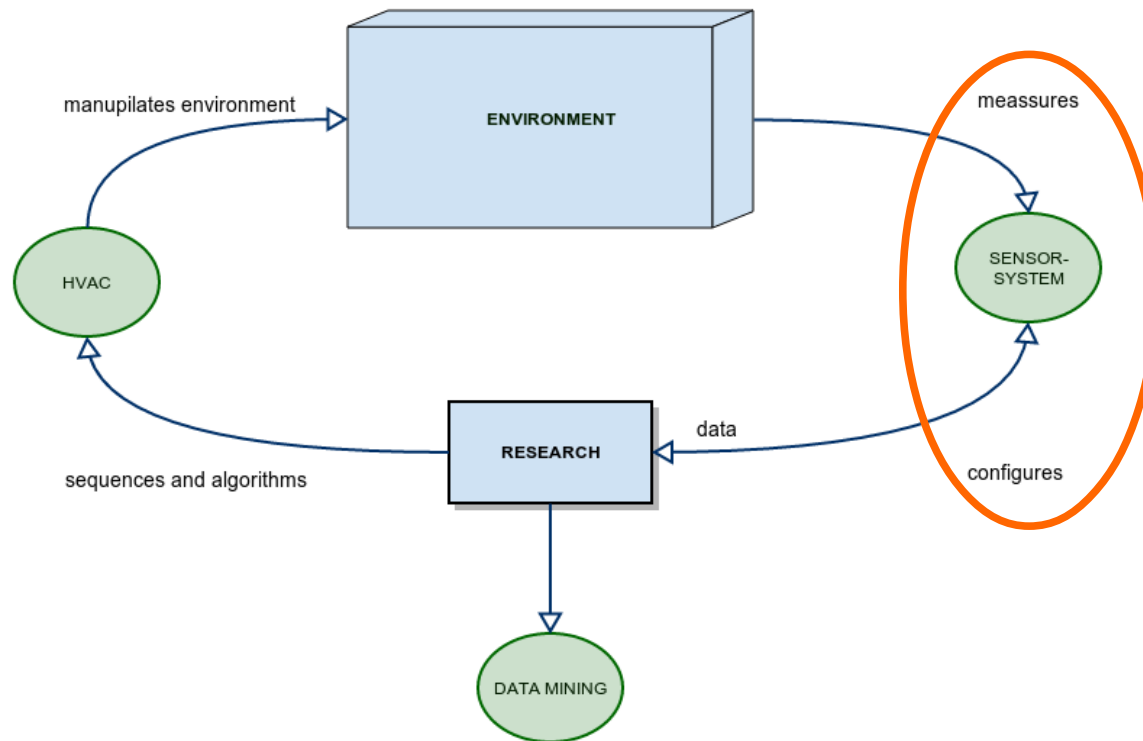
...

Open for **extension**

Closed for **modification**

Environment

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

Long time

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

System Challenges

TOP 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 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 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 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 Challenges

TOP Challenges

Correlation and timing

Measurements need to be correlated to

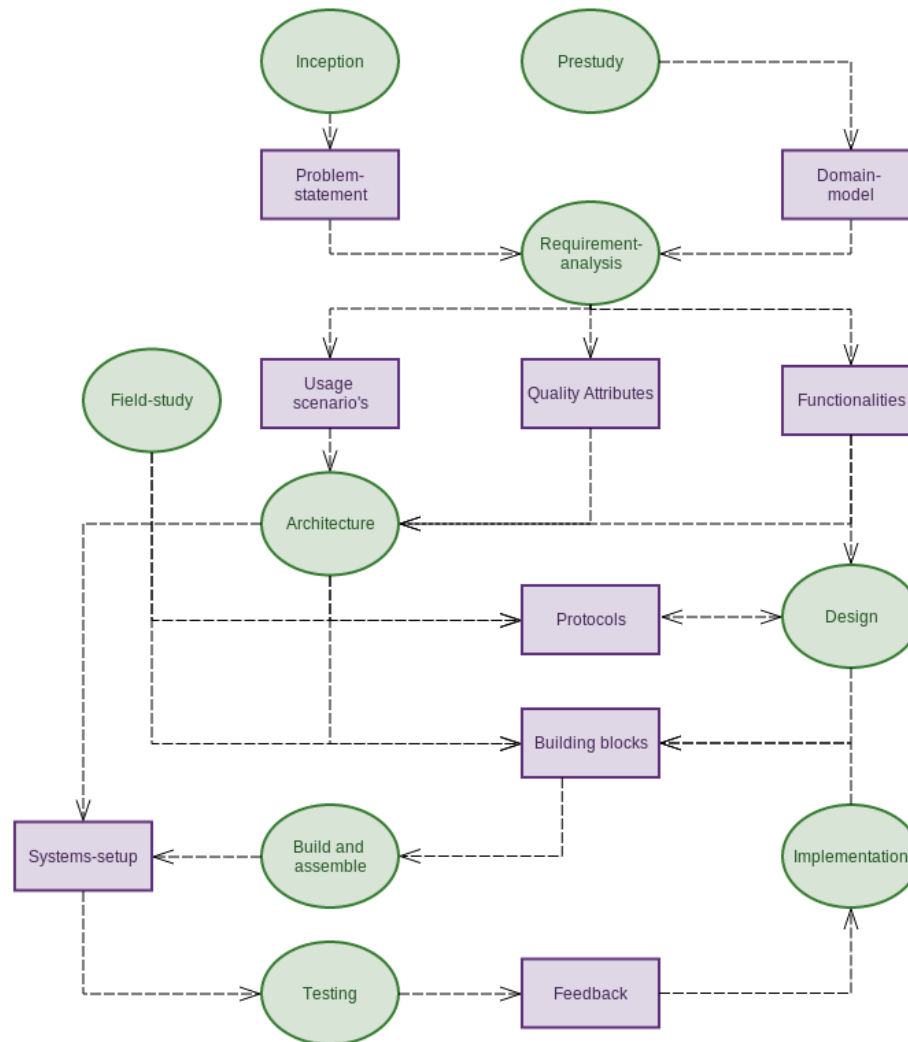
Time

Configuration of sensors

Approach

Process of development?
Building blocks?

Approach

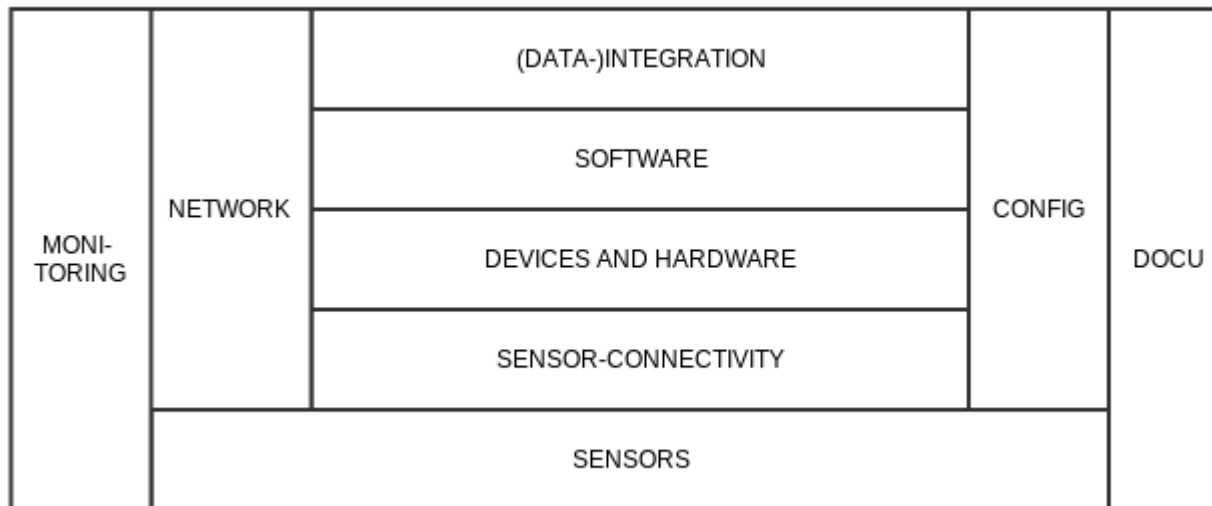


Approach

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		

Design and architecture

Concept?

