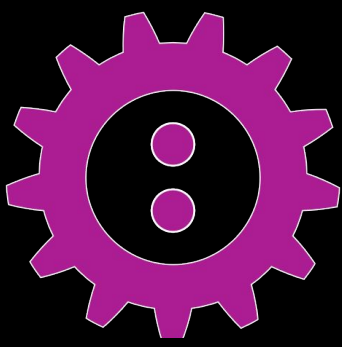


FOSDEM



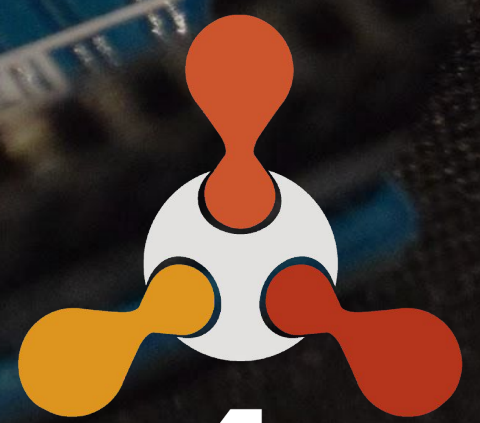
# SDR4IoT

... an Experiment Part of Fed4FIRE+ in  
w-iLab.t Testbeds



RTONE  
IOT MAKERS

@alexis0duque

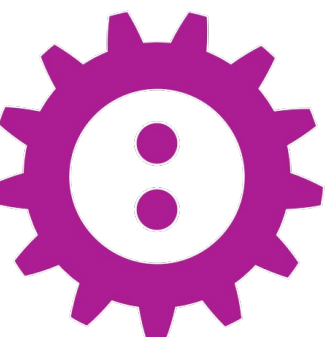


FED4FIRE  
FEDERATION FOR FIRE PLUS

#FOSDEM #FSR #SDR #IoT #ML

@alexis0duque





# Who am I?

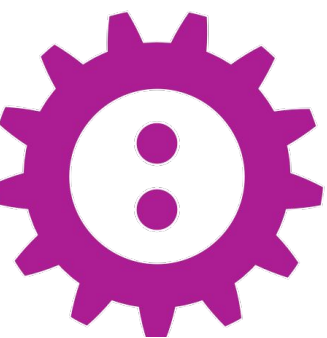
**Alexis DUQUE**

Director of Research & Development



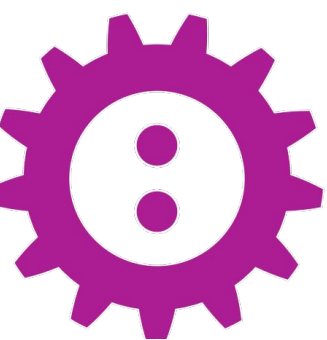
-  @alexis0duque
-  alexisduque
-  alexisd@rtone.fr
-  alexisduque.me
-  <https://goo.gl/oNUWu6>





## Outline

- **Motivation**
- **Fed4FIRE+** H2020 project
- Wireless testbeds **w-iLab.t** at iMEC
- Accessing the testbed
- **Our experiment**
- Further Work



## Motivation

SDR hardware is popularizing

Software library are maturing

Lot of interest and work in academia

So, lets embed & use **SDR4IoT!** 📶😊

**Fingerprinting**

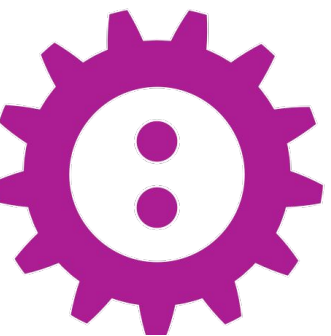
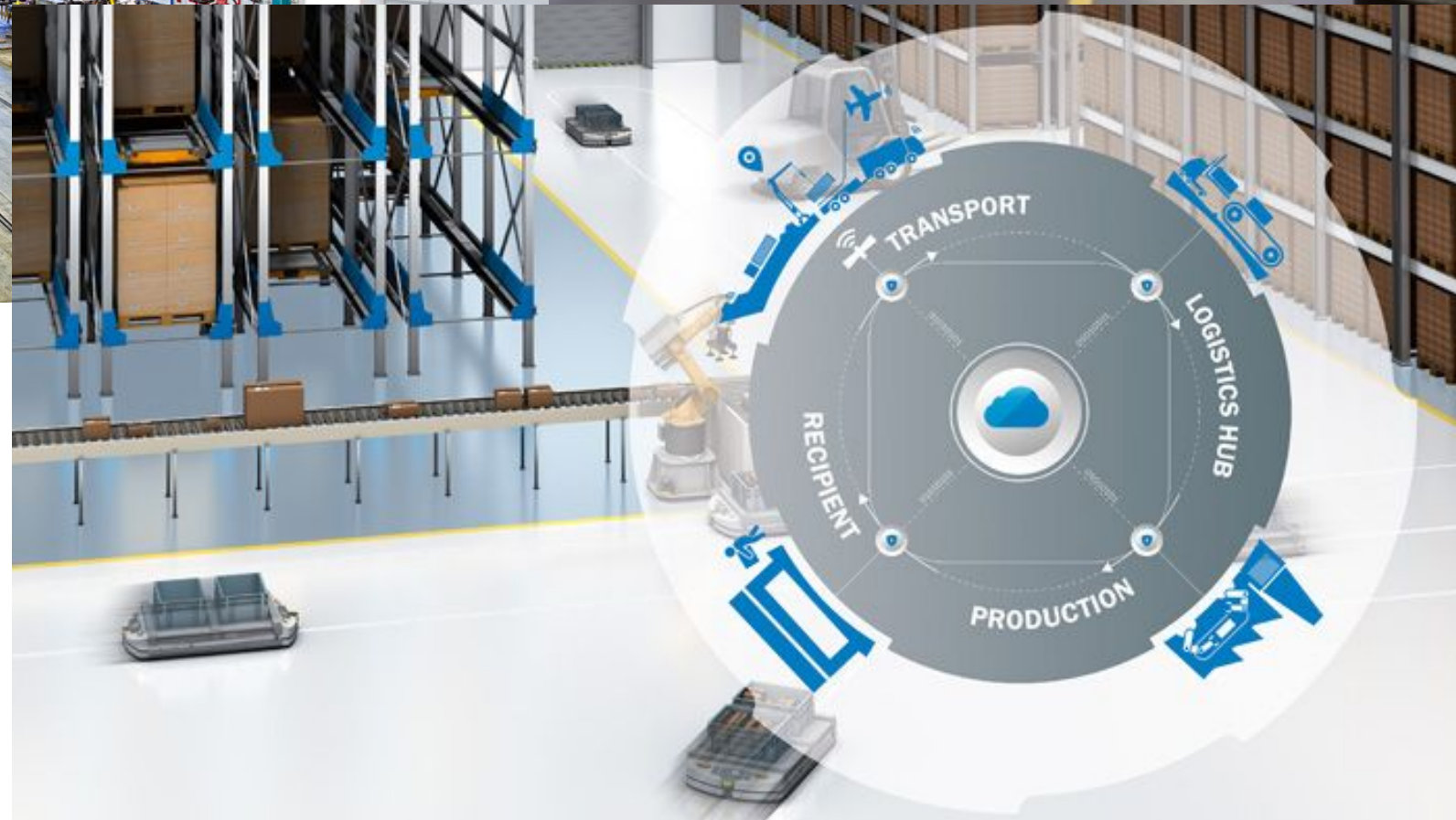
**Passive  
Authentication**

**Localization**



FOSDEM

# Motivation




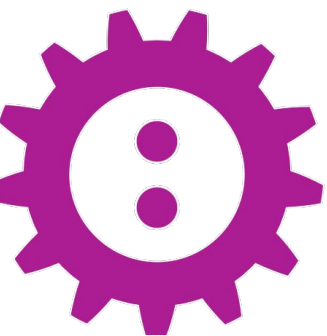


# State of the Art

R. C. Bunescu, “**Deep Learning Convolutional Neural Networks for Radio Identification.**”, 2018.

S. Rajendran, W. Meert, D. Giustiniano, V. Lenders, and S. Pollin, “**Deep Learning Models for Wireless Signal Classification with Distributed Low-Cost Spectrum Sensors.**”, 2018.

