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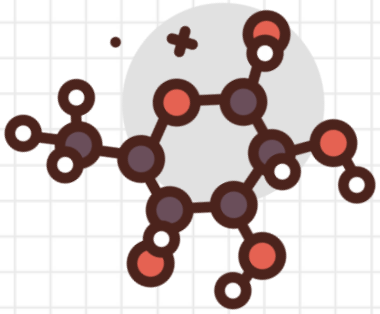
CGM Telemetry System

Continuous Glucose Monitoring System

Application domain: smart health care

Goal: development of an IoT telemetry and control system to monitor the glucose level of the patients and trigger an alarm when it is too high.

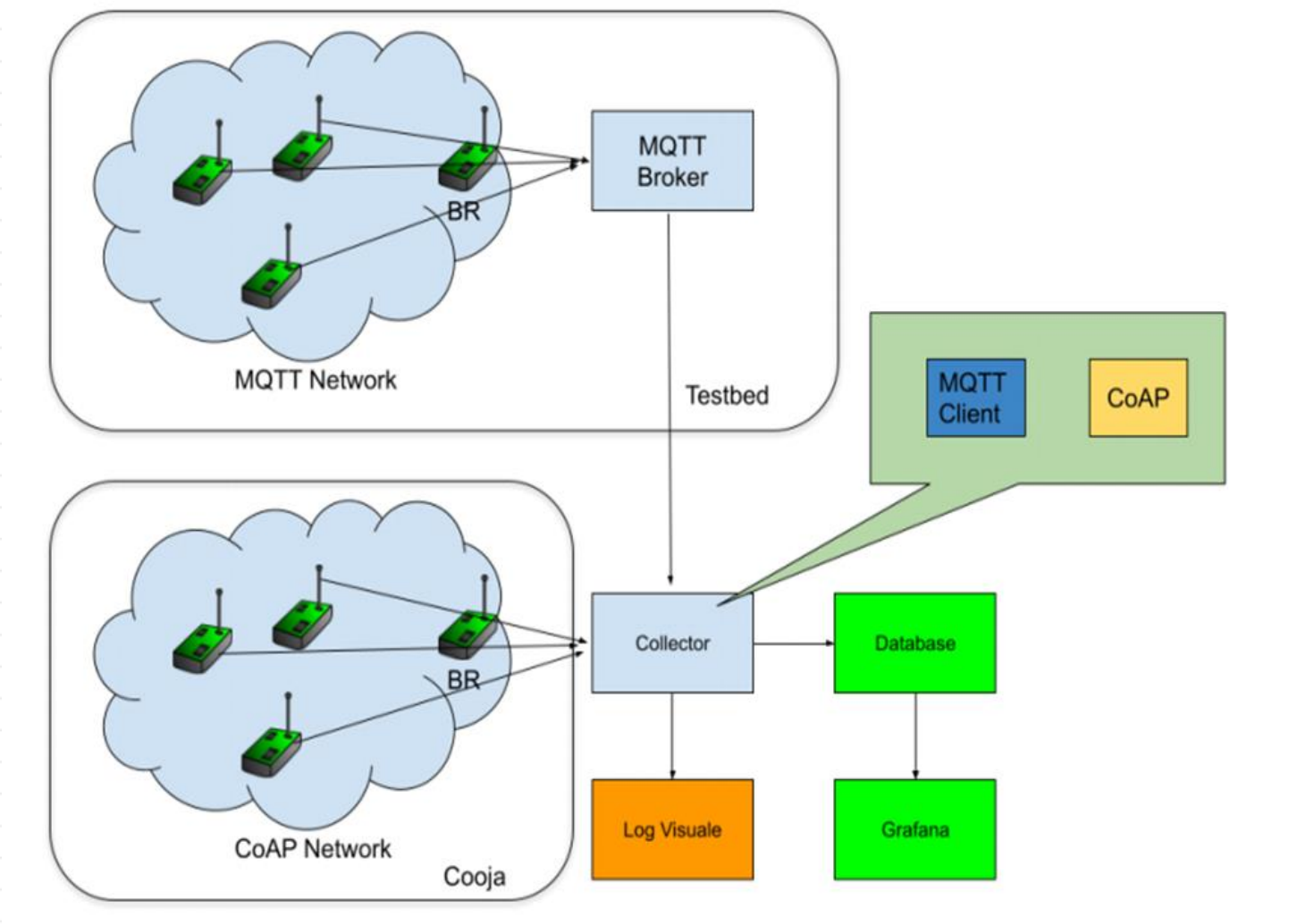


A CGM system can give you insights into how your glucose levels continuously change throughout the day and the night