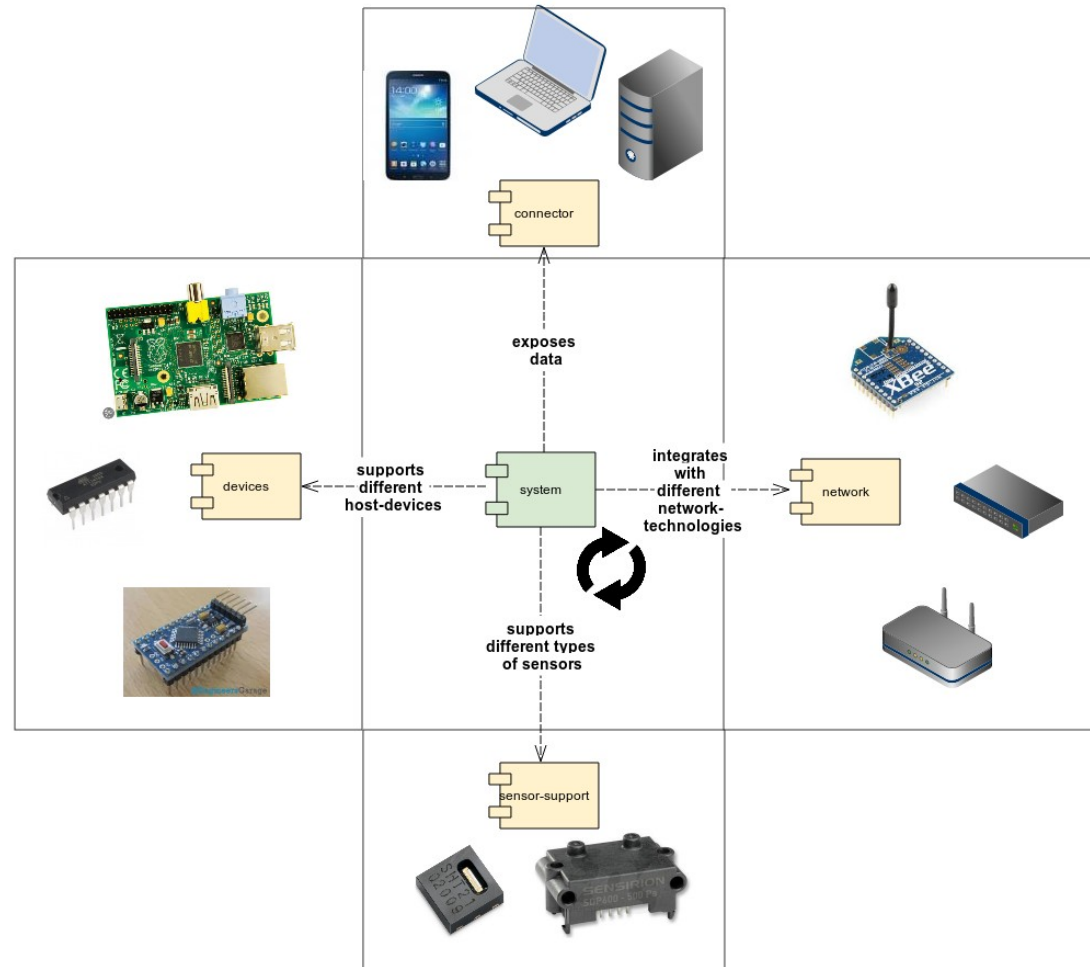
Principles?

Design?

Building blocks?

System Concept

System-concept: **runtime and dependencies**



System Concept

System-concept **Runtime**

Scheduling measurements

Relying on system abstractions

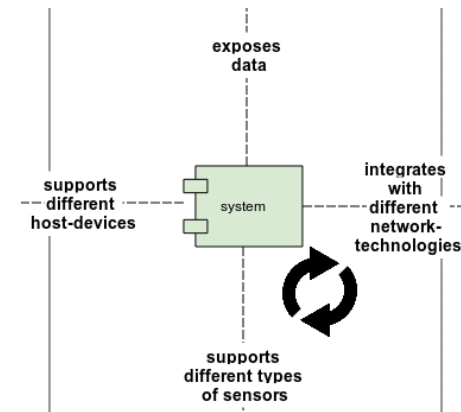
Integration

Storage

Device-abstractions

More sensors

Of different types



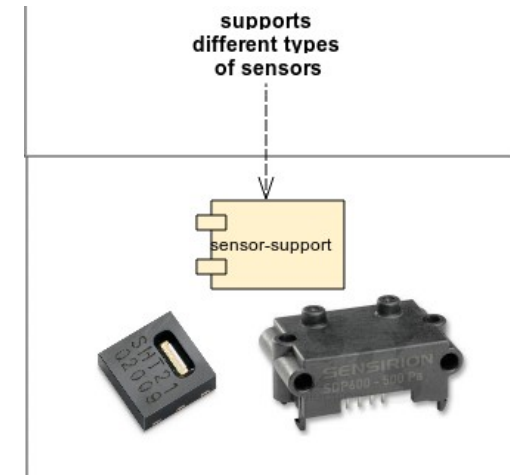
System Concept

System-concept: **Support different sensors**

System supports

Extracting data from
multiple Sensors

Multiple types via
Sensor-abstraction



System Concept

System-concept: **Support different devices**

Isolate system-dependencies

Scheduling

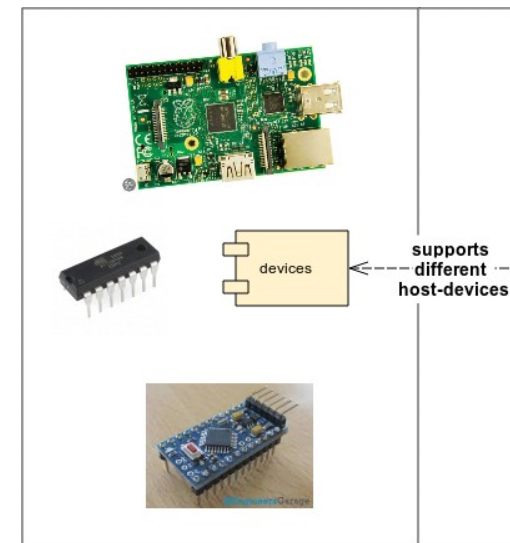
Digital interfaces

...

Support for

Low level (c-api)

High level (java)



System Concept

System-concept: **Network independence**

Integration-capability isolated

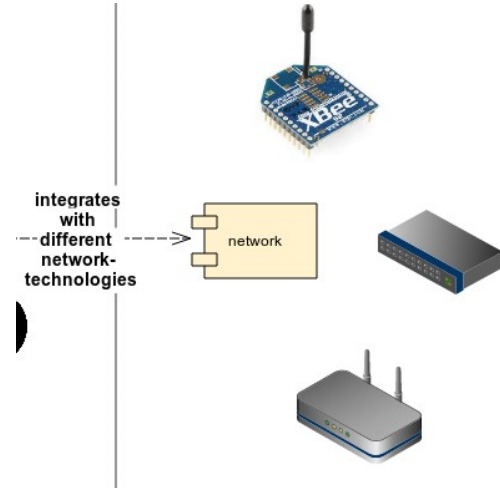
Local integration

Zigbee

WIFI

MQTT

...



