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)

Rapsberry 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**

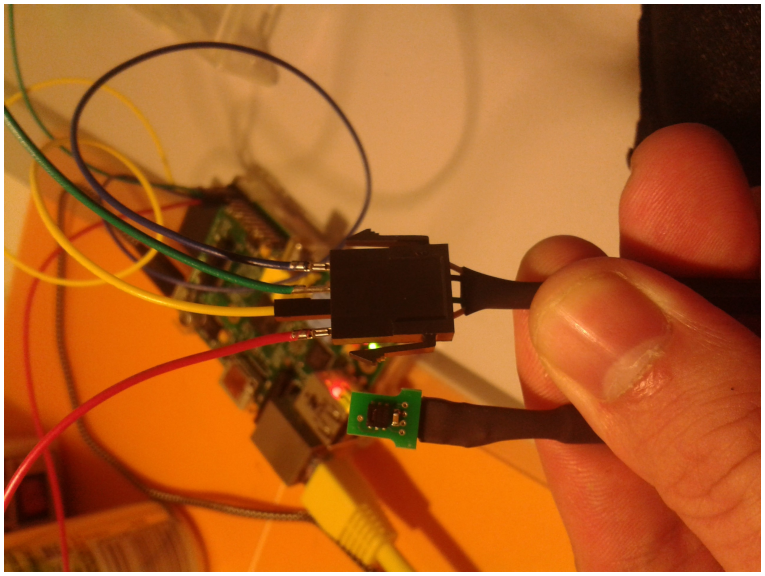
Startup requirements

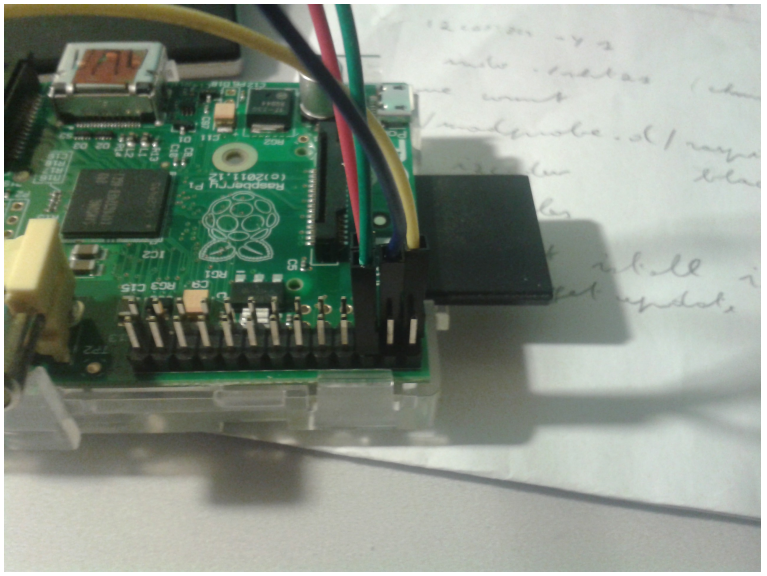
Demand

- 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

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

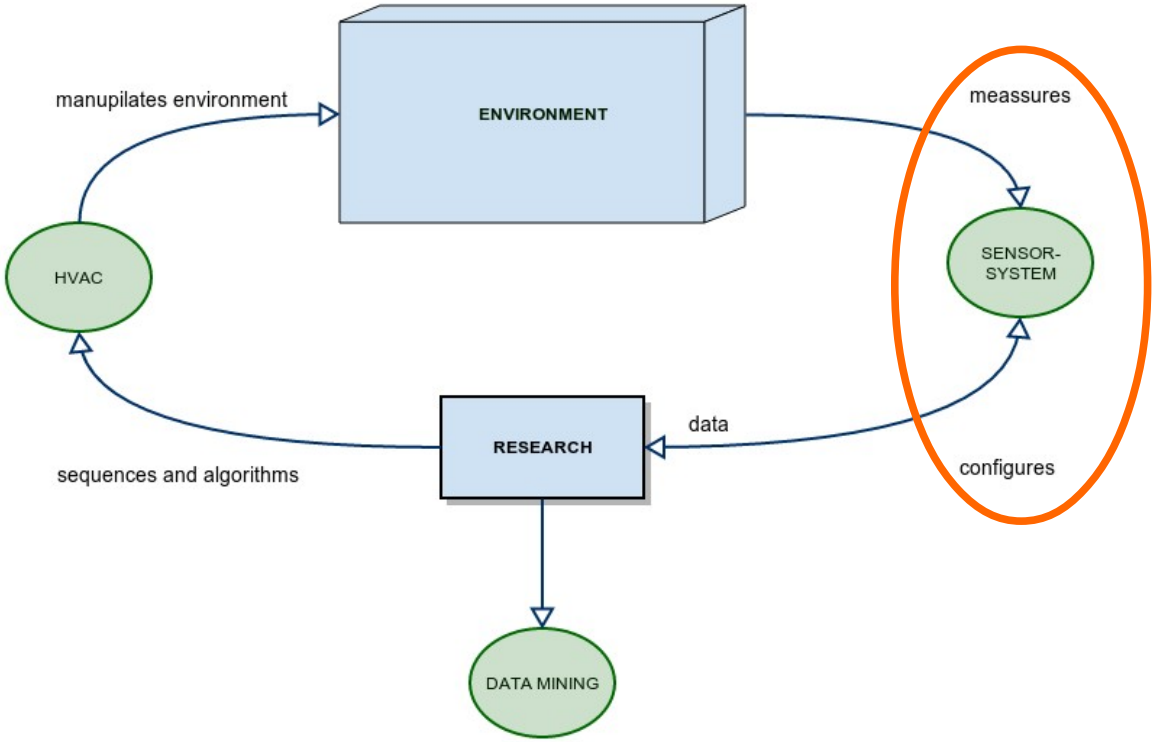
- Scope limited to **digital** (**smart**) sensors
  - Digital interface (i2c, spi or custom)
  - Integrated MCU performing
    - Calibration
    - Linearization
- No focus on **classic sensors**
  - Manual calibration
  - Precision resistors
  - ...