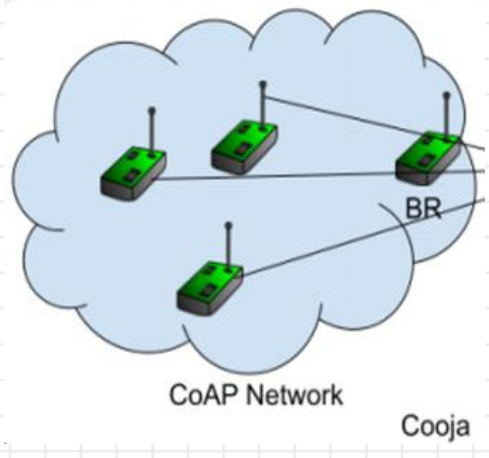
With a continuous glucose monitoring you can uncover how food, exercise and medicines affect your glucose levels

General Architecture

System Architecture



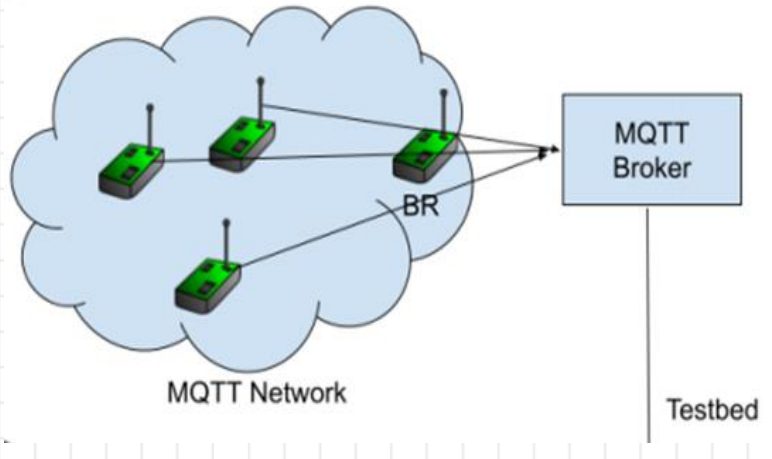
CoAP Network



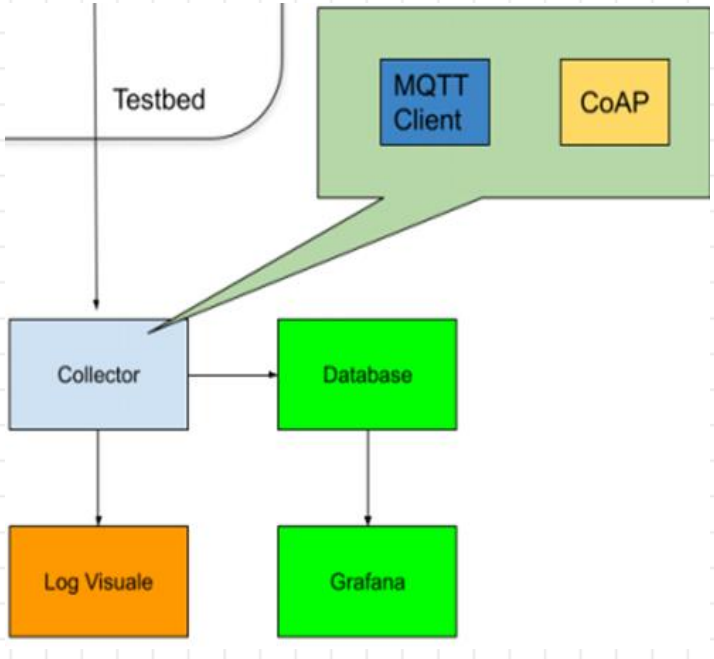
- In Cooja simulator is deployed a network with four cooja mote.
- One of them behaves as border router.
- The other three emulate glucose sensors able to detect blood sugar levels.