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

System Concept

System-concept: **Data exposure**

Connectors for clients

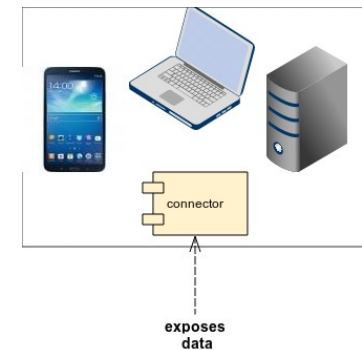
Open protocols to integrate
with various kind of devices

Current provided protocol

REST exposing

JSON

CSV (under construction)



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



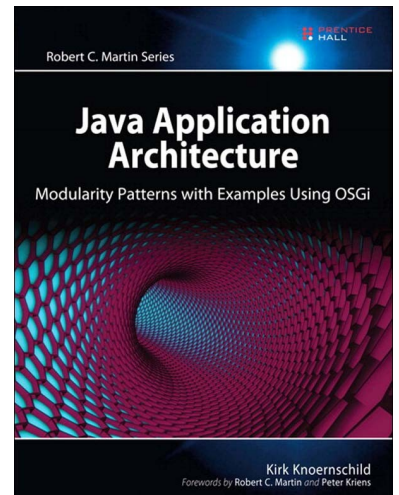
Robert C. Martin Series

PRENTICE
HALL

Java Application
Architecture

Modularity Patterns with Examples Using OSGi

Kirk Knoernschild
Forewords by Robert C. Martin and Peter Kriens



Development principles

SOLID

Introduced by Robert C-Martin

Principles for improving

Flexibility

Extensibility

Modularity

Testability

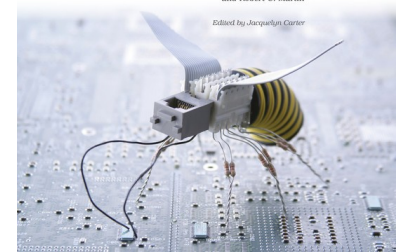
Introduced in OO but applicable
to all programming-paradigms

The Pragmatic
Programmers

Test-Driven Development
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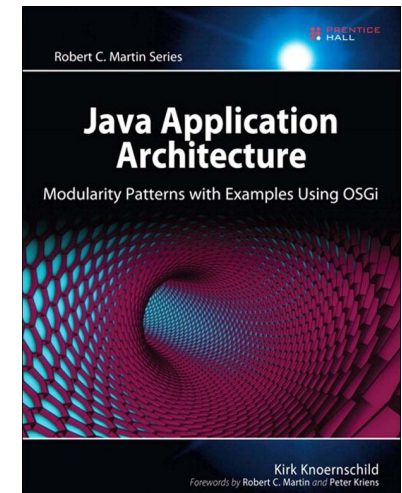
Robert C. Martin Series

PRENTICE
HALL

**Java Application
Architecture**

Modularity Patterns with Examples Using OSGi

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Development principles

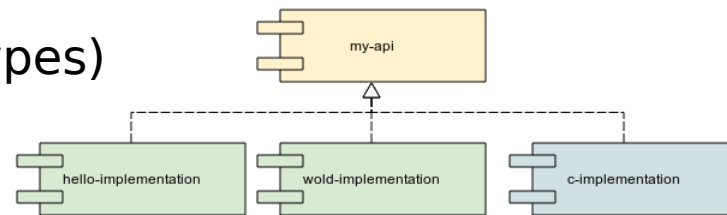
Modularity

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

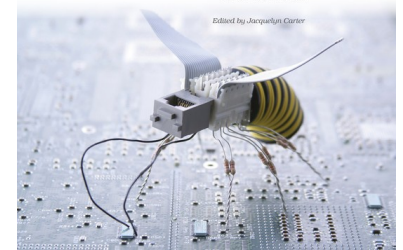
(Discovered/invented by Kent Beck)

The Pragmatic
Programmers

Test-Driven Development for Embedded C

James W. Grenning
Forewords by Jack Ganssle
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Edited by Jacquelyn Carter



Robert C. Martin Series

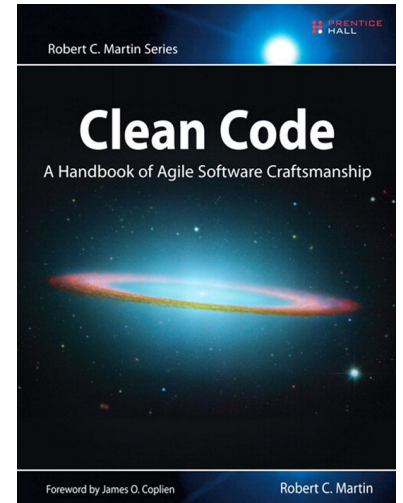
PRENTICE
HALL

Clean Code

A Handbook of Agile Software Craftsmanship

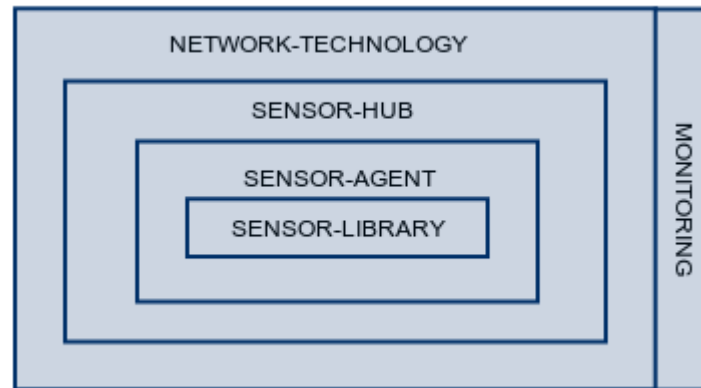
Foreword by James O. Coplien

Robert C. Martin



System Architecture

Design-concept: **Layering**



Different building blocks

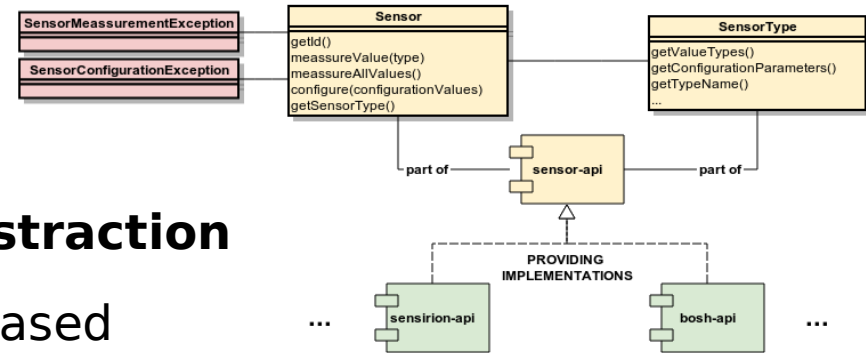
Built on top

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)