C. Morin, L. S. Cardoso, J. Hoydis, J.-M. Gorce, and **T. Vial**,  “**Transmitter Classification with Supervised Deep Learning,**” in CROWNCOM’19, 2019.



# SoA Limitation

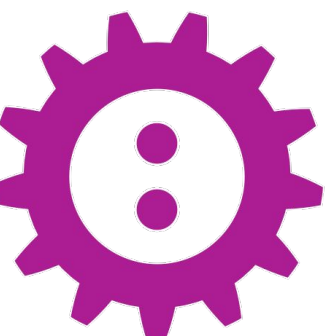
**Not real-world IoT device**

Not conventional communication protocols

**Not reproducible**

**Too small dataset:** few devices, few RF traces, ...

**Nodes position do not change, ML** doesn't learn localization



# Our Idea

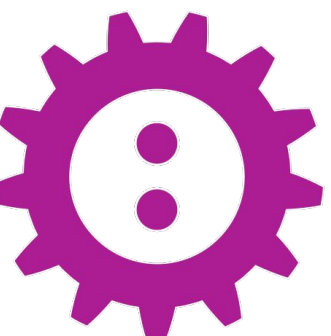
Use **off the shelf** emitter form true **IoT nodes**

**Widely used RF protocols** in **2.4 GHz ISM band**

**SDR-based receiver**

**Collect and share a large dataset** and reproducible RF fingerprints

Further rely on **Machine Learning** for **authentication** and **localization**



**But we need extensive experiments -> large testbed**

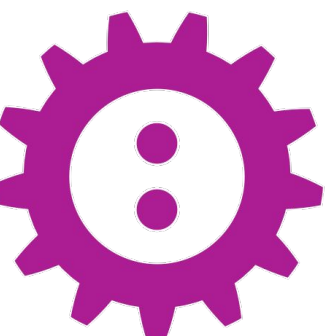


FOSDEM

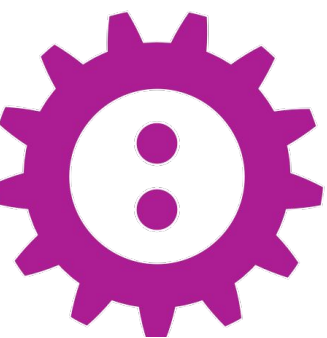
# Fed4FIRE+



**Fed4FIRE+** is a project under the EU programme **H2020**, offering the largest federation worldwide of **Next Generation Internet (NGI) testbeds**, which provide **open, accessible and reliable facilities** supporting a wide variety of different research and innovation communities and initiatives in Europe, including the **5G PPP projects and initiatives**.



**FOSDEM**



# Fed4FIRE+ SME Open Call



**COMPETITIVE  
CONTINUOUS CALL**

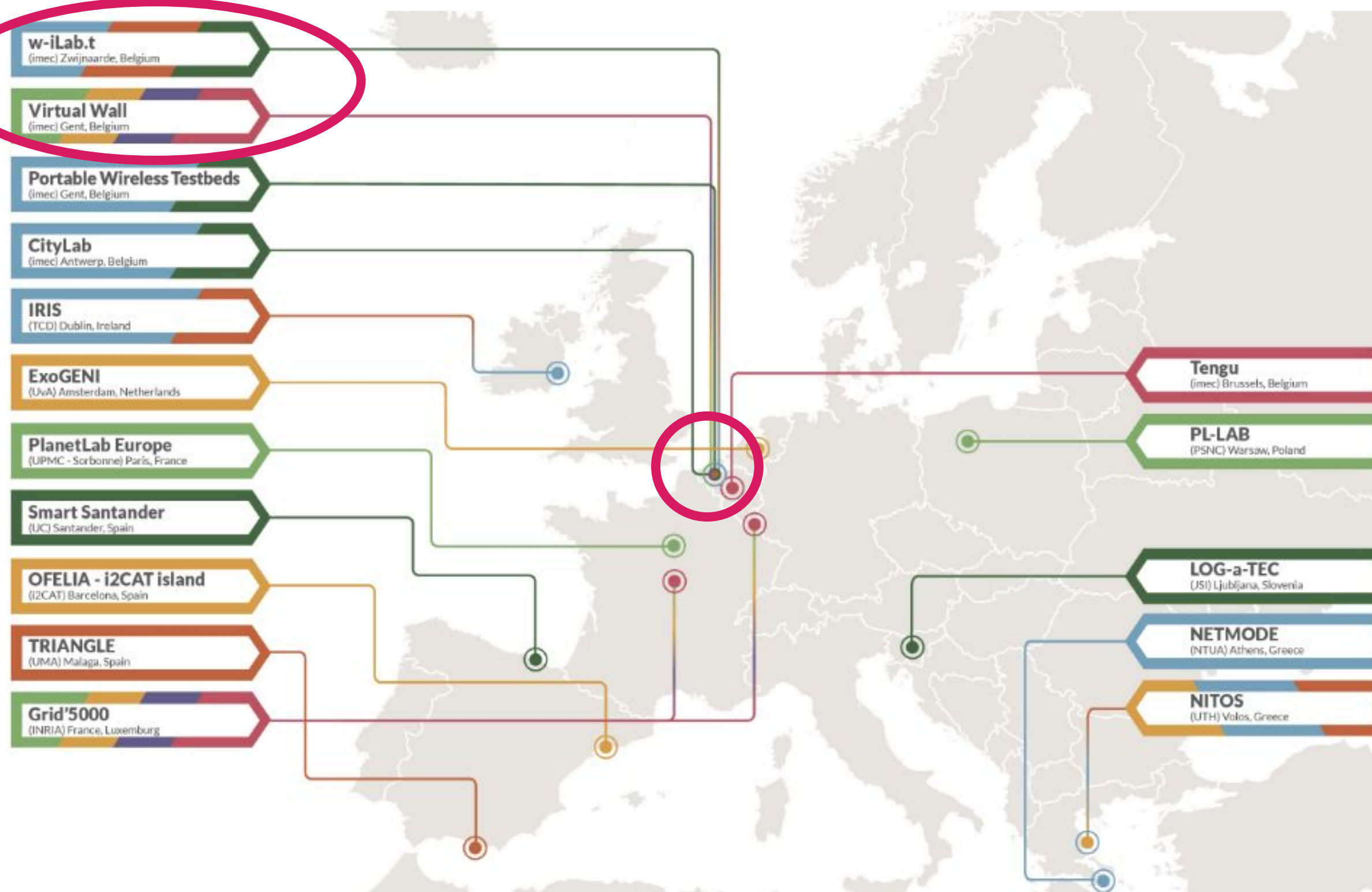
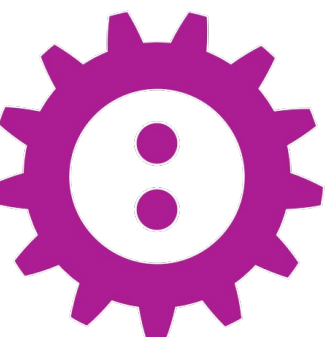
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**SME CASCADED  
EXPERIMENTS**



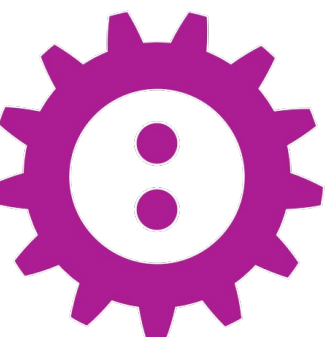


# FOSDEM





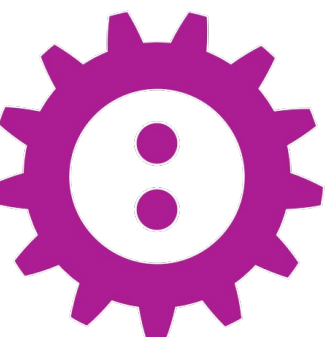
FOSDEM



# IMEC w-iLab.t testbeds







# IMEC w-iLab.t testbeds

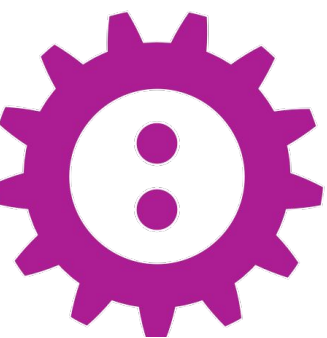


**2 testbed locations**

**<http://doc.ilabt.imec.be>**

- **w-iLab.1**: datacenter with 44 embedded PCs (WiFi and sensor nodes)
- **w-iLab.2**: industrial room with 100 fixed + 15 mobile nodes (WiFi, sensor, LTE, SDR)