MQTT Network

- Network of four real devices exploiting MQTT to report data.
- One device behaves as border router, other three devices as glucose sensors.
- Nodes publish and get notifications about the topics through the MQTT Broker that they are connected to via the border router.
- Mosquitto broker is exploited.



Collector



- Collector is implemented in Java using **Californium** and **Paho**.
- It is in charge of storing data in a MySQL db and showing a visual log.
- Moreover, it handles all the logic regarding the alarm system.
- Finally, a web interface plots glucose patients' trend.

Glucose Sensor

CoAP

The glucose server exposes two resources.

- Glucose resource acts as a glucose level detector
- Alarm resource is triggered when the glucose level overcome a certain threshold

MQTT

The glucose mqtt client publishes its sensed glucose values on the topic “glucose”

It also subscribes to topic “sampling_rate” and “alarm” to set the initial rate and turn on the leds in case of risk.

General Behavior

Basically, there are three aspects that characterize the device

- Sampling Rate
- Sensing
- Warning

At the beginning is possible to set a custom sampling rate.

The default value is 8s.

It's possible to configure the sampling rate changing it when the system starts or communicating via serial line with the nodes.

General Behavior

Basically, there are three aspects that characterize the device

- Sampling Rate
- **Sensing**
- Warning

The glucose level produced is emulated changing it each time the simulation timer expires.

The rand method is set (with the node ID in CoAP) and used to produce random values.

According to those values the glucose level may increase or decrease.

General Behavior

Basically, there are three aspects that characterize the device

Sensing

Warning

Each time a new glucose level is provided a simple check is done to verify if the value overcome some **thresholds**.

A fasting blood sugar level of 99 mg / dL or lower is **normal**, 100 to 125 mg / dL indicates you have **prediabetes**, and 126 mg / dL or higher indicates you have **diabetes**.