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

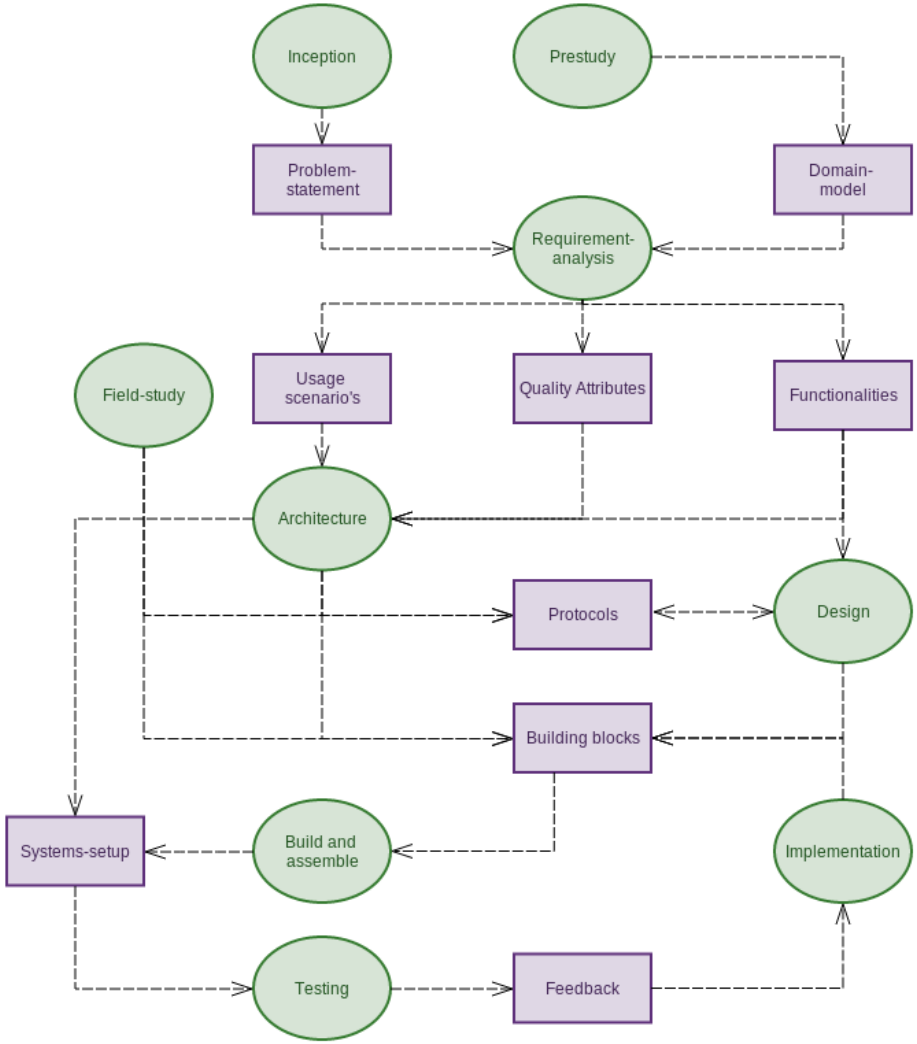
Scenario's

Scenario: Large buildings

- Mobile scenario
- No HVAC
- No assumptions on
  - Electricity
  - Network

- Similar to primary scenario
- More constrained environment

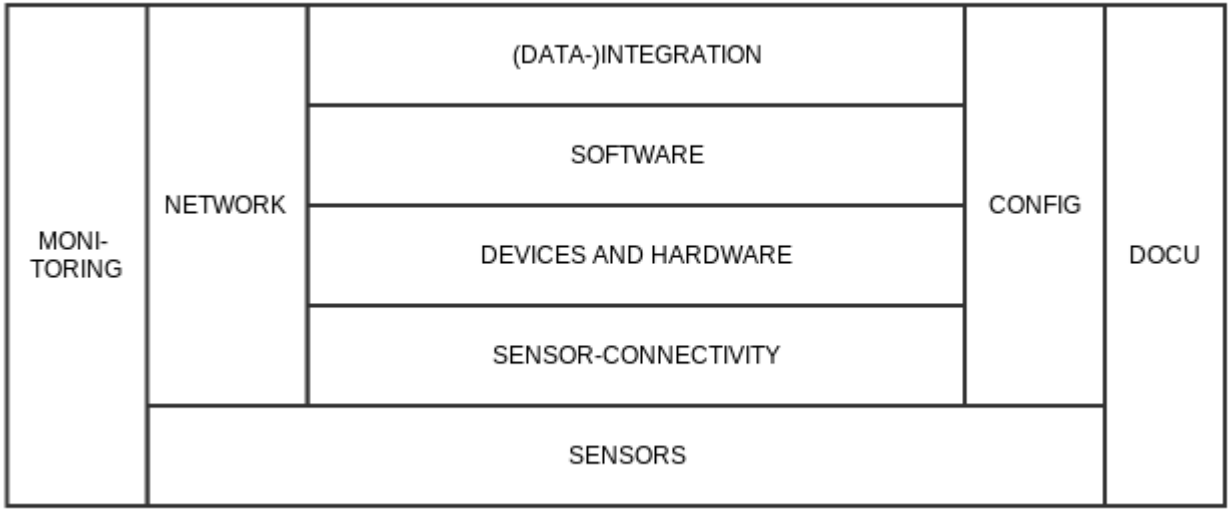
Approach


Inception
Prestudy
Problem-statement
Domain-model
Requirement-analysis
Field-study
Usage scenario's
Quality Attributes
Functionalities
Architecture
Protocols
Design
Building blocks
Systems-setup
Build and assemble
Implementation
Testing
Feedback

Approach

Category of building blocks (solutions)

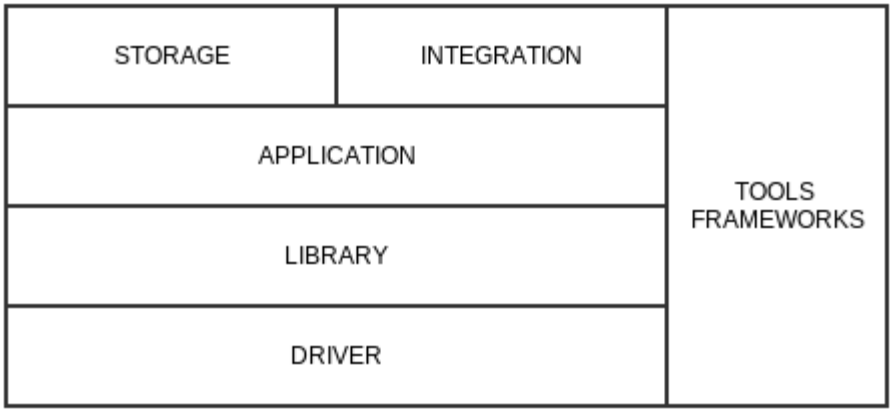
- Hardware, software, documentation
- Serve as annotation in thesis



Approach

Category of solutions

- Hardware, software, documentation
- Serve as annotation in thesis



System Challenges

TOP 5 Challenges

- **Multiple sensors**
  - **Concurrent** access
    - e.g. Sensirion-sensors having same i2c-adress
  - **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)