**Use cases:** wireless, sensor, mobile, networking, SDR, 3rd party hardware



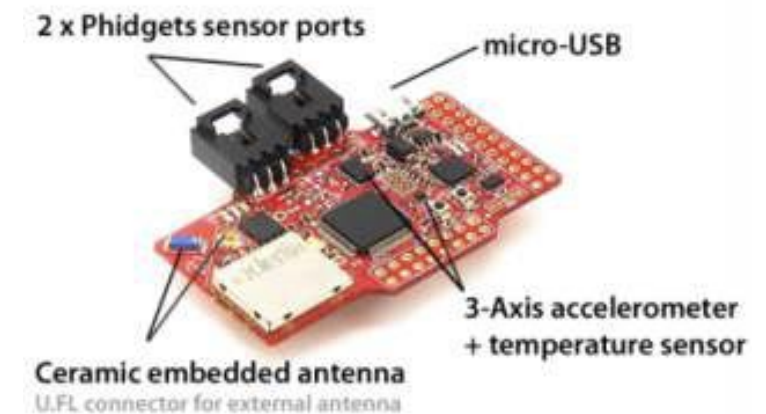
# IMEC w-iLab.t testbeds - IoT Devices

## Zolertia Re-Mote

- 2.4GHz / 868MHz
- UWB-shield



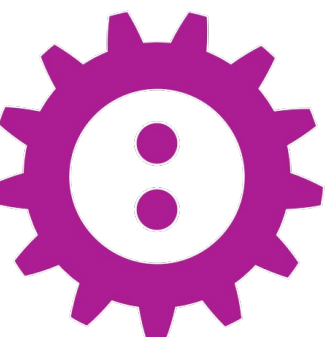
## Zolertia Z1 RM090



## Nordic Semiconductor nRF52 DK







# IMEC w-iLab.t testbeds - SDR

**USRP B210 (x4) & B200 (x4)**

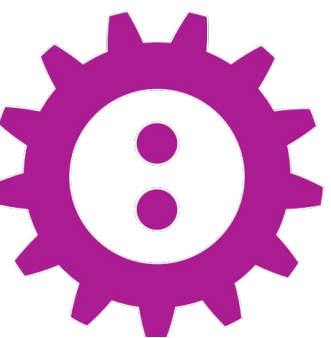
**USRP N210 (x6)**

**USRP x310 (x2)**

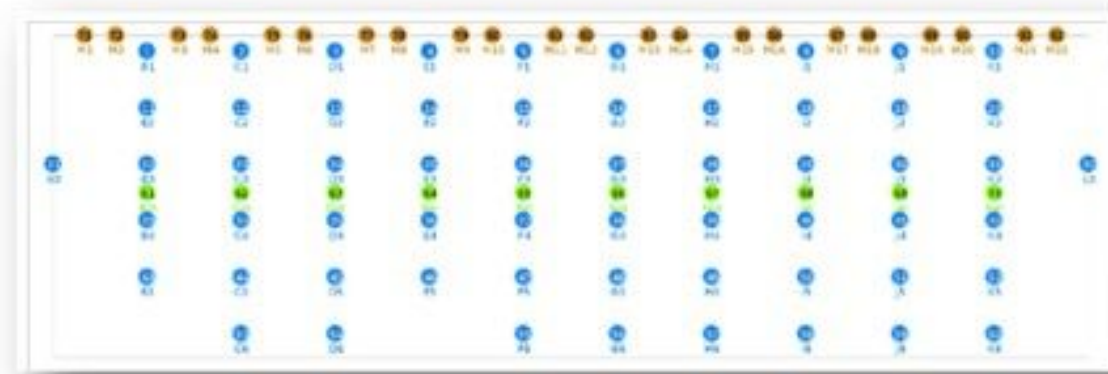
**Xilinx ZedBoard Zync-7000 SoC (x1)**

**ZC706 with Zync-7000 SoC (x3)**

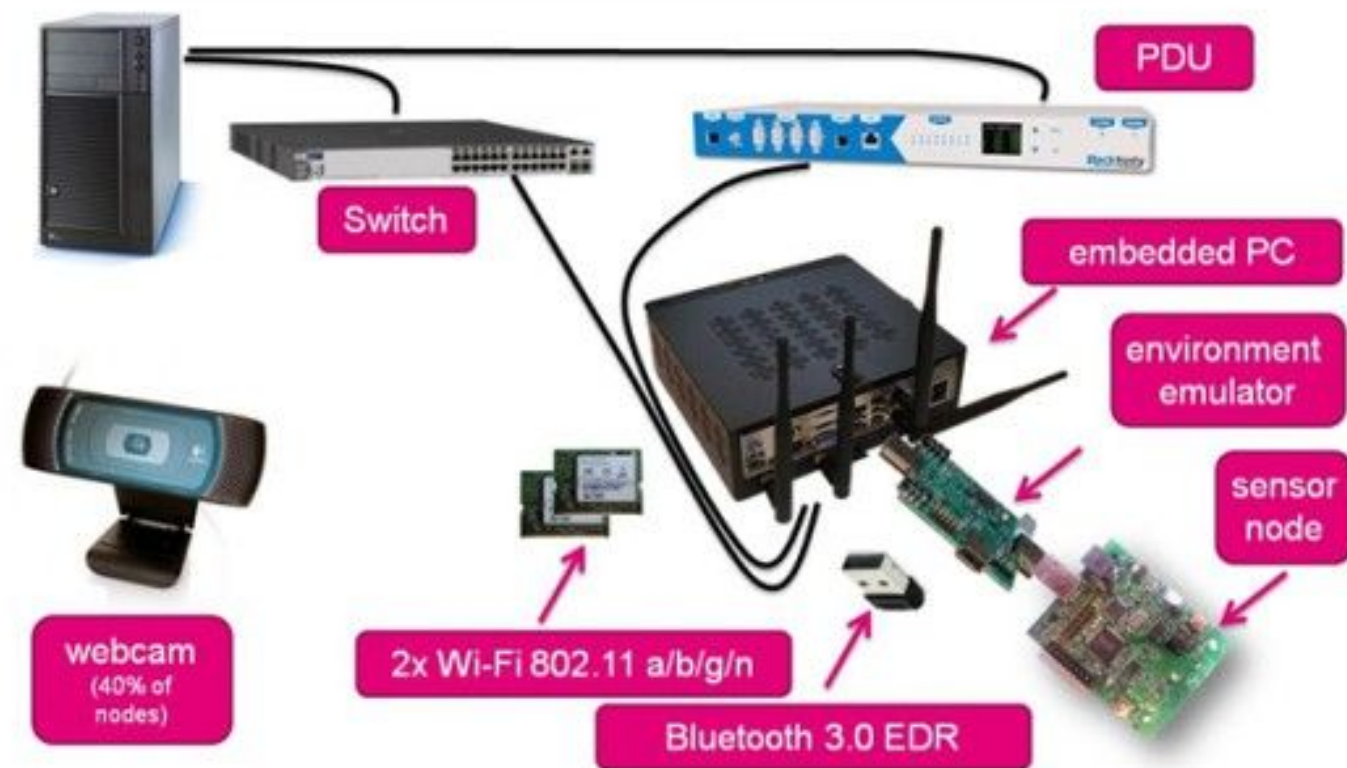
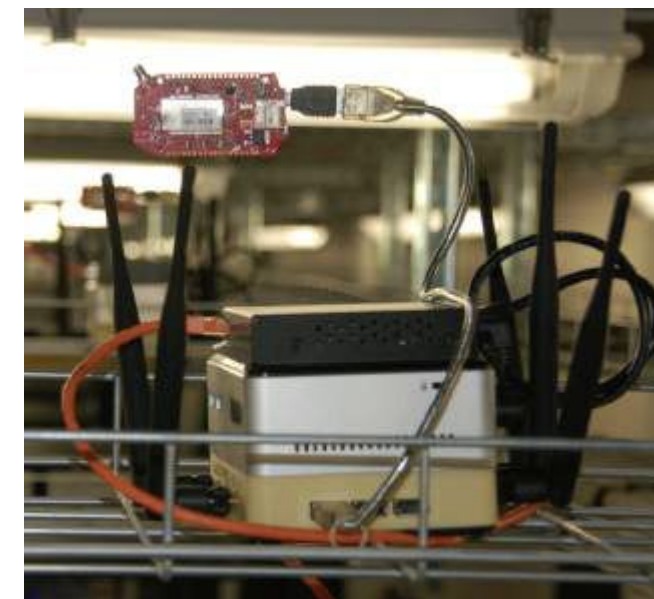