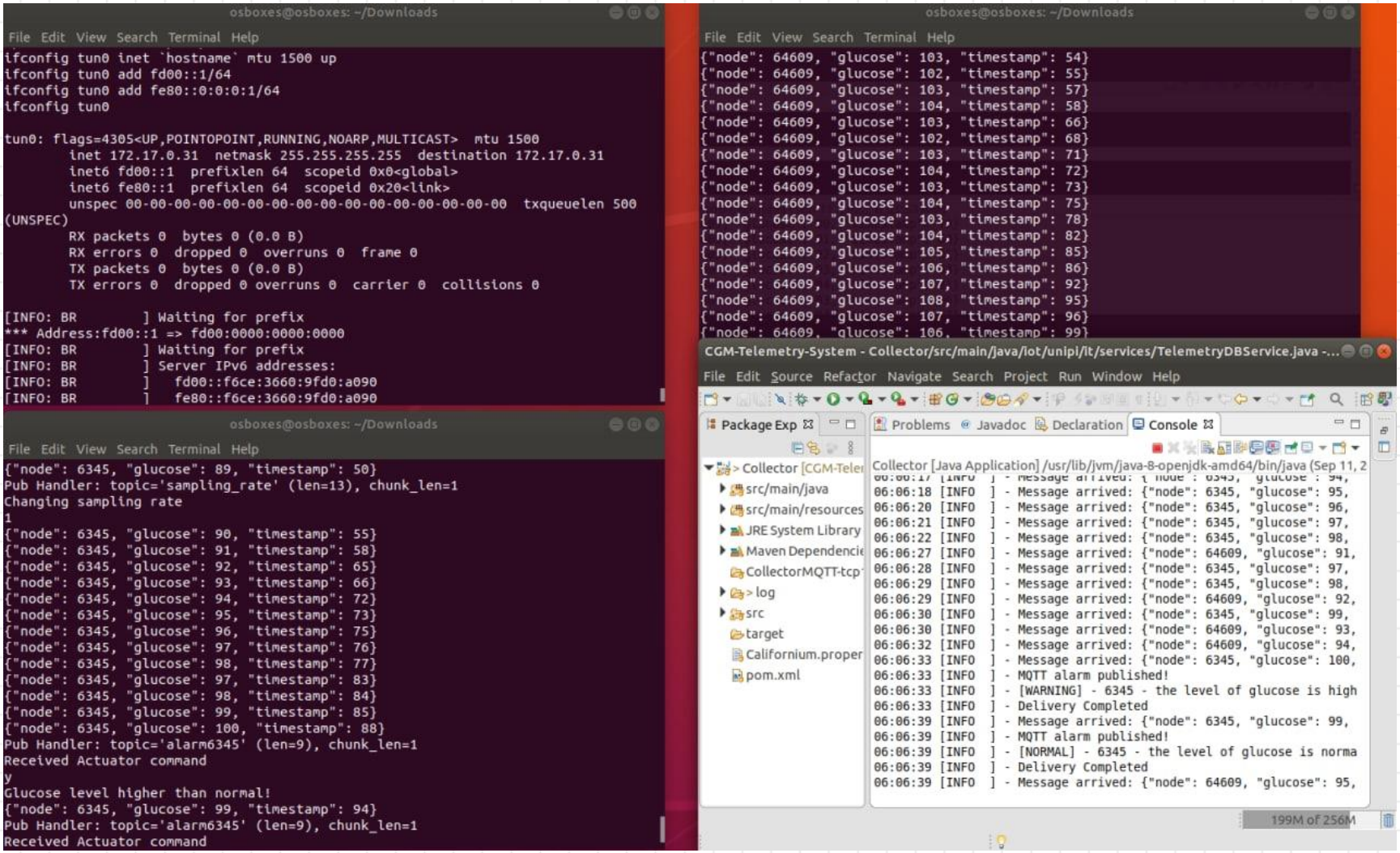
LEDS MEANING

The alarm is implemented using LEDs. There are four possible cases:

 Yellow	Trying to contact the collector
 Green	Working correctly
 Green + Yellow	Glucose lever higher than 100 mg/dL
 Green + Red	Glucose lever higher than 125 mg/dL