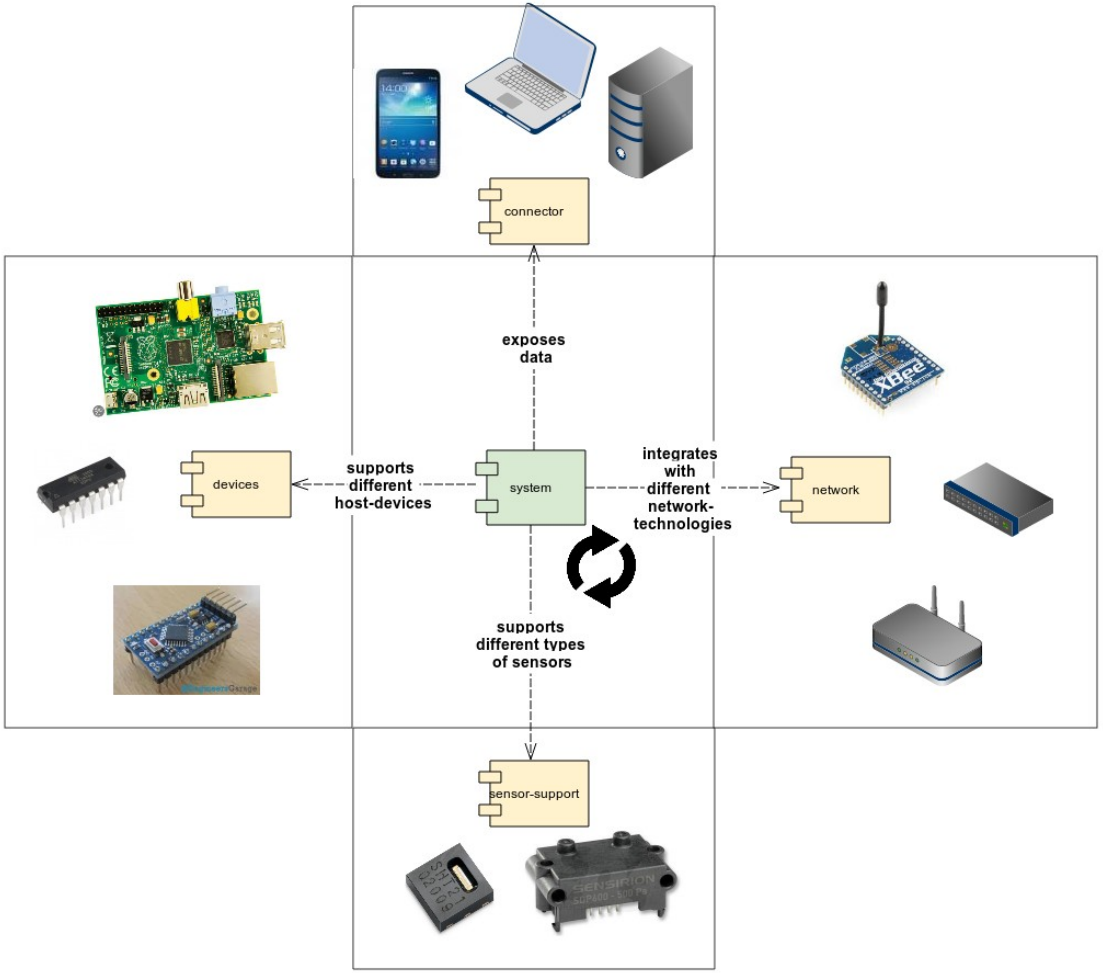
System Challenges

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

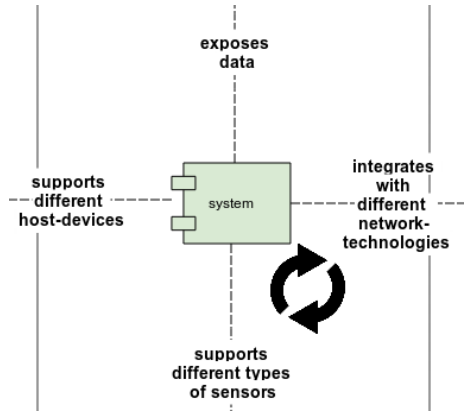
System-concept: **runtime and dependencies**



System Architecture

System-concept **Runtime**

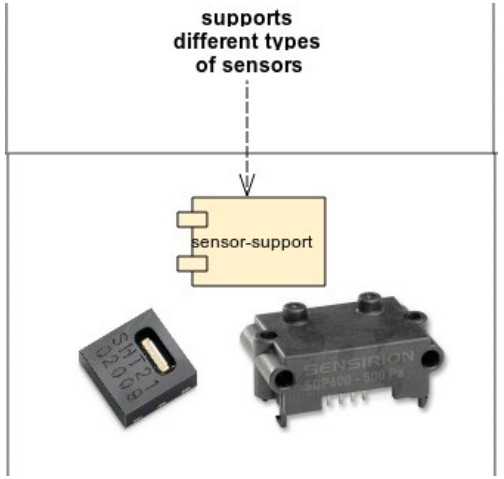
- Scheduling measurements
- Relying on system abstractions
  - Integration
  - Storage
  - Device-abstractions
  - More sensors
  - Of different types



System Architecture

System-concept: **Support different sensors**

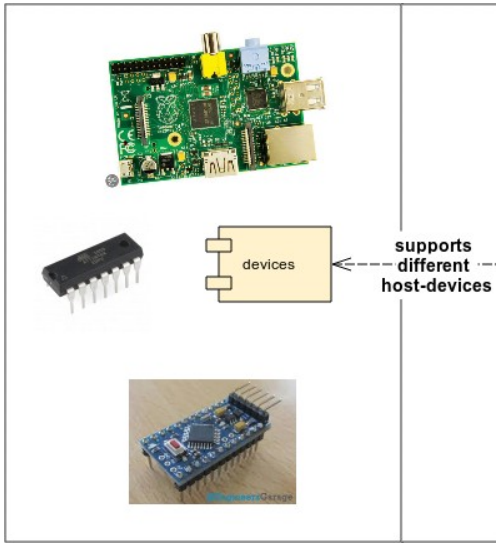
- System supports
  - Extracting data from multiple Sensors
  - Multiple types via Sensor-abstraction



System Architecture

System-concept: **Support different devices**

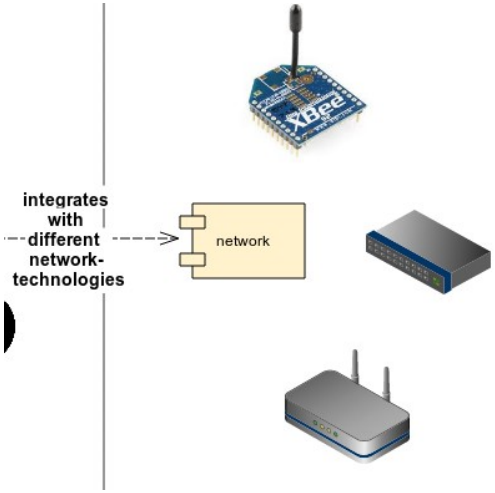
- Isolate system-dependencies
  - Scheduling
  - Digital interfaces
  - ...
- Support for
  - Low level (c-api)
  - High level (java)



System Architecture

System-concept: **Network independence**

- Integration-capability isolated
  - Local integration
  - Zigbee
  - WIFI
  - MQTT
  - ...