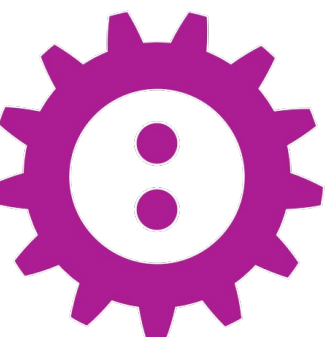
## IMEC w-iLab.2 testbed



"pseudo-shielded" environment, Zwijnaarde: [60+20 nodes]



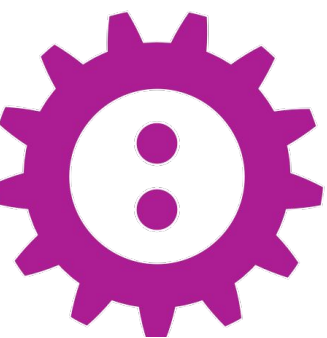




## IMEC w-iLab.2 testbed



FOSDEM

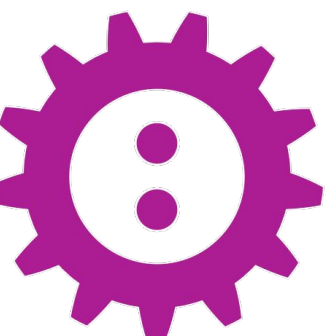


# Our Experiment - Access Testbed

**First Time** : Request an account at  
<https://authority.ilabt.iminds.be/signup.php>



# FOSDEM



Home

Documentation

## iMinds Authority

Sign Up

Login

### Join Project

Accounts and projects >

#### Personal Information

Username (max. 8 chars)

Full Name

Email

Institute or company

Please Select Country

Please Select State

City

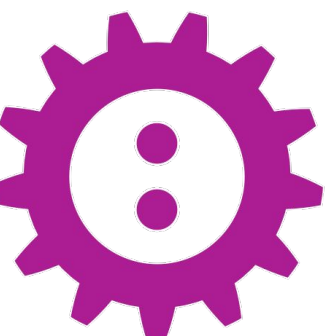
Password

Confirm Password

#### Project Information

Join Existing Project  Start New Project

Project Name



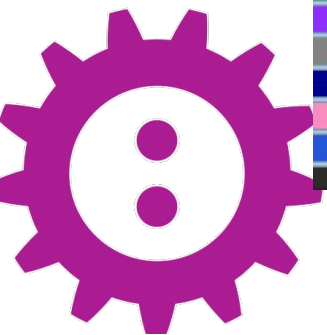
# Our Experiment - Access Testbed

**First Time** : Request an account at  
<https://authority.ilabt.iminds.be/signup.php>

1. Browse and reserve resources at  
<http://inventory.wilab2.ilabt.iminds.be/>.



# FOSDEM



Inventory Filters View Reservation **Inventory Mode** w-ilab2 inventory

World coordinates: [1000,-500] | Zoc Show all reservations (calendar)

Reservation starts on: 2020-01-30 1: and ends on: 2020-01-30 1:

Show available nodes in this timeslot

Nodes already reserved (38): apuP1, apuQ1, apuQ2, apuR2, apuS4, apuT4, apuU4, apuV4, mobile1, mobile11, mobile12, mobile2, mobile5, nucY1, server11, server13, server4, zc706zyncSDR2, zotacB3, zotacB4, zotacC3, zotacC4, zotacD1, zotacD3, zotacE2, zotacE4, zotacF1, zotacF2, zotacF4, zotacG1, zotacG2, zotacG3, zotacH2, zotacI1, zotacI3, zotacI4, zotacK6

Free nodes have green borders, reserved nodes (by others) are shown with red borders.

Node Selection

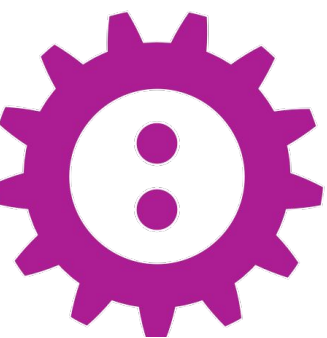
Nodes in your selection :  
Select nodes...

Select a project: SDR4IOT (Use this project name when swapping in with JFed)

Reserve selected nodes Show my reservations

#16723 SDR4IOT: 2020-01-30 13:00:00 - 2020-01-30 13:59:59: 1 node(s): mobile12

Node colors:  
ZOTAC  
USRP  
USRPX310  
SERVER5P  
SERVER1P  
SERVER1G2X  
MOBILE  
LTE-FEMTOCELL  
WARP  
DSS  
ALIX  
APU  
NUC2014  
OTHER



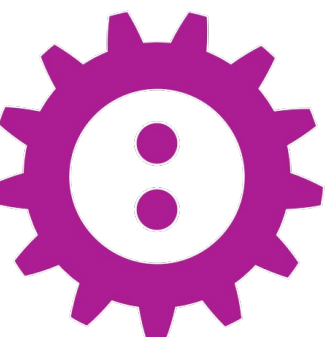
# Our Experiment - Access Testbed

**First Time** : Request an account at  
<https://authority.ilabt.iminds.be/signup.php>

1. Browse and reserve resources at  
<http://inventory.wilab2.ilabt.iminds.be/>.
2. Install jFed, start up jFed and login through the iLab.t