Remote TestBed

TESTBED


osboxes@osboxes: ~/Downloads
File Edit View Search Terminal Help
ifconfig tun0 inet `hostname` mtu 1500 up
ifconfig tun0 add fd00::1/64
ifconfig tun0 add fe80::0:0:0:1/64
ifconfig tun0
tun0: flags=4305<UP,POINTOPOINT,RUNNING,NOARP,MULTICAST> mtu 1500
inet 172.17.0.31 netmask 255.255.255.255 destination 172.17.0.31
inet6 fd00::1 prefixlen 64 scopeid 0x0<global>
inet6 fe80::1 prefixlen 64 scopeid 0x20<link>
unspec 00-00-00-00-00-00-00-00-00-00-00-00-00-00-00-00 txqueuelen 500 (UNSPEC)
RX packets 0 bytes 0 (0.0 B)
RX errors 0 dropped 0 overruns 0 frame 0
TX packets 0 bytes 0 (0.0 B)
TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0
[INFO: BR] Waiting for prefix
*** Address:fd00::1 => fd00:0000:0000:0000
[INFO: BR] Waiting for prefix
[INFO: BR] Server IPv6 addresses:
[INFO: BR] fd00::f6ce:3660:9fd0:a090
[INFO: BR] fe80::f6ce:3660:9fd0:a090
osboxes@osboxes: ~/Downloads
File Edit View Search Terminal Help
{"node": 6345, "glucose": 89, "timestamp": 50}
Pub Handler: topic='sampling_rate' (len=13), chunk_len=1
Changing sampling rate
1
{"node": 6345, "glucose": 90, "timestamp": 55}
{"node": 6345, "glucose": 91, "timestamp": 58}
{"node": 6345, "glucose": 92, "timestamp": 65}
{"node": 6345, "glucose": 93, "timestamp": 66}
{"node": 6345, "glucose": 94, "timestamp": 72}
{"node": 6345, "glucose": 95, "timestamp": 73}
{"node": 6345, "glucose": 96, "timestamp": 75}
{"node": 6345, "glucose": 97, "timestamp": 76}
{"node": 6345, "glucose": 98, "timestamp": 77}
{"node": 6345, "glucose": 97, "timestamp": 83}
{"node": 6345, "glucose": 98, "timestamp": 84}
{"node": 6345, "glucose": 99, "timestamp": 85}
{"node": 6345, "glucose": 100, "timestamp": 88}
Pub Handler: topic='alarm6345' (len=9), chunk_len=1
Received Actuator command
y
Glucose level higher than normal!
{"node": 6345, "glucose": 99, "timestamp": 94}
Pub Handler: topic='alarm6345' (len=9), chunk_len=1
Received Actuator command
osboxes@osboxes: ~/Downloads
File Edit View Search Terminal Help
{"node": 64609, "glucose": 103, "timestamp": 54}
{"node": 64609, "glucose": 102, "timestamp": 55}
{"node": 64609, "glucose": 103, "timestamp": 57}
{"node": 64609, "glucose": 104, "timestamp": 58}
{"node": 64609, "glucose": 103, "timestamp": 66}
{"node": 64609, "glucose": 102, "timestamp": 68}
{"node": 64609, "glucose": 103, "timestamp": 71}
{"node": 64609, "glucose": 104, "timestamp": 72}
{"node": 64609, "glucose": 103, "timestamp": 73}
{"node": 64609, "glucose": 104, "timestamp": 75}
{"node": 64609, "glucose": 103, "timestamp": 78}
{"node": 64609, "glucose": 104, "timestamp": 82}
{"node": 64609, "glucose": 105, "timestamp": 85}
{"node": 64609, "glucose": 106, "timestamp": 86}
{"node": 64609, "glucose": 107, "timestamp": 92}
{"node": 64609, "glucose": 108, "timestamp": 95}
{"node": 64609, "glucose": 107, "timestamp": 96}
CGM-Telemetry-System - Collector/src/main/java/iot/unipi/it/services/TelemetryDBService.java -...
File Edit Source Refactor Navigate Search Project Run Window Help
Package Exp
Problems Javadoc Declaration Console
Collector [Java Application] /usr/lib/jvm/java-8-openjdk-amd64/bin/java (Sep 11, 2
Collector [CGM-Tele
src/main/java
src/main/resources
JRE System Library
Maven Dependencie
CollectorMQTT-tcp
log
src
target
Californium.proper
pom.xml
06:06:18 [INFO] - Message arrived: {"node": 6345, "glucose": 95,
06:06:20 [INFO] - Message arrived: {"node": 6345, "glucose": 96,
06:06:21 [INFO] - Message arrived: {"node": 6345, "glucose": 97,
06:06:22 [INFO] - Message arrived: {"node": 6345, "glucose": 98,
06:06:27 [INFO] - Message arrived: {"node": 64609, "glucose": 91,
06:06:28 [INFO] - Message arrived: {"node": 6345, "glucose": 97,
06:06:29 [INFO] - Message arrived: {"node": 6345, "glucose": 98,
06:06:29 [INFO] - Message arrived: {"node": 64609, "glucose": 92,
06:06:30 [INFO] - Message arrived: {"node": 6345, "glucose": 99,
06:06:30 [INFO] - Message arrived: {"node": 64609, "glucose": 93,
06:06:32 [INFO] - Message arrived: {"node": 64609, "glucose": 94,
06:06:33 [INFO] - Message arrived: {"node": 6345, "glucose": 100,
06:06:33 [INFO] - MQTT alarm published!
06:06:33 [INFO] - [WARNING] - 6345 - the level of glucose is high
06:06:33 [INFO] - Delivery Completed
06:06:39 [INFO] - Message arrived: {"node": 6345, "glucose": 99,
06:06:39 [INFO] - MQTT alarm published!
06:06:39 [INFO] - [NORMAL] - 6345 - the level of glucose is norma
06:06:39 [INFO] - Delivery Completed
06:06:39 [INFO] - Message arrived: {"node": 64609, "glucose": 95,
199M of 256M