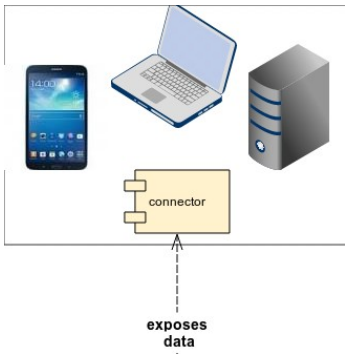


!! System provides abstraction and pluggability to adapt, not all implementations exists !!

System Architecture

System-concept: **Data exposure**

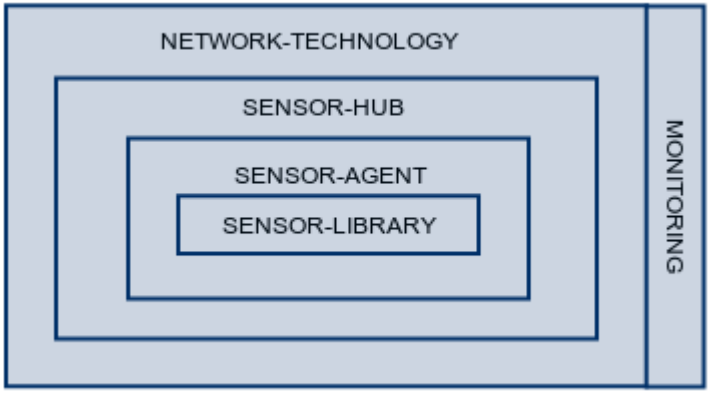
- Connectors for clients
  - Open protocols to integrate with various kind of devices



- Current provided protocol
  - REST exposing
    - JSON
    - CSV (under construction)

System Architecture

Design-concept: **Layering**

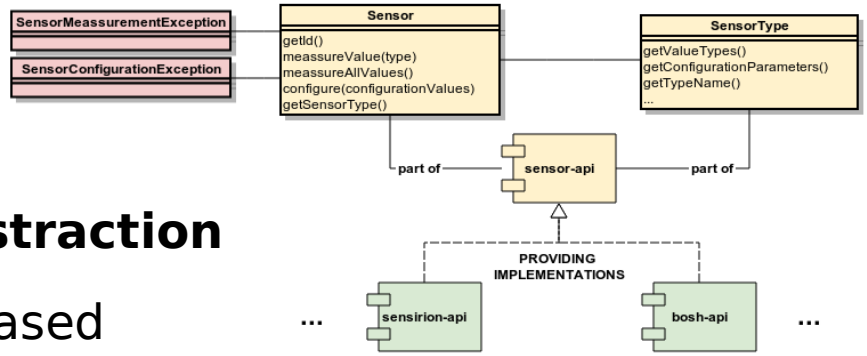


Different building blocks

- Built on top
- Inner layers can be used independently
- Segregation by interface

System Architecture

Layer: **Sensor-API**



Sensor- and SensorType-abstraction

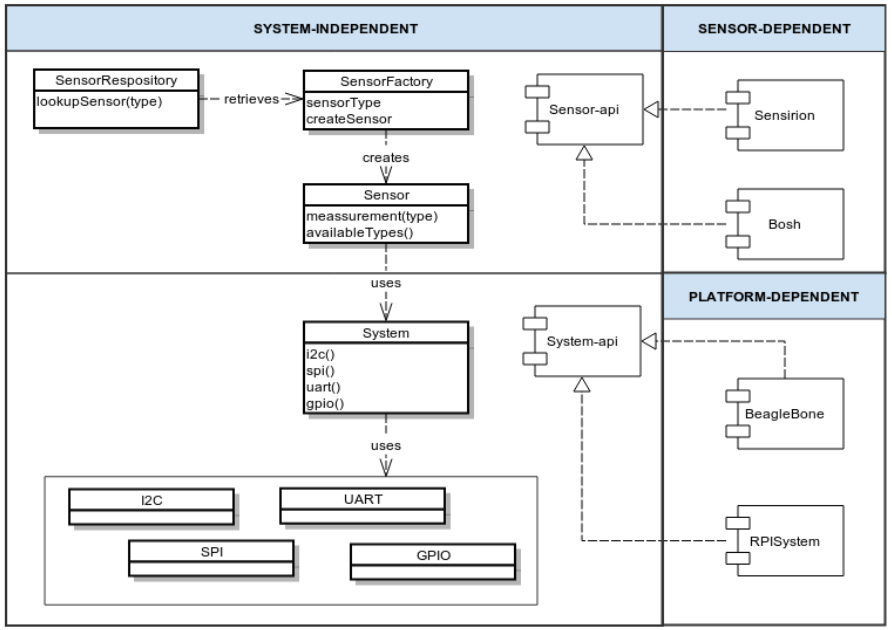
- Interfaces key-value pair based
- Modules containing concrete implementations
- Standardized exceptions

Goal

- Provide a repository for reuse (Github-project)
- Isolate the processing logic
- Provide an abstraction layer for Sensor-agent

System Architecture

Layer: **Sensor-API**



System-abstraction of

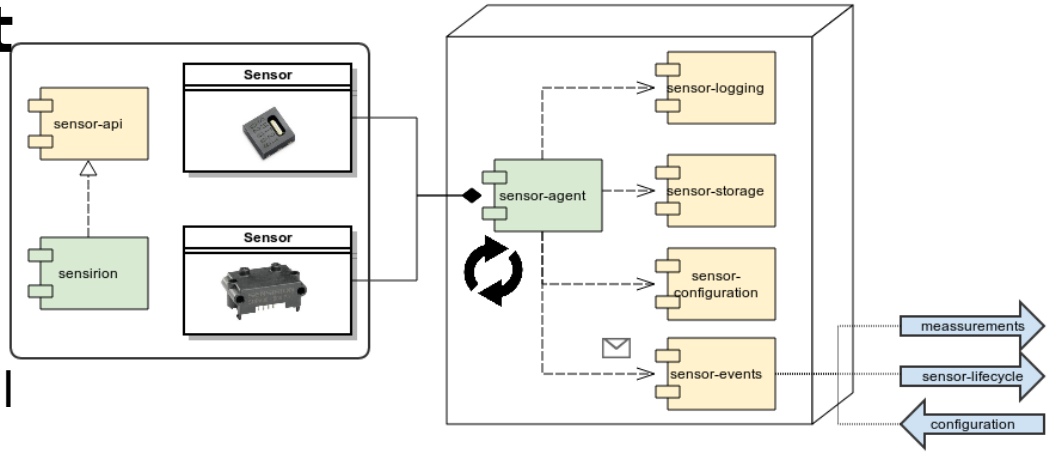
- Digital interfaces (i2c, spi, uart)
- Pin-access
- Timing