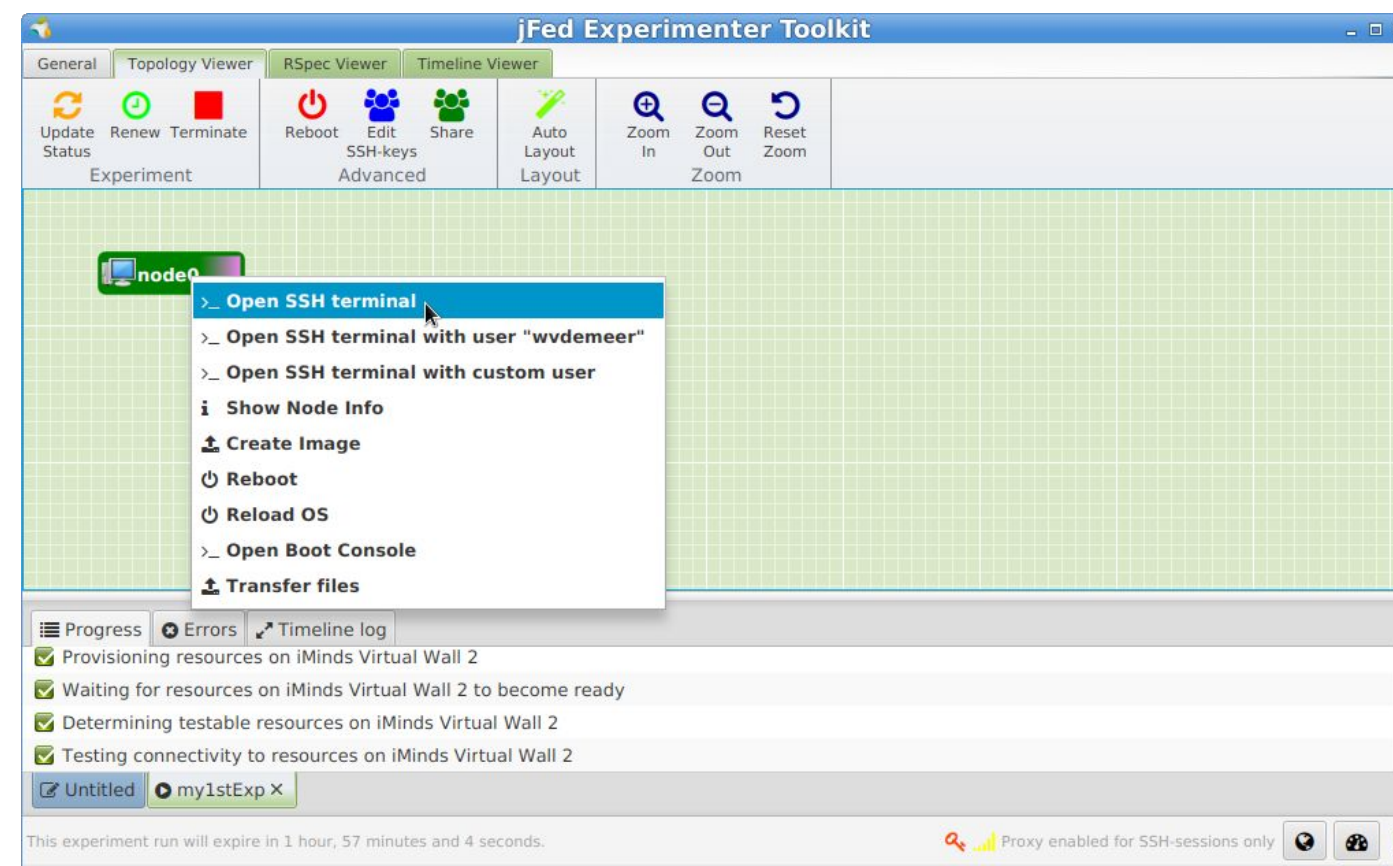
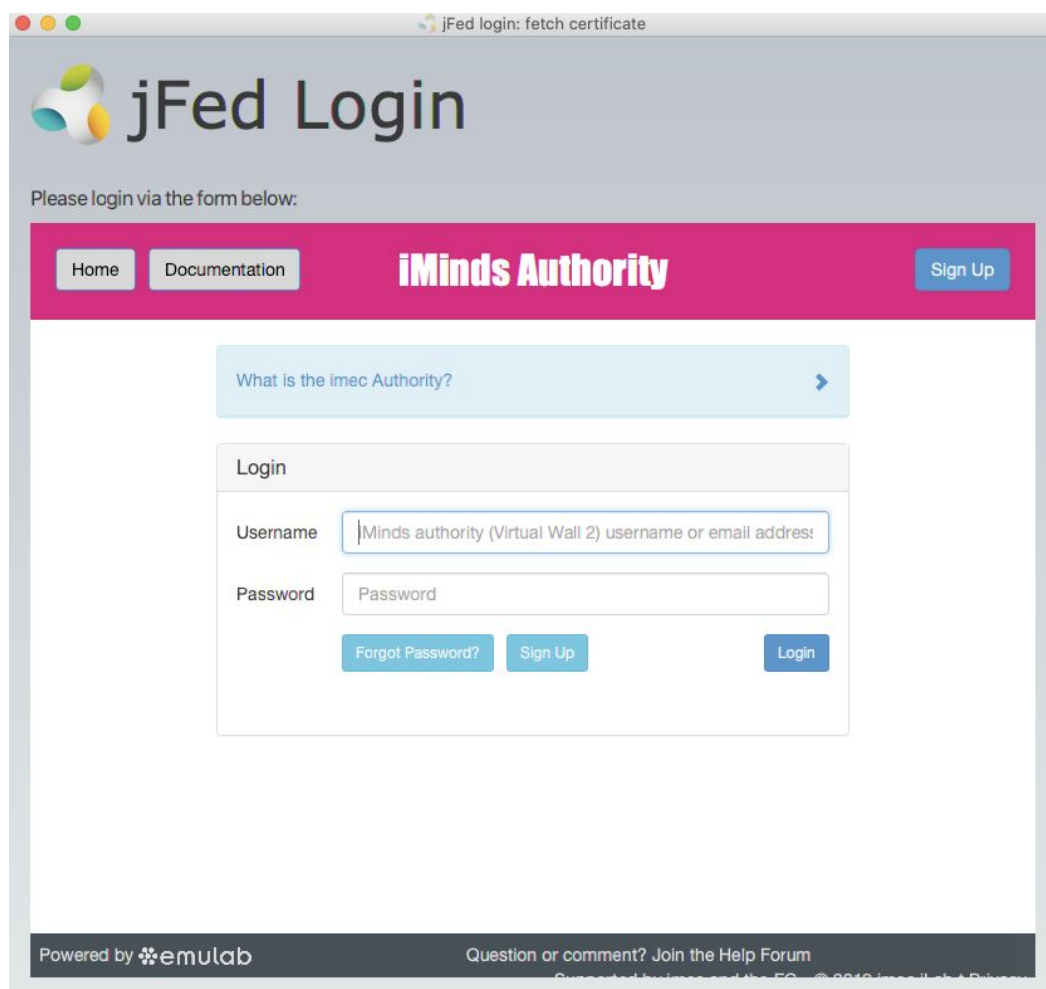




# Our Experiment - jFed



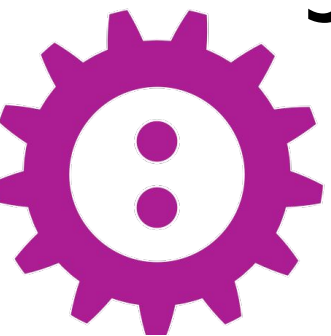
**jFed Experimenter GUI** and CLI allow end-users to provision and manage experiments <https://jfed.ilabt.imec.be/downloads/>



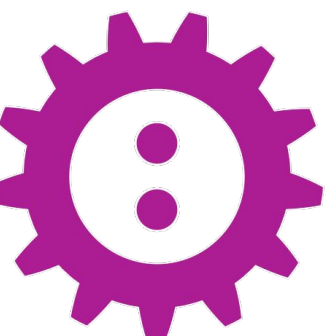
# Our Experiment - Access Testbed

**First Time** : Request an account at  
<https://authority.ilabt.iminds.be/signup.php>

1. Browse and reserve resources at  
<http://inventory.wilab2.ilabt.iminds.be/>.
2. Install jFed, start up jFed and login through the iLab.t
3. Load/copy your experiments XML (.rspec)
4. Click Run and give your experiment a name.
5. Double click the nodes and you should have SSH access on the nodes.







Sliver Testbed	Sliver ID	Expiration time	Status
imec WiLab 2	urn:publicid:IDN+wilab2.ilabt.iminds.be+sliver+73436	2020-01-30 14:10:20	READY

### Node login information

Node name	Hostname	Port	Username	Login
mobile12	mobile12.wilab2.ilabt.iminds.be	22	alexisd	>_ Login

### Manifest RSpec

Choose which manifest RSpec you want to view: Combined Manifest RSpec Save...

```

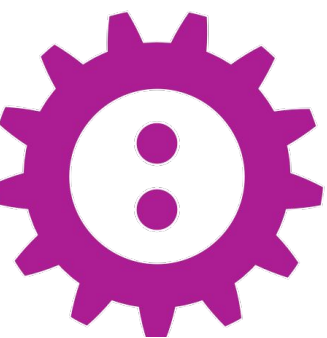
30T13:12:10.121+01:00" xmlns:emulab="http://www.protogeni.net/resources/rspec/ext/emulab/1"
xmlns:delay="http://www.protogeni.net/resources/rspec/ext/delay/1" xmlns:jfed-command="http://jfed.iminds.be/rspec/ext/jfed-command/1"
xmlns:client="http://www.protogeni.net/resources/rspec/ext/client/1" xmlns:jfed-ssh-keys="http://jfed.iminds.be/rspec/ext/jfed-ssh-keys/1"
xmlns:jfed="http://jfed.iminds.be/rspec/ext/jfed/1" xmlns:sharedvlan="http://www.protogeni.net/resources/rspec/ext/shared-vlan/1"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:schemaLocation="http://www.geni.net/resources/rspec/3
http://www.geni.net/resources/rspec/3/request.xsd ">
4
5   <node client_id="mobile12" exclusive="true" component_manager_id="urn:publicid:IDN+wilab2.ilabt.iminds.be+authority+cm"
6   component_id="urn:publicid:IDN+wilab2.ilabt.iminds.be+node+mobile12" sliver_id="urn:publicid:IDN+wilab2.ilabt.iminds.be+sliver+73436">
7
8     <sliver_type name="raw-pc"/>
9
10    <services>
11      <login authentication="ssh-keys" hostname="mobile12.wilab2.ilabt.iminds.be" port="22" username="alexisd"/>
12    </services>