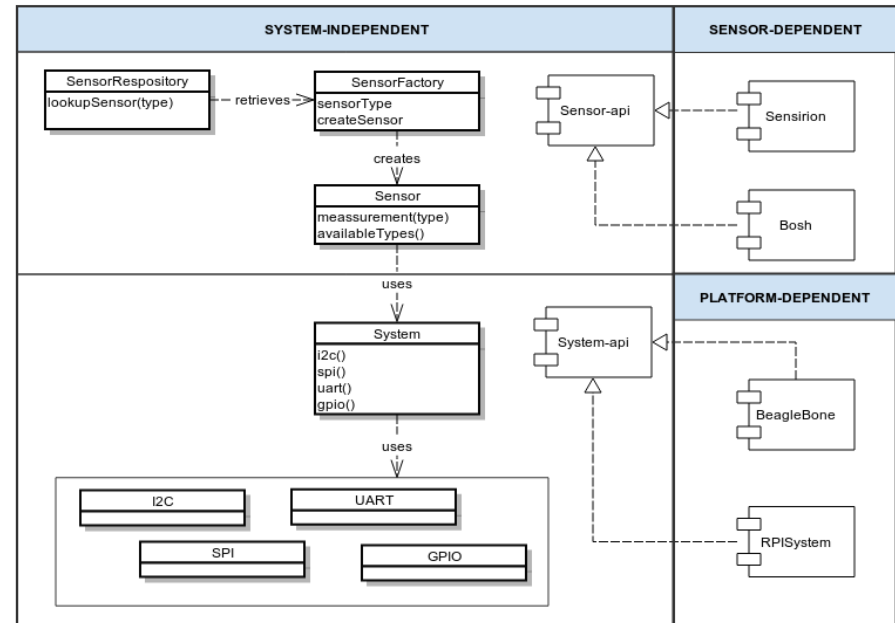
Pin-access

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

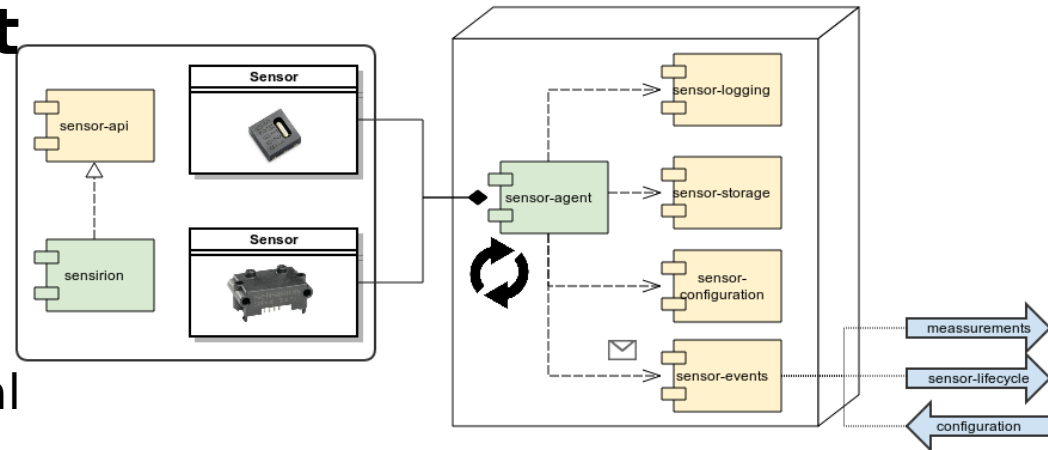
Notifies and communicates via sensor-events

Goal

Use the sensor-api without low-level coding

Set up a measurement system based on configuration

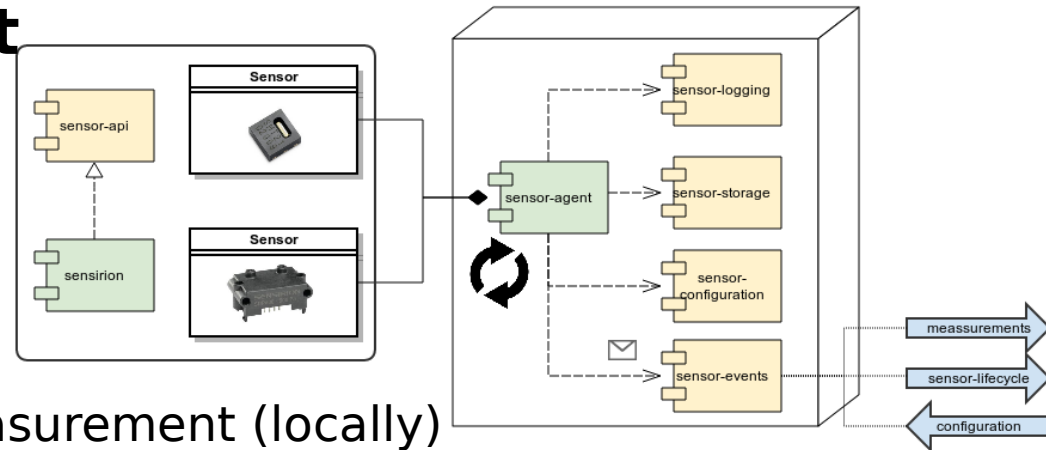
Plug-in architecture for cross-cutting-concerns



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)

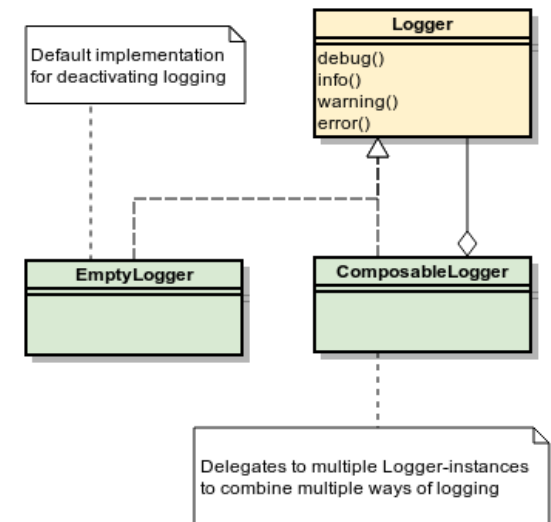
Instructions for reconfiguration (in)

System Architecture

Layer: **Sensor-Agent**

Abstractions

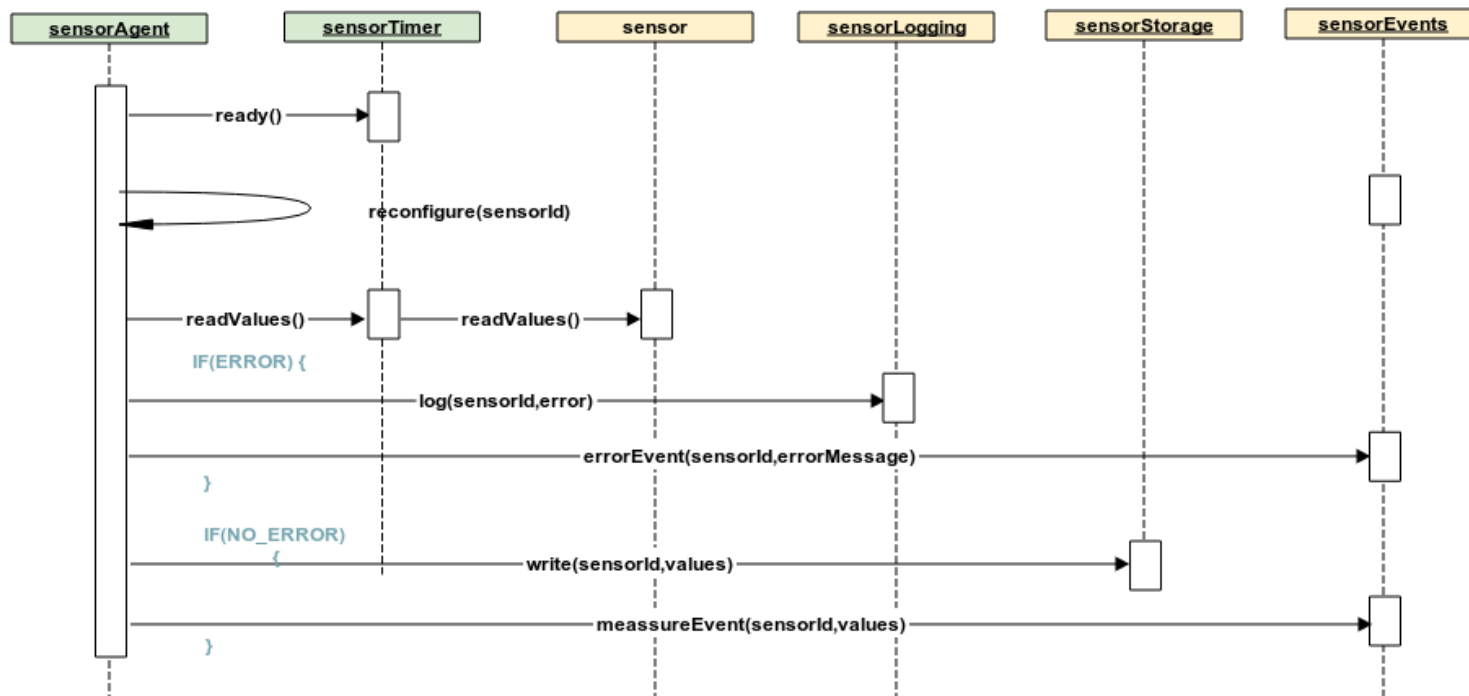
are interchangeable
interface segregation
dependency injection
can be combined (or composed)
are deactivated by default
by default empty implementations