Goal

- Portability (vs scenario's)
- Choice of libraries (e.g. RPi can work JME or Pi4j)

System Architecture

Layer: **Sensor-Agent**



Runtime or application

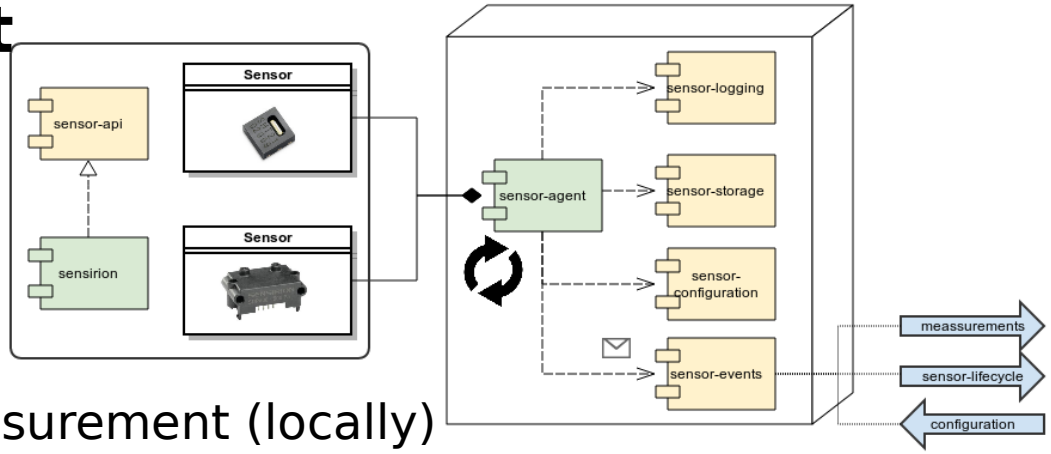
- Captures data at interval
- Manages sensors via sensor-api-abstraction
- Notifies and communicates via sensor-events

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**

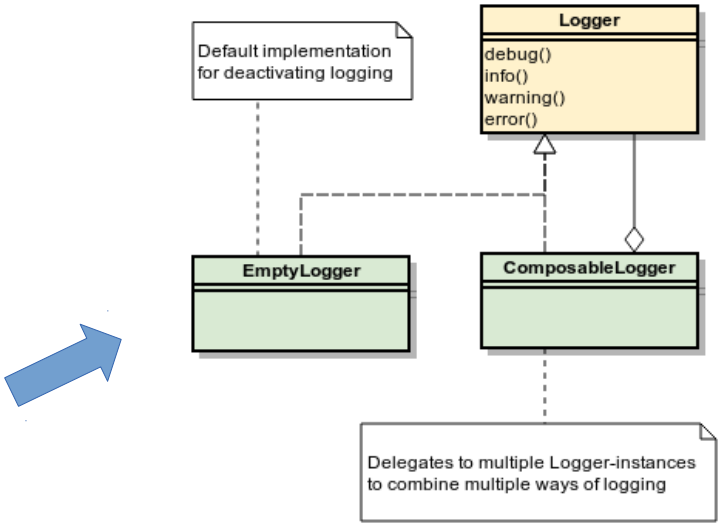
New measurement (out)
Sensor activated or reconfigured (out)
Instructions for reconfiguration (in)

System Architecture

Layer: **Sensor-Agent**

Abstractions

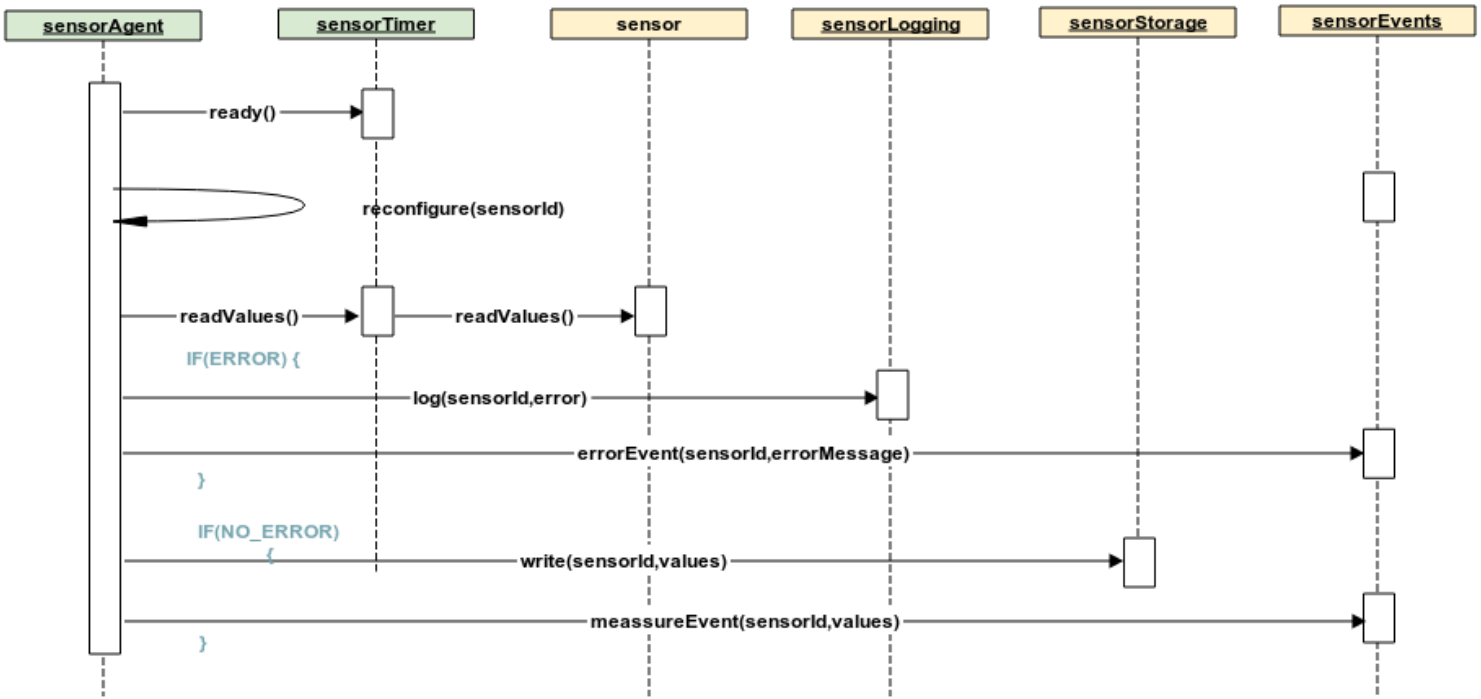
- are interchangeable
  - interface segregation
  - dependency injection
- can be combined (or composed)
- are deactivated by default
  - by default empty implementations