```

Progress Errors Timeline log

- Register experiment testAlex
- Gathering experiment members info
- Processing experiment information
- Allocating resources on imec WiLab 2
- Provisioning resources on imec WiLab 2
- Waiting for resources on imec WiLab 2 to become ready
- Determining testable resources on imec WiLab 2
- Testing connectivity to resources on imec WiLab 2

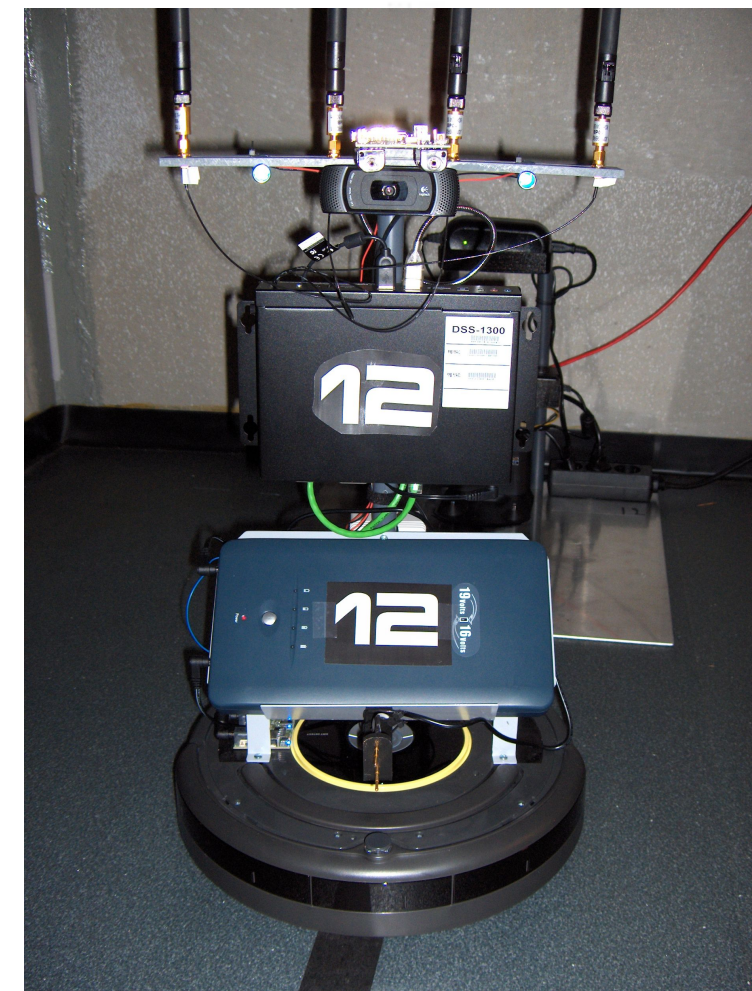
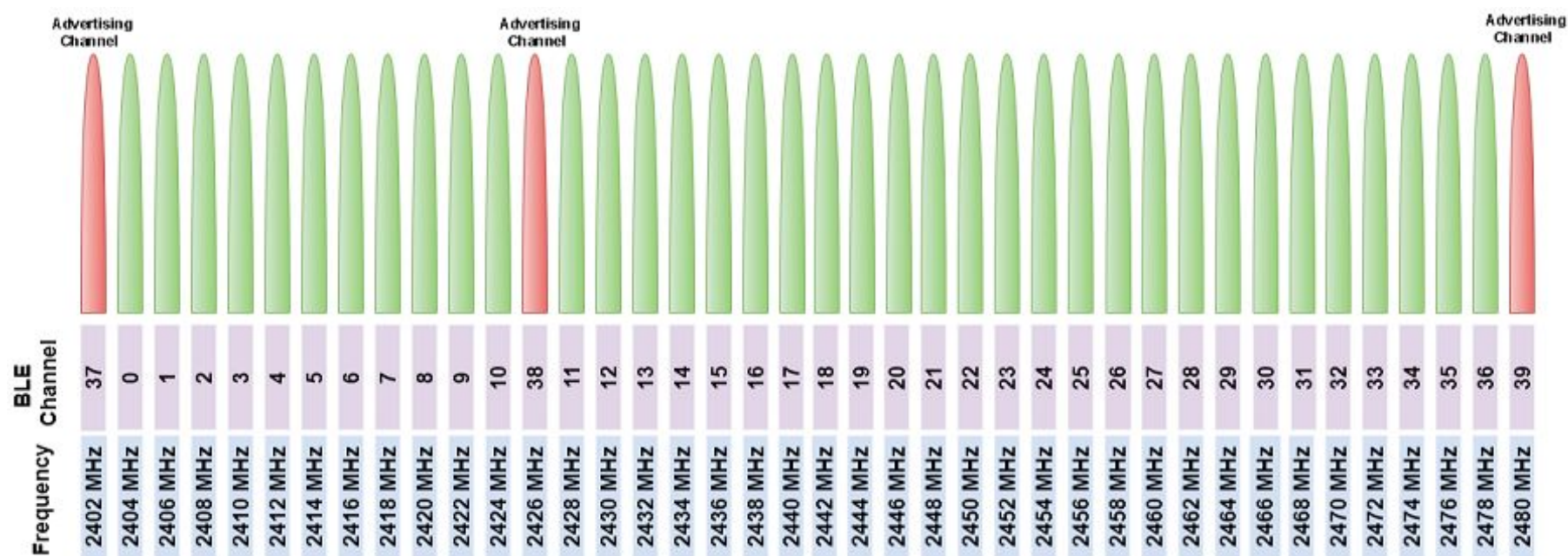
te testAlex X



# Our Experiment - Emission

## Huawei Nexus 6P

- Custom Bluetooth Low Energy App
- Advertising as a Bluetooth HRM Peripheral
- 2.4 GHZ GFSK





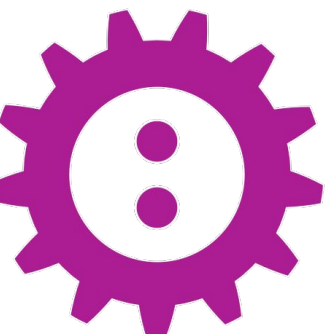
# Our Experiment - Reception

## USRP N210

- GNU Radio Compagnon
- Output Raw I/Q data (PHY)
- Decode Bluetooth Low Energy Packets