System Architecture

Layer: **Sensor-Agent**

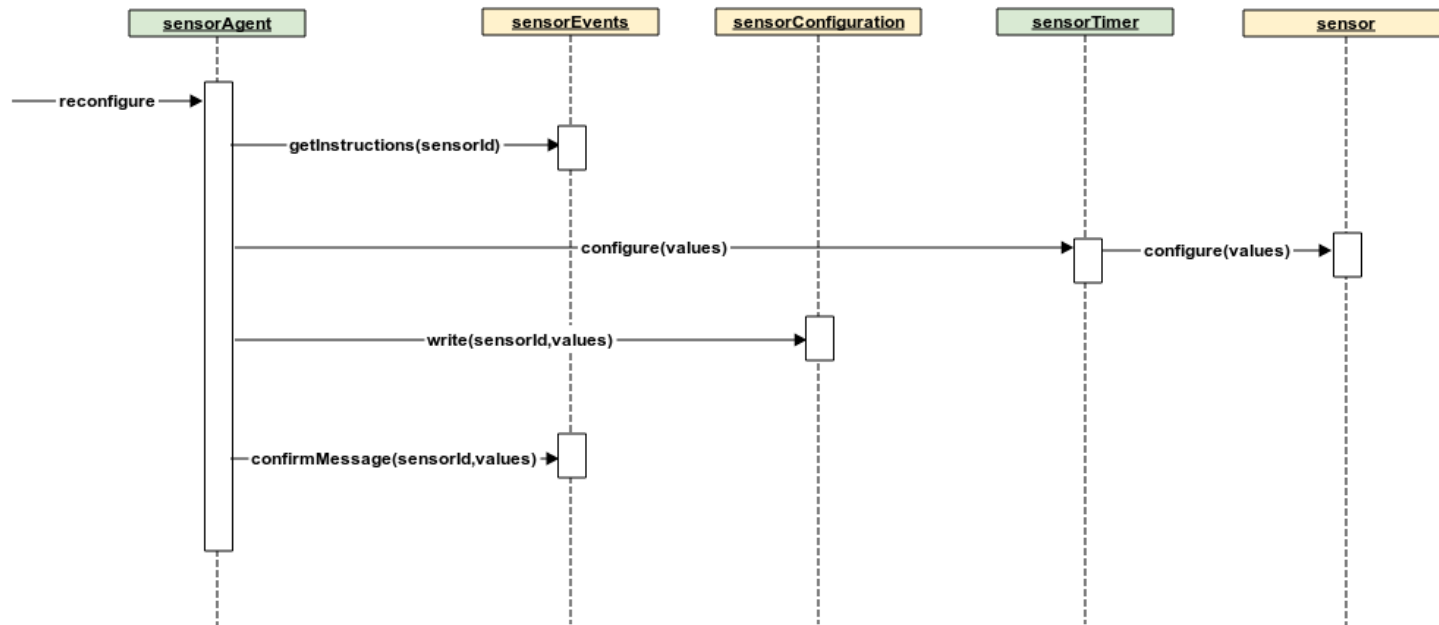
Runtime sequence



System Architecture

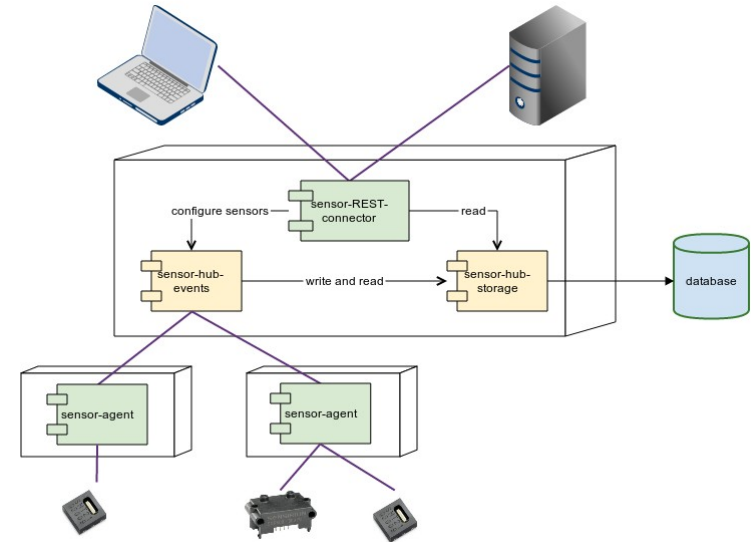
Layer: **Sensor-Agent**

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

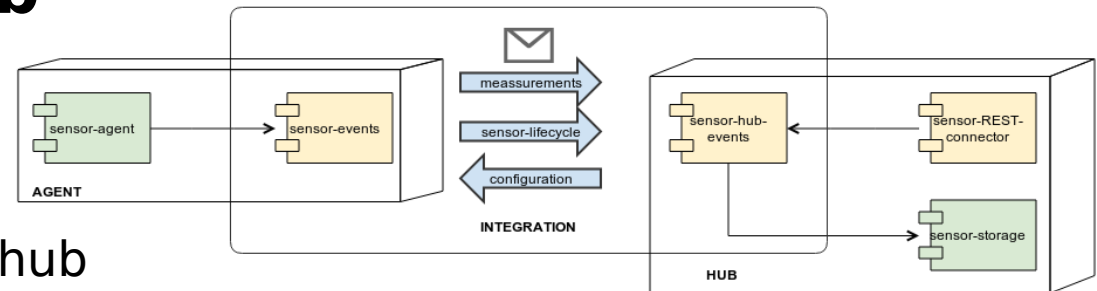
Collecting and storing data from different sensors