System Architecture

Layer: **Sensor-Agent**

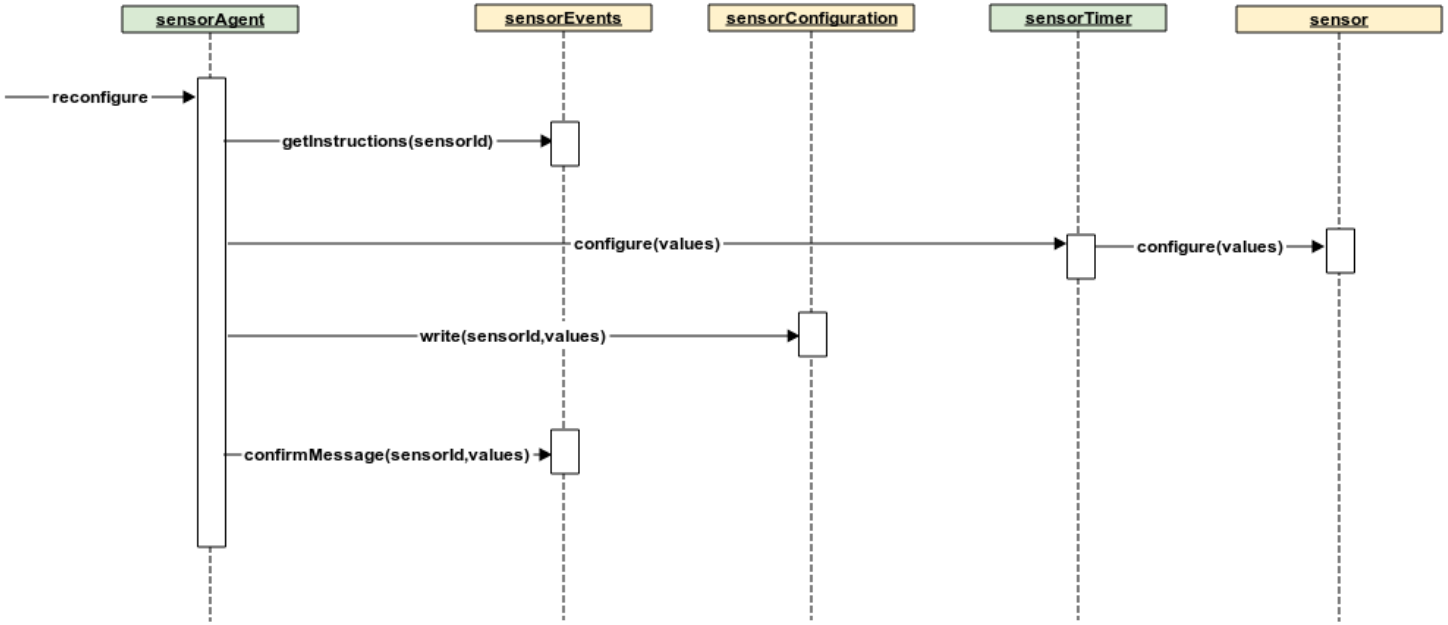
Runtime sequence



System Architecture

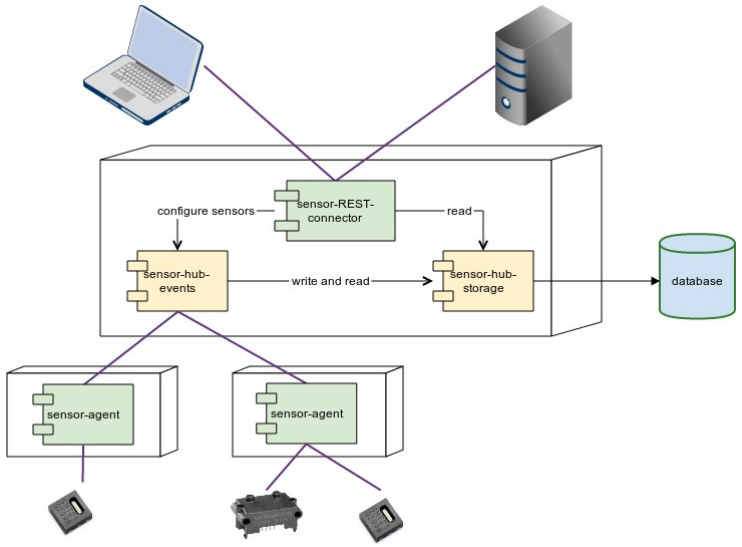
Layer: **Sensor-Agent**

Configuration sequence



System Architecture

Layer: **Sensor-Hub**



Runtime or (web-)application

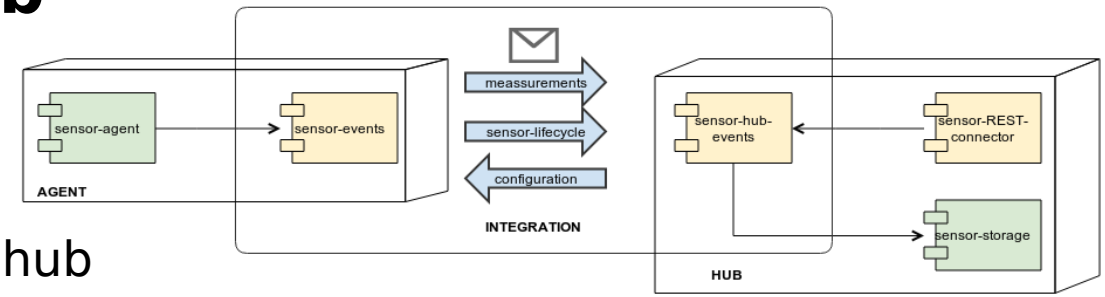
- Communicating with agents
- Centralizing data-storage
- Exposing data to users (and other devices/servers)