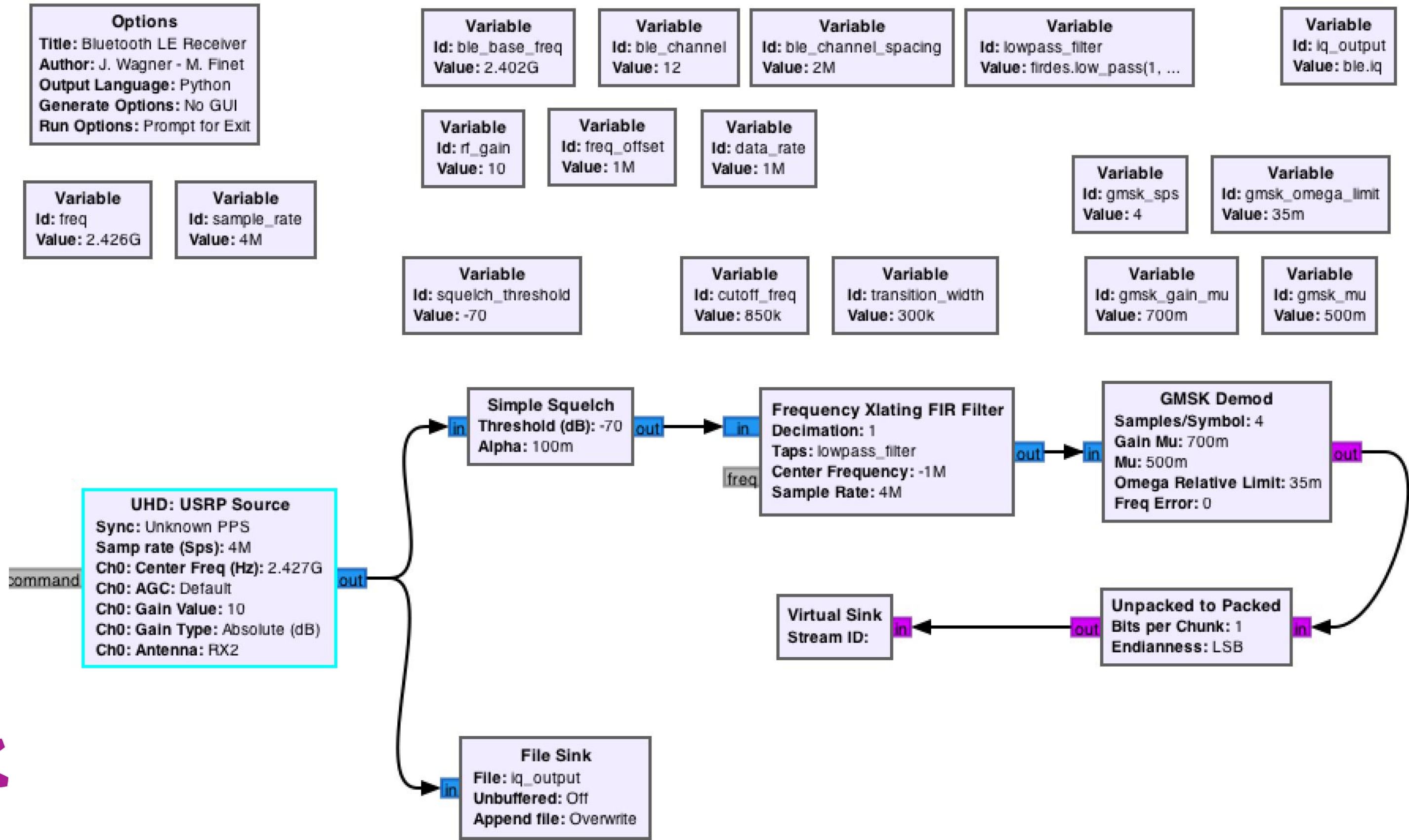
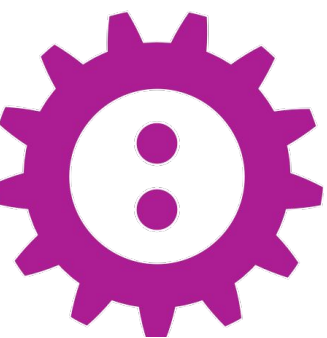
rely on `ble_dump`<sup>1</sup> by drtyhlpr



[1] [https://github.com/drtyhlpr/ble\\_dump](https://github.com/drtyhlpr/ble_dump)



# FOSDEM



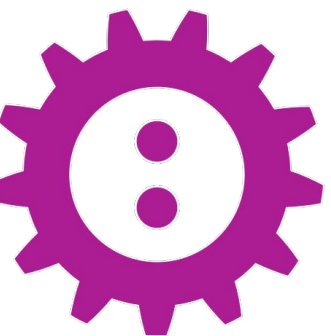
# Our Experiment - Scenario

Receiver (USRP) don't move, emitters (smartphone) **can move**

**One emitters sequentially**

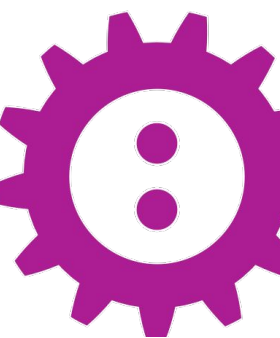
- same position
- same receiver
- different receivers
- different positions

**N emitters at the same time**





# FOSDEM



Robot Dashboard

https://robotcontrol.wilab2.ilabt.iminds.be/#

Incognito

robot dashboard

Live Abort Scene Initialize Play Play all Action

World coordinates: [3775,300] | Zoom: 0.5x | Snapping to: 25 | Mouse Coordinates: 2325,300

Moving axis3 (moved)

New Scene

Scene 1

Live info & actions:

Tail: 1 Limit

to: 50 datapoints

Refresh

Clear Safe Return

Feed from: axis3. 00:13 remaining. (Renew)

Wilab2 Control #3 1970-10-18 16:12:36

Focus 5 follow

#FOSDEM #FSR #SDR #IoT #ML

@alexis0duque





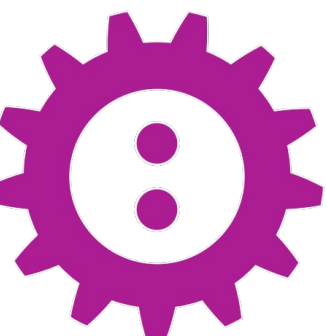
# Our Experiment - Next steps

**Write documentation and open-source codes, scripts, and datasets**

**Zenodo**

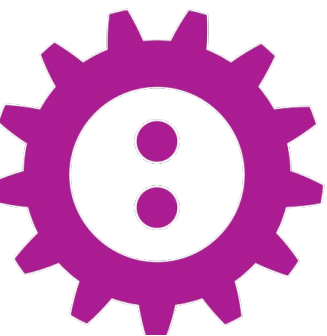


- + **Other RF and node types**
- + **Extensive use of robot for mobility**





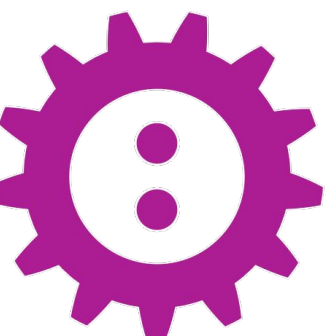
# FOSDEM



#FOSDEM #FSR #SDR #IoT #ML

@alexis0duque





# Our Experiment - Next steps

**Write documentation and open-source** codes, scripts, and datasets

**Zenodo**



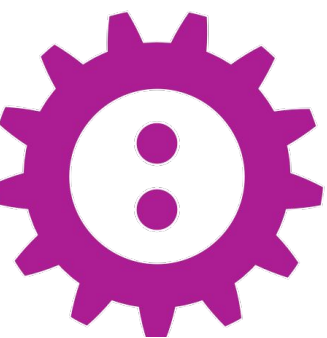
**VirtualWall** for data science and machine learning



- Fingerprinting with deep learning
- Try different deep learning algorithm



**FOSDEM**



# Fed4FIRE+ SME Open Call



**COMPETITIVE  
CONTINUOUS CALL**

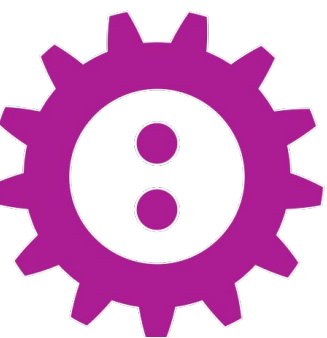
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**SME CASCADED  
EXPERIMENTS**