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

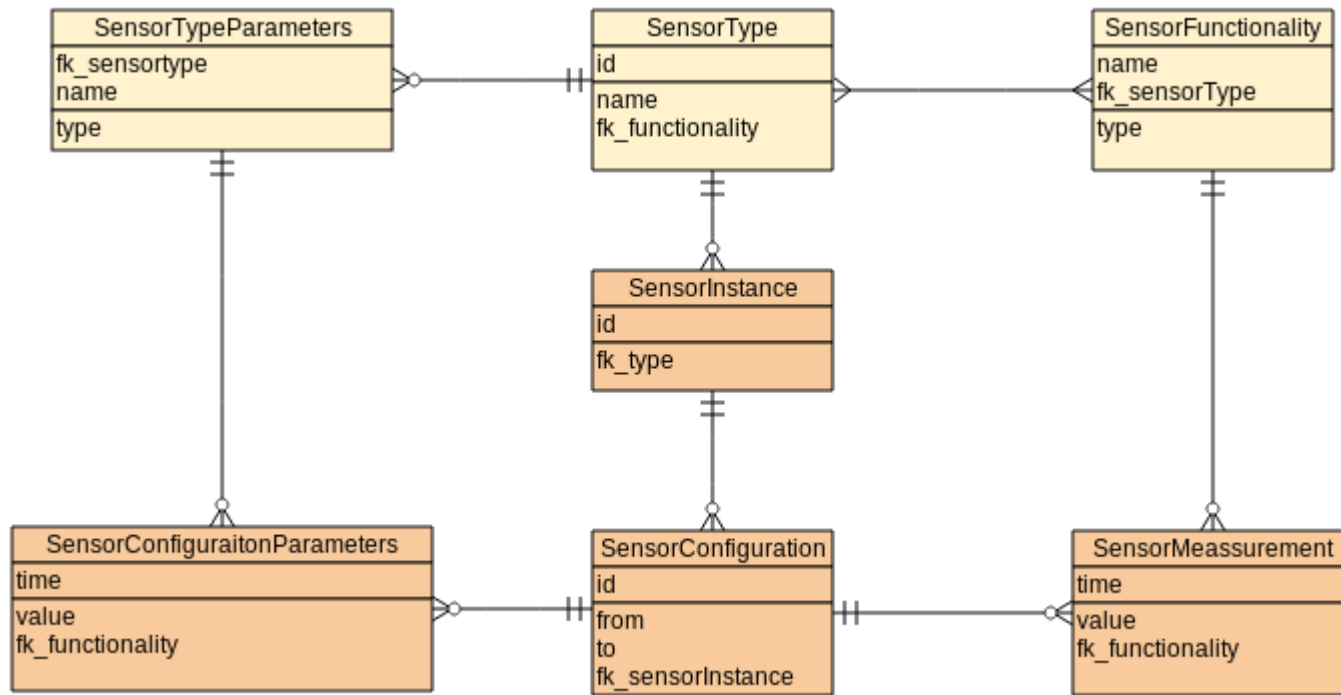
Should integrate with same protocol

Code is message based

System Architecture

Layer: **Sensor-Hub**

Datamodel



System Architecture

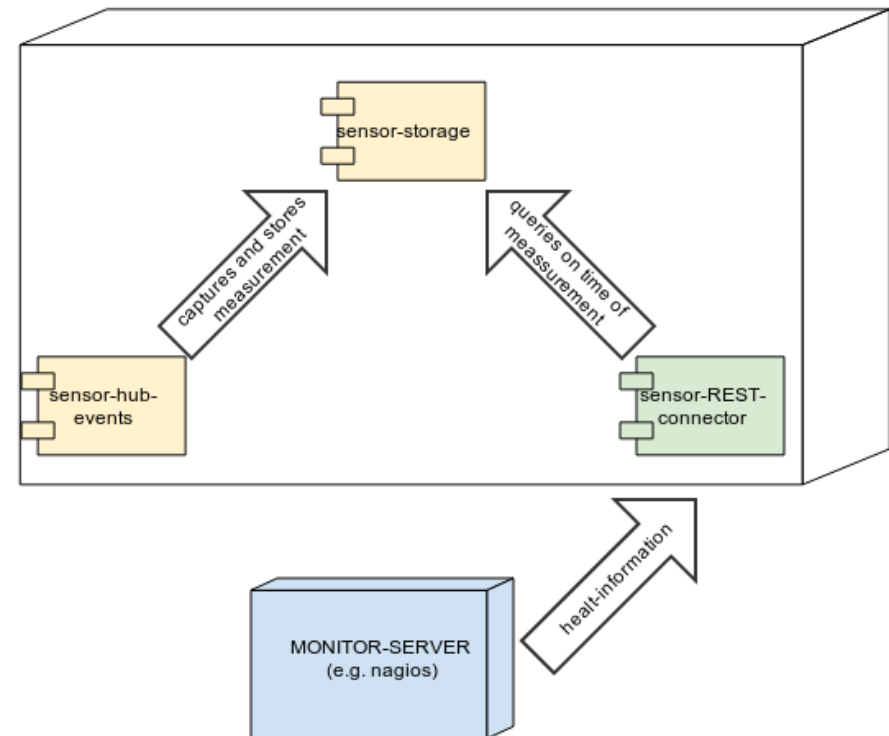
Layer: **Monitoring**

Monitor tool can query for

Error events

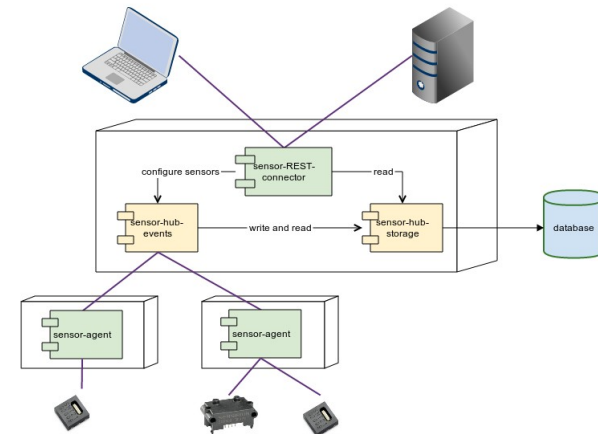
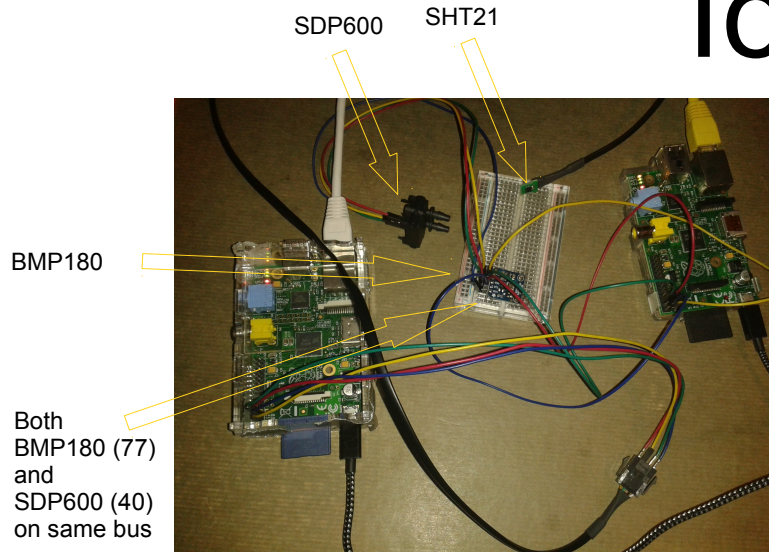
Deactivated agents
or sensors
(activity-monitoring)

REST-interface



In practice
Today?
Status?
Future?

Today



```

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
00:  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
10:  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
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70:  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
pi@raspberrypi ~ $
pi@raspberrypi: ~ pi@raspberrypi: ~ bart@bvpers2: ~/eindwerkgit/sensors_documentation
    
```

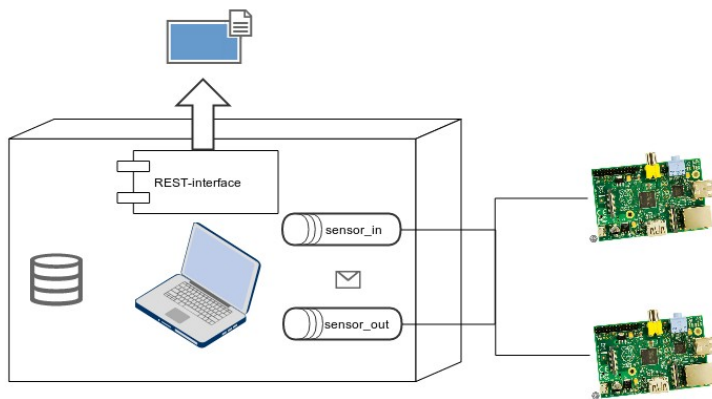
```

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!
pi@raspberrypi ~ $ Connection to 192.168.1.137 closed by remote host.
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
00:  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
10:  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
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70:  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
pi@raspberrypi ~ $
pi@raspberrypi: ~ pi@raspberrypi: ~ bart@bvpers2: ~/eindwerkgit/sensors_documentation
    
```

Today



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 is titled 'Queues' and displays a table with the following data:

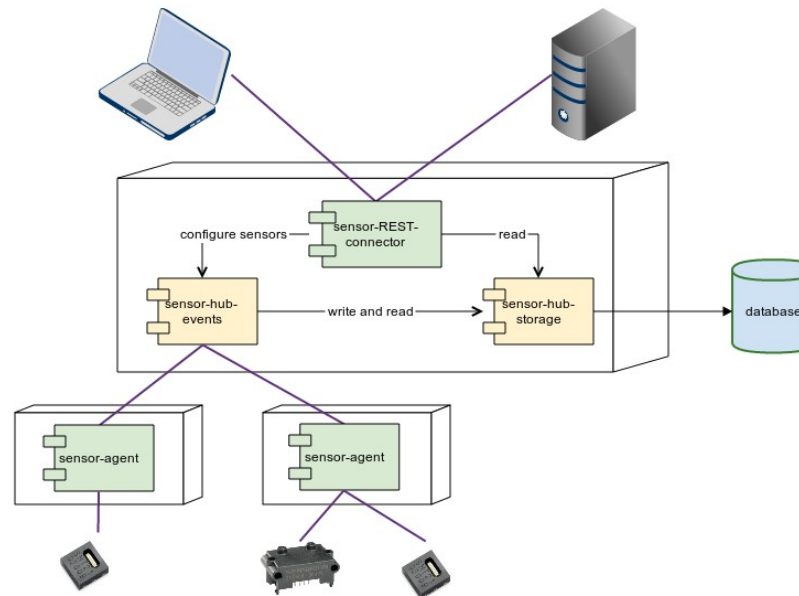
Name ↑	Number Of Pending Messages	Number Of Consumers	Messages Enqueued	Messages Dequeued	Views	Operations
sensor_in	0	0	0	0	Browse Active Consumers atom rss	Send To Purge Delete
sensor_out	0	0	0	0	Browse Active Consumers atom rss	Send To Purge Delete

On the right side of the page, there are three sections: 'Queue Views' (with links for Graph and XML), 'Topic Views' (with a link for XML), and 'Subscribers Views' (with a link for XML). Below these is a 'Useful Links' section with links for Documentation, FAQ, Downloads, and Forums. The footer of the page displays 'Copyright 2005-2013 The Apache Software Foundation. (printable version)' and 'activemq.apache.org'.