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

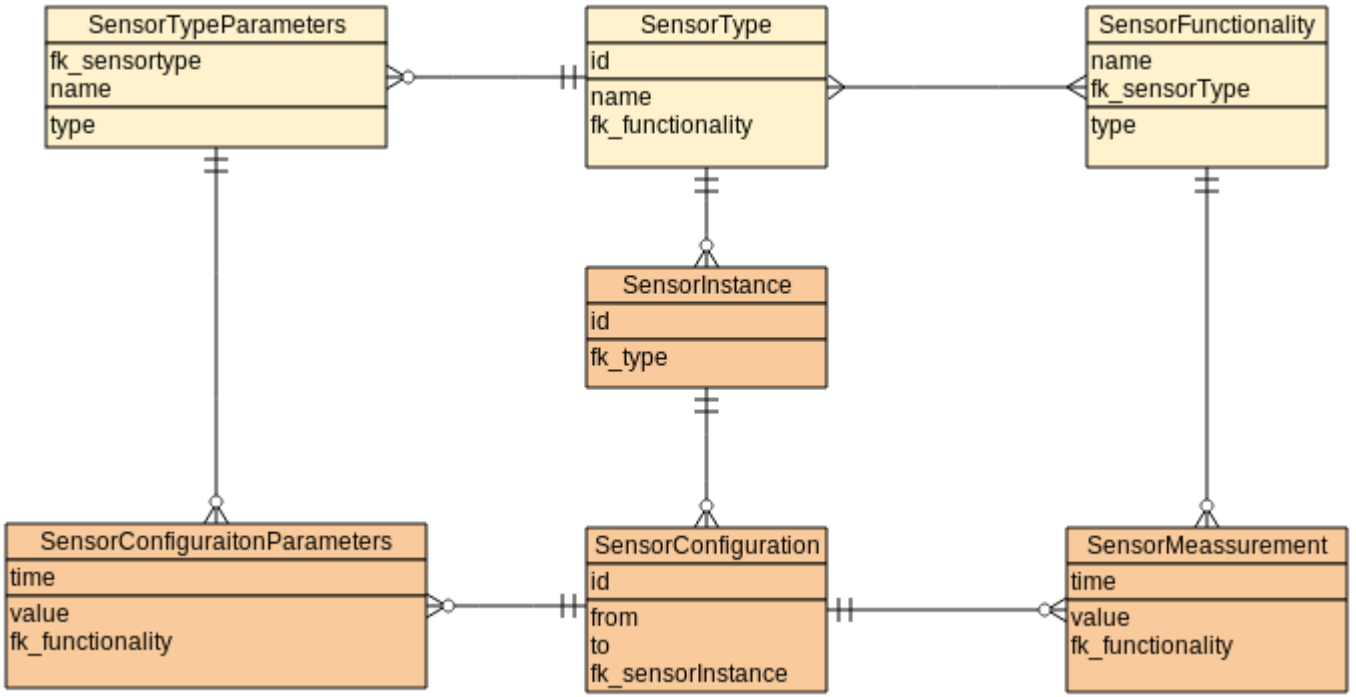
Sensor-hub-events and sensor-events

- Should integrate with same protocol
- Code is message based

System Architecture

Layer: **Sensor-Hub**

Datamodel



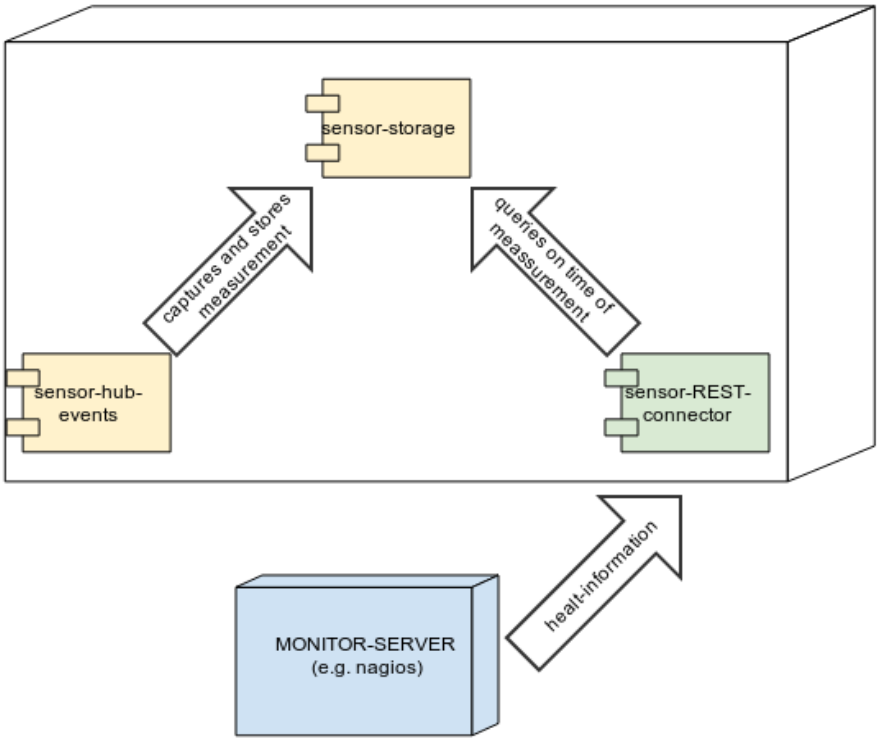
System Architecture

Layer: **Monitoring**

Monitor tool can query for

- Error events
- Deactivated agents or sensors (activity-monitoring)

REST-interface



Development principles

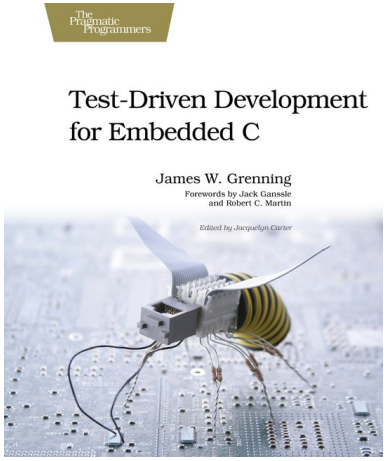
S Single Responsibility Principle

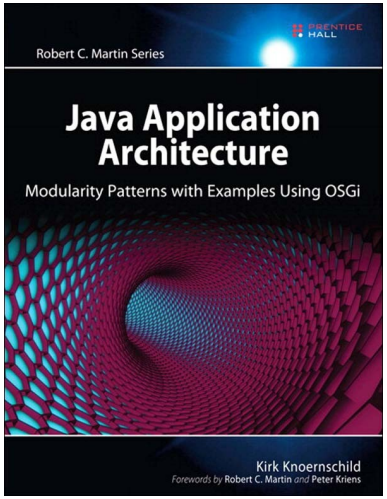
O Open Closed Principle

L Liskov Substitution Principle

I Interface Segregation Principle

D Dependency Inversion Principle





Development principles

Modularity

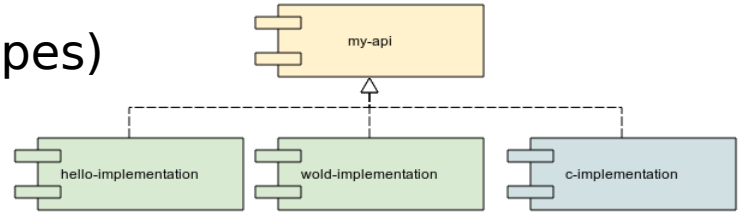
Package code and classes into reusable and composable package