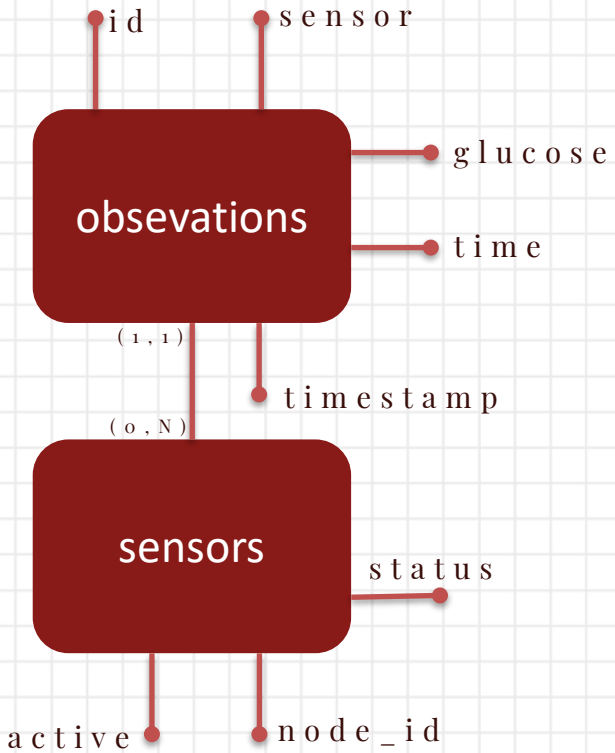
Data Format

Data Encoding

- The JSON format is chosen for the encoding of the messages in the application.
- This choice is due to the simplicity, flexibility and low-redundancy of JSON, without any difficulty when parsing the message in Java on the collector's side.
- The collector sends plain text commands to the nodes because of their simplicity (r -> red, y -> yellow or g ->green for the leds).

{node: 1234, glucose: 90, timestamp: 64}

Database Structure



id: unique identifier for the observation,
sensor: string used to identify the node
glucose: integer representing the glucose level,
timestamp: integer that represents the moment in which the data has been generated respect and absolute time,
time: datetime value that is added by default when the row is added,
status: express the node's status
active: Boolean representing node's state.

Visual Log

When the application starts some logs are printed out on the console in order to show what are happening.

The **Log4j** library provides advanced log managing features. From the collector's side logs are both shown on the command line and written in a txt file.

Logs are used when nodes check the connectivity, start the registration process, modify leds color or notify strange glucose levels'.

```
00:17.246  ID:2   REGISTERED
00:17.246  ID:2   Starting glucose server
00:17.285  ID:2   [INFO: App       ] Handling glucose put request...
00:17.285  ID:2   [INFO: App       ] New sampling rate: 5
00:17.301  ID:2   [INFO: App       ] Handling glucose get request...
00:17.301  ID:2   {"node id":2,"glucose":90,"timestamp":17}
```

```
16:03:52 [INFO  ] - MQTT Connected!
16:03:52 [INFO  ] - Coap server is ready!
16:03:53 [INFO  ] - A new smart device: [fd00:0:0:0:203:3:3:3] is now registered!
16:03:55 [INFO  ] - A new smart device: [fd00:0:0:0:202:2:2:2] is now registered!
16:03:56 [INFO  ] - A new smart device: [fd00:0:0:0:204:4:4:4] is now registered!
```

```
16:05:16 [INFO  ] - [WARNING] - fd00:0:0:0:203:3:3:3 - the level of glucose (93 mg/dL) is higher than normal!
16:05:46 [INFO  ] - [CRITICAL] - fd00:0:0:0:203:3:3:3 - the level of glucose (94 mg/dL) is too high!
16:05:58 [INFO  ] - [WARNING] - fd00:0:0:0:202:2:2:2 - the level of glucose (93 mg/dL) is higher than normal!
16:06:03 [INFO  ] - [CRITICAL] - fd00:0:0:0:202:2:2:2 - the level of glucose (94 mg/dL) is too high!
16:06:18 [INFO  ] - [WARNING] - fd00:0:0:0:202:2:2:2 - the level of glucose (93 mg/dL) is higher than normal!
16:06:23 [INFO  ] - [NORMAL] - fd00:0:0:0:202:2:2:2 - the level of glucose (92 mg/dL) is normal!
```

Web-Interface

Grafana

Grafana is exploited to visualize easily the measurements done by each sensor in a panel.

The y-axis represents the glucose level (mg/dl) while the x-axis expresses the time.

The plot is divided into three different area in order to highlight alarm situations:

- Green
- Yellow
- Red

THE END

THANK YOU FOR LISTENING