Recap of top challenges

Multiple sensors

Support for “heterogeneous sensor networks”



Recap of top challenges

Reliability

Data Loss

- Local and centralized storage

- Scalability of sensor-hub and centralized storage

Support for different devices

- For different non-functional requirements

Monitoring

- Sensor-Hub can propagate errors

- Sensor-Hub can non-activity of Sensor-agents

Recap of top challenges

Correlation and timing

- Data-model integrates configuration-id's

- Timing is kept centralized

- Few seconds difference can be tolerated

- Sensor-Hub can be programmed to check differences (if required)

Recap of top challenges

Usability and Configurability

System requires no low-level programming
to set up sensors

Sensor-configuration and -timing
can be configured via hub

Recap of top challenges

Extensibility

Sensor-implementation are abstracted behind generic interface

New sensors can be added by implementing an interface

Status

Java-implementations

Sensor-API

SHT21 and SDP600 done

STS21, BMP118 ongoing

Sensor-Agent (activemq)

READY TO BE TESTED !!!

Sensor-HUB (Activemq and Tomcat)

READY TO BE TESTED !!!

DEPLOYMENT-refinements (configuration and discovery)

Status

C-implementations

Sensor-API

SHT21 done

SDP600, STS21, BMP118 ongoing

System-support limited to RPI

Sensor-Agent

Raspberry Pi ongoing

AVR ongoing

Status

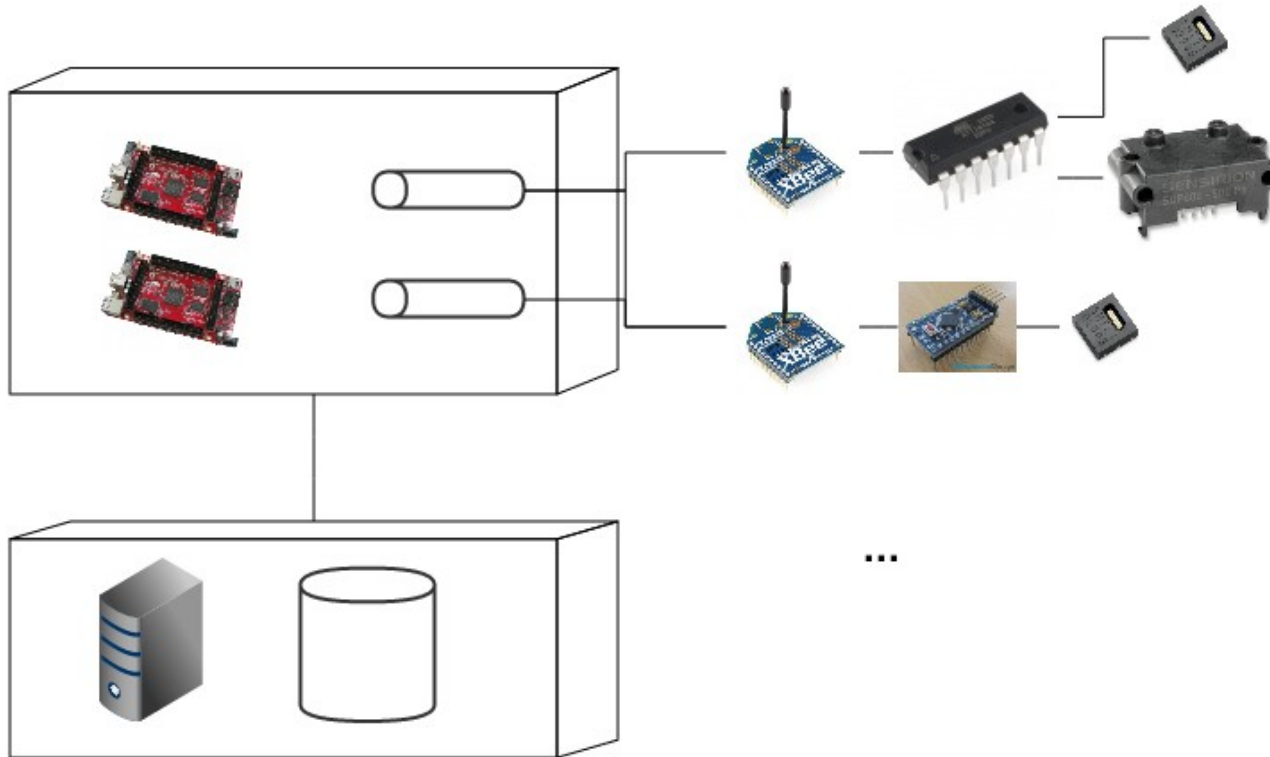
Documentation

Deployment-guide

Mini-training on Raspberry Pi

Structured documentation on supported sensors ongoing

Future scenarios



Future scenarios

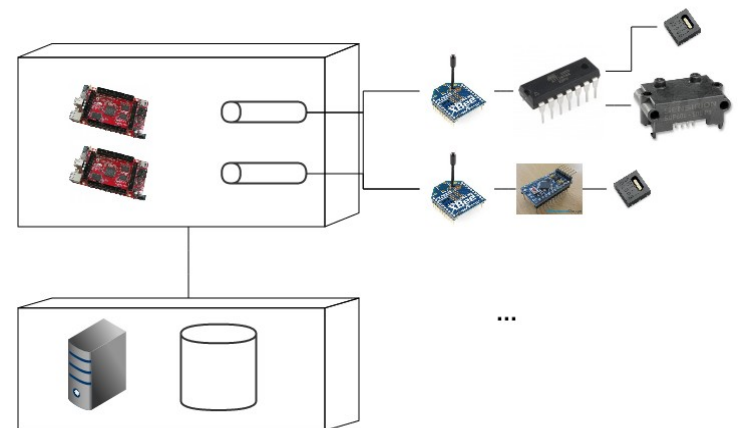
Adding sensors

Sensor-abstraction

Adding new implementation to sensor-agent

Keep attention

C and Java-implementation should remain in sync



Future scenarios

Elaborating/Finishing the C-agents

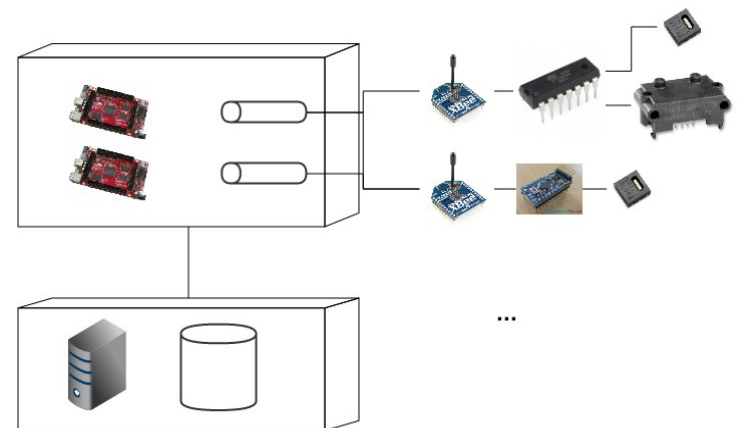
(currently only on Raspberry Pi)

Support for AVR

Allowing low-level devices

Larger scenario's (networks)

Constrained environments



Future scenarios

New integration-mechanisms

Data-Link, Network, Transport

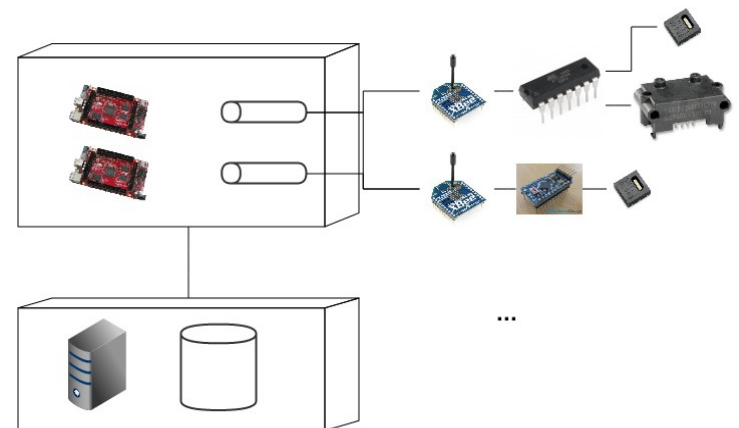
Meshing networks

Zigbee - IEEE 802.15.4 – Bluetooth light – RF

Middleware

MQTT (Message Queuing Telemetry Transport)