Provide

api-components

(interfaces and types)

concrete implementations

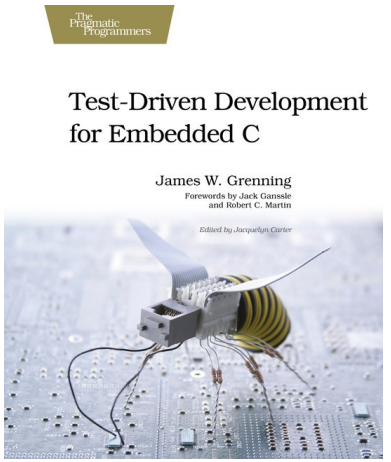


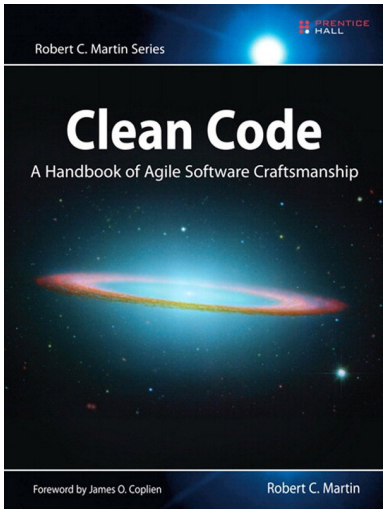
Code needs to be **SOLID**

Development principles

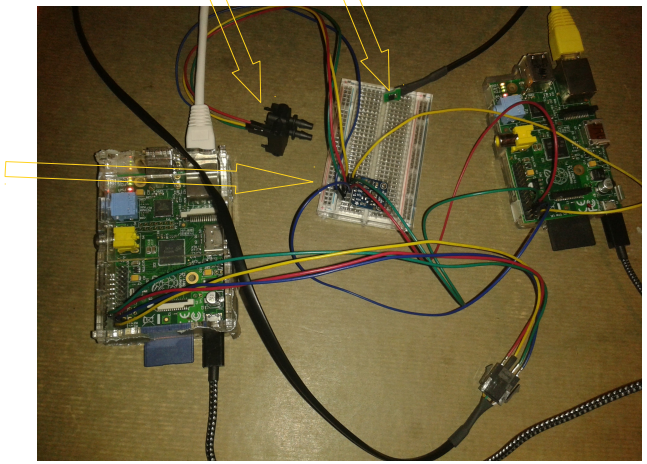
Test Driven Development (**TDD**)

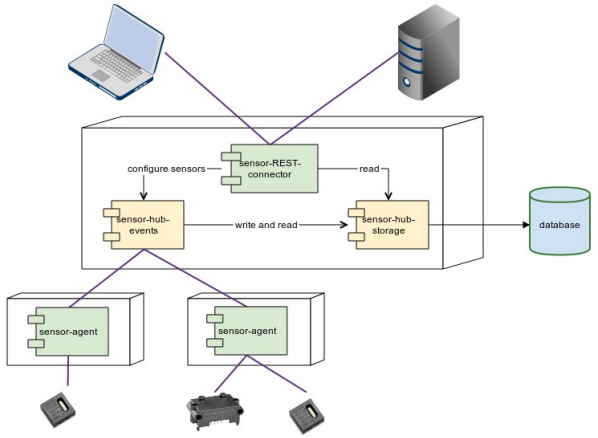
- Drive your code trough tests
- Just enough code
- Isolate dependencies

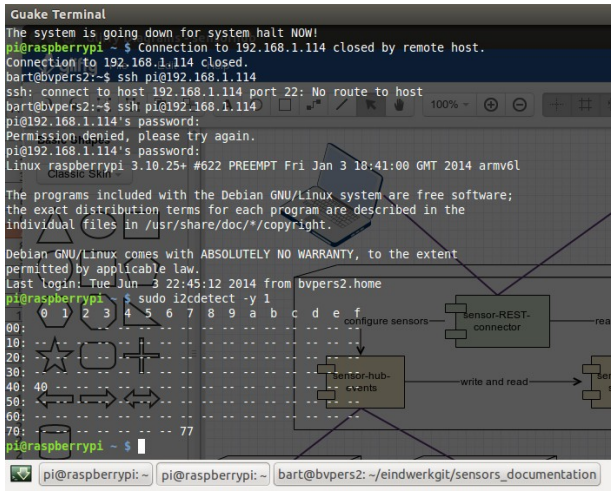


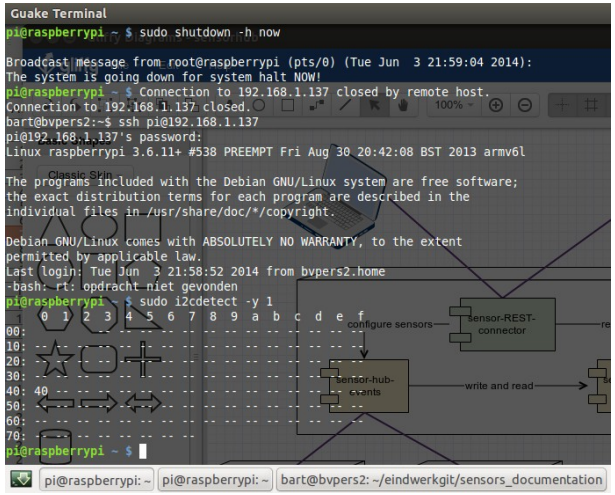


In practice


SDP600
SHT21
BMP180


configure sensors
sensor-REST-connector
read
sensor-hub-events
write and read
sensor-hub-storage
database
sensor-agent
sensor-agent


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
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
pi@raspberrypi ~ $
pi@raspberrypi: ~
pi@raspberrypi: ~
bart@bvpers2: ~/eindwerkgit/sensors_documentation

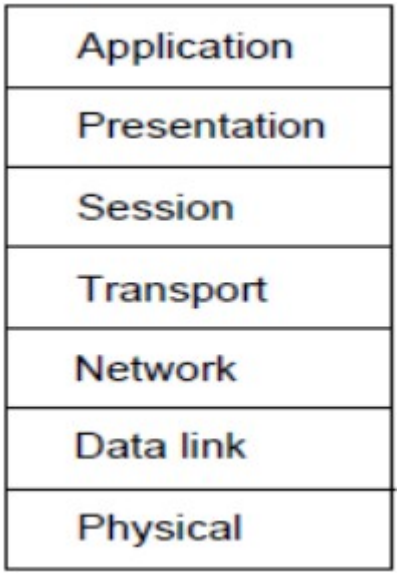

localhost:8080/restapi/api/sensors/1/measurements
Applicaties
compiler desig...
deredactie.be: ...
deredactie.be: ...
Google
YouTube - Broa...
groept
Functies zoeken
Google
scala fp
Nieuw tabblad
Come Home - A...
Save to Mendele
[{"functionality":"temperature","measurementTime":"2014.06.04 - 22:27:21","measurementValue":-46.85},{"functionality":"humidity","measurementTime":"2014.06.04 - 22:27:21","measurementValue":-6.0},
{"functionality":"temperature","measurementTime":"2014.06.04 - 22:27:36","measurementValue":-46.85},{"functionality":"humidity","measurementTime":"2014.06.04 - 22:27:36","measurementValue":-6.0}]

Tools and platforms

T

Technology positioning

Netwerk and IOT



Wifi
Zigbee
Ethernet
MQ
MQTT

Conclusion

Conclusion

Roadmap