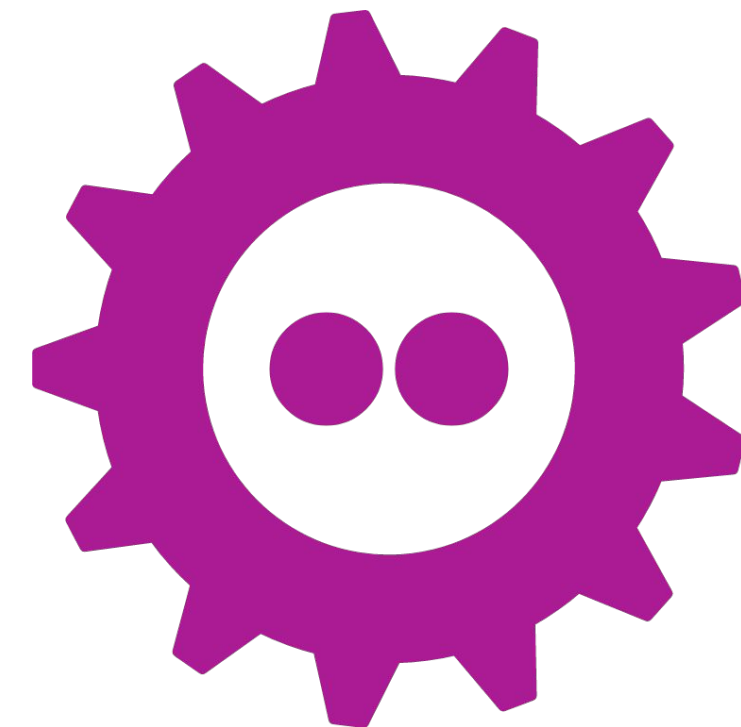
**STAGE 2**



FOSDEM



# Thanks!

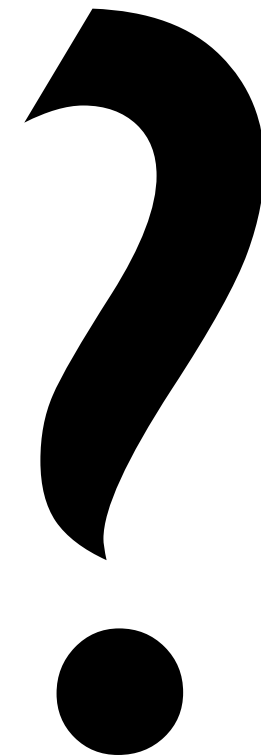
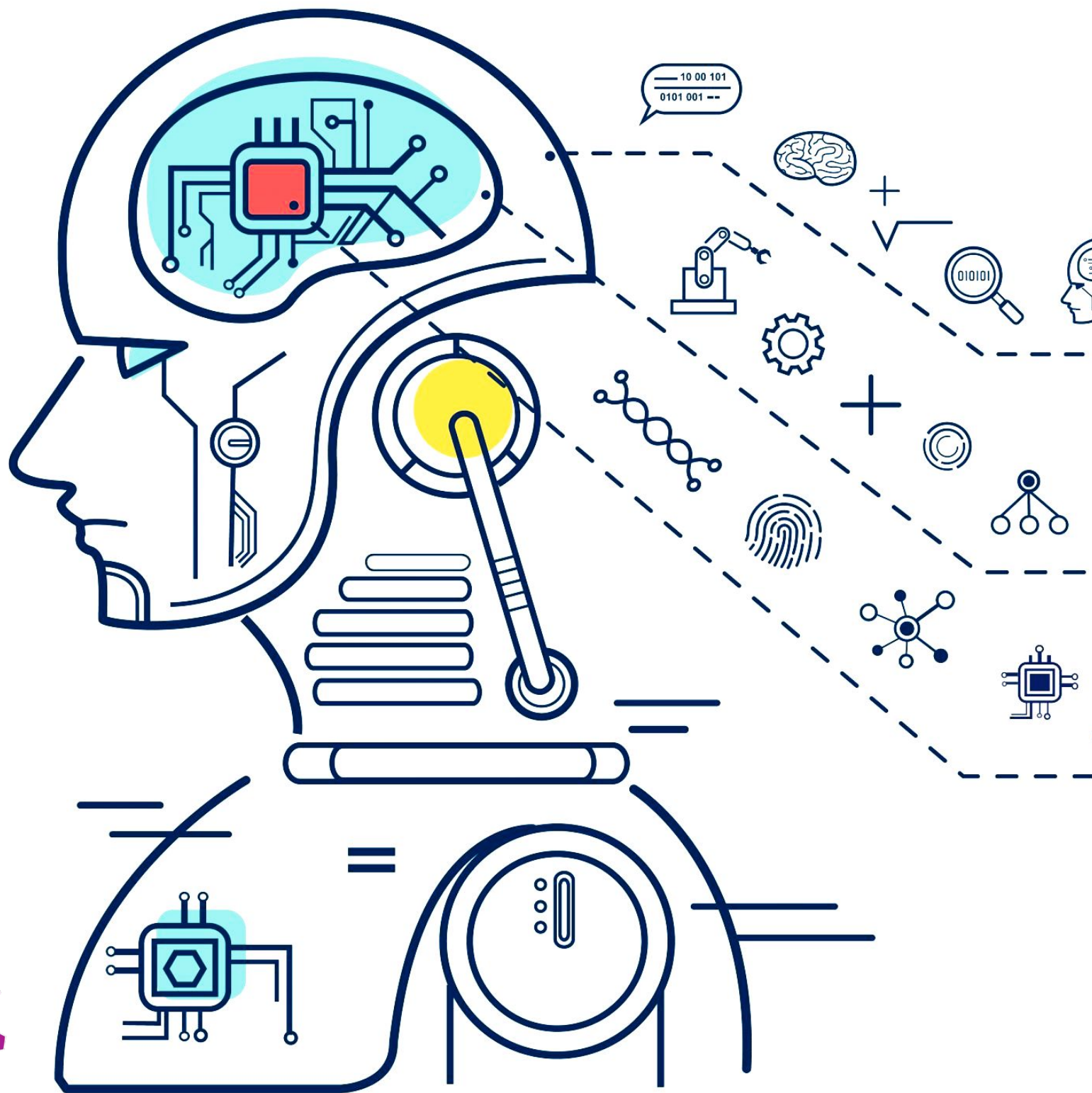
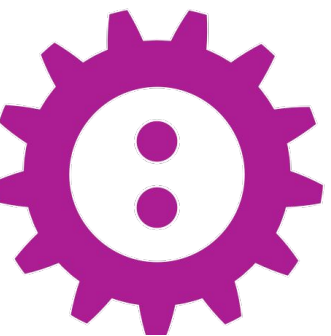


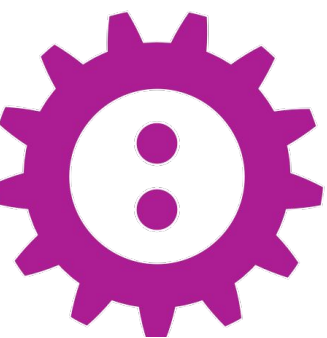
**w-iLab.t Team**  
Brecht Vermeulen,  
Pieter Becue





# FOSDEM





# References

<https://www.fed4fire.eu/>

<https://www.fed4fire.eu/event/continuous-call-sme-cascaded-experiments/>

<https://jfed.ilabt.imec.be/>

<https://doc.ilabt.imec.be/ilabt/wilab/>

<https://doc.ilabt.imec.be/ilabt/wilab/tutorials/lte.html#control-an-android-smartphone-via-adb>

<https://doc.ilabt.imec.be/ilabt/jupyter/index.html>

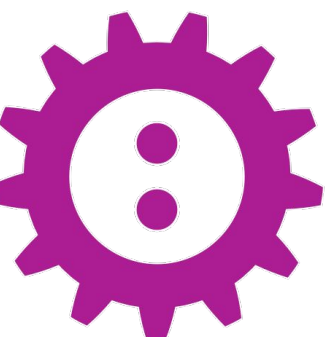
<https://zenodo.org/>

<https://gnuradio-eu-20.sciencesconf.org/>

<https://www.tensorflow.org>

<https://rtone.eu>

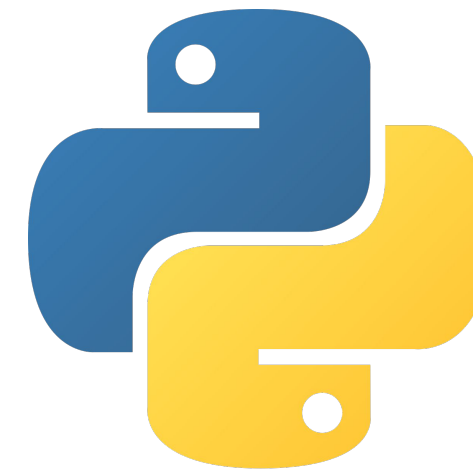




# Our Experiment - Outputs

## 2 Distinct Datasets

Further serialized with Pickle



$\langle Y, X, \text{NodeTx}, \text{NodeRx}, \text{Timestamp}, I, Q \rangle$

$\langle Y, X, \text{NodeTx}, \text{NodeRx}, \text{Timestamp}, \text{packet} \rangle$