MQTT-SN (MQTT for Sensor Networks)



Future scenarios

Scaling

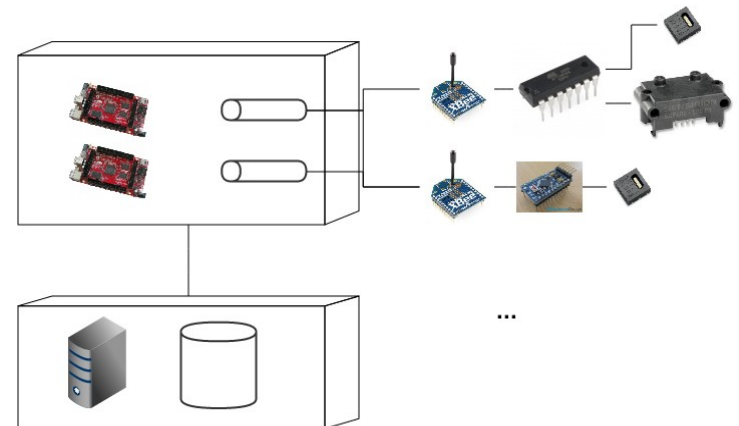
Adding more sensor-hubs

(load balancing ActiveMq)

Storage and backup on server

Monitoring

Monitor rest-interface with Nagios



Future scenarios

SensorHub: Raspberry Pi best option?

	Raspberry Pi	BeagleBone Black	pcDuino	Olinuxino Micro	Cubietruck
Memory	4 / 32 GB DDR-1600	4 / 32 GB DDR-1600 ECC	2 / 16 GB DDR-1600	2 / 16 GB DDR-1600	2 / 16 GB DDR-1600
Clockspeed	700 MHz	1 GHz	1 GHz	1 GHz	1 GHz
CPU-core(s)	ARM-11	ARM-Cortex-A8	ARM-Cortex-A8	Dual ARM-Cortex-A7	Dual ARM-Cortex-A7
GPU-core	Videocore IV	SGX530	Mali-400	Dual Mali-400	Dual Mali-400
Hardware Codecs	H264, MPEG-4 AVC (MPEG-2, VC-1 optioneel)	-	MPEG-1/2/4 AVC, JPEG, H.263, H.264, AVS, VC1, WMV7/8, VP-6	MPEG-1/2/4 AVC, JPEG, H.263, H.264, AVS, VC1, WMV7/8, VP-6	MPEG-1/2/4 AVC, JPEG, H.263, H.264, AVS, VC1, WMV7/8, VP-6
RAM	512 MB	512 MB	1 GB	1 GB	2 GB
Flash	-	2 GB	2 GB	4 GB	2 GB



Future scenarios

SensorHub: Raspberry Pi best option?

	Raspberry Pi	BeagleBone Black	pcDuino	Olinuxino Micro	Cubietruck
Lithium-battery	-	-	-	Supported	Supported
Video	HDMI, Composer	Micro-HDMI	HDMI	HDMI, VGA (adapter)	HDMI, VGA
Connections	2 * USB 2.0	USB 2.0	2 * USB 2.0	3 * USB 2.0	3 * USB 2.0, Bluetooth
Audio	Audio-jack	-	-	Audio-jack, Micro	Audio-jack, SPDIF
Network	Fast Ethernet	Fast Ethernet	Fast Ethernet	Fast Ethernet	Gigabit, WIFI
Storage	SD	micro-SD	micro-SD	SD, micro-SD, SATA	SD, micro-SD, SATA
Usage	Media Center ++ PC + Home automation +	Home automation ++	PC +	Media Center + Router + NAS ++ SERVER ++ Home automation + Mobile ++	Media Center + Router ++ NAS +++ SERVER ++ Home automation + Mobile +
Price	35 €	45 €	60 €	65 €	95 €



Future scenarios

SensorHub: Raspberry Pi best option?

Depends on scenario

- + Accessible
- + Well documented and supported by community
- Stability and industry compliance
- Performance (strength is GPU not CPU)

Recommended for **educational scenario's**

Depending on storage-setup and power required

BeagleBone



Olinuxino



Cubieboard



Future scenarios

SensorHub: Raspberry Pi best option?

Sensor-hub and -agent

Portable

Java is supported on most (all) high-level devices

C is supported on all low-level devices

System-dependencies isolated

Recommended for **educational scenario's**

Depending on storage-setup and power required

BeagleBone

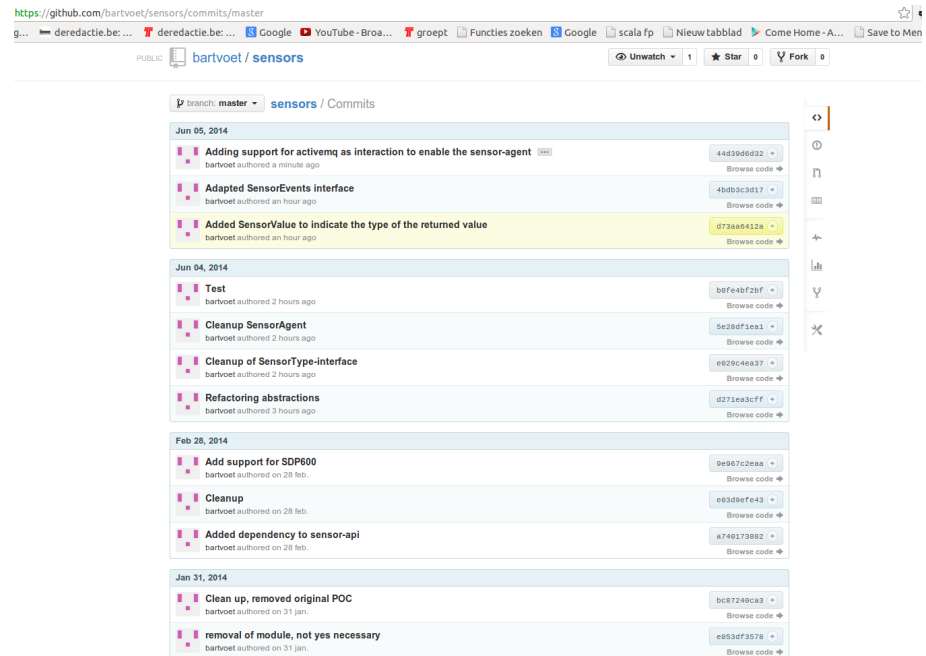
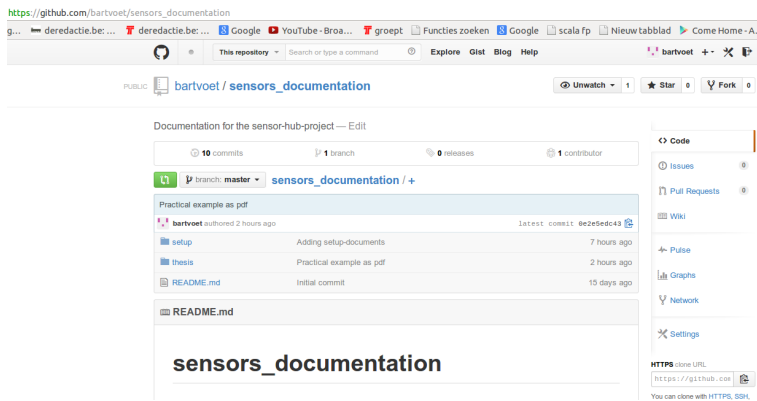
Olinuxino

Cubieboard



More information

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



Thank you for the attention!
Ready for Questions.