IMEC WIRELESS TESTBEDS

BRECHT VERMEULEN, PIETER BECUE, BART BRAEM

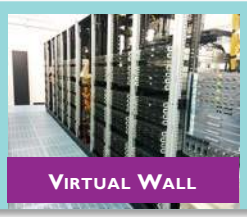
Device, data & experiment management

TESTBED MGMT
One click experiment setup & management

DEVICE MANAGEMENT
Configuration and maintenance
Management and monitoring

SERVICE MGMT
Manage and scale on-demand services

Scalable AI, Cloud and big data services (data processing)



VIRTUAL WALL

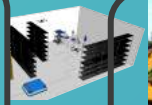
GPULAB

CLOUD AND CONTAINER-ON-DEMAND

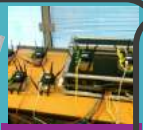
OBELISK

Federated Large-scale validation testbeds (communication, sensing, actuation)

W-ILAB.T



INDUSTRIAL IoT LAB



PORTABLE TESTBED

OFFICELAB

VIRTUAL WALL

CITYLAB

SMART HIGHWAY

HOMELAB

INTERACTION LAB

DE KROOK

TECHNOLOGY-DRIVEN → APPLICATION-DRIVEN

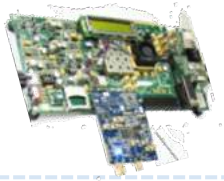
Rapid hardware prototyping

imec IDLab INTERNET & DATA LAB

UNIVERSITEIT GENT

Universiteit Antwerpen

OCTA: DYNAMIC HARDWARE SENSOR PLATFORM
Fast sensor prototyping



REAL-TIME SDR
Fast gateway prototyping
Multiple virtual radios on a single chip.

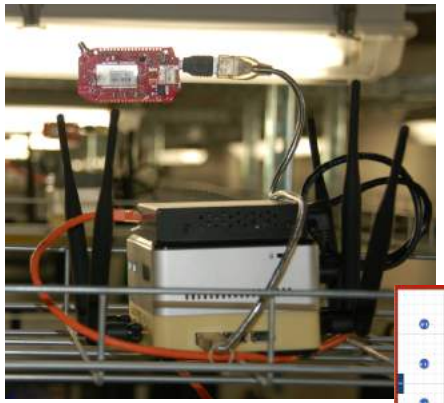
PUBLIC

WILAB TESTBED

2 testbed locations: http://doc.ilabt.imec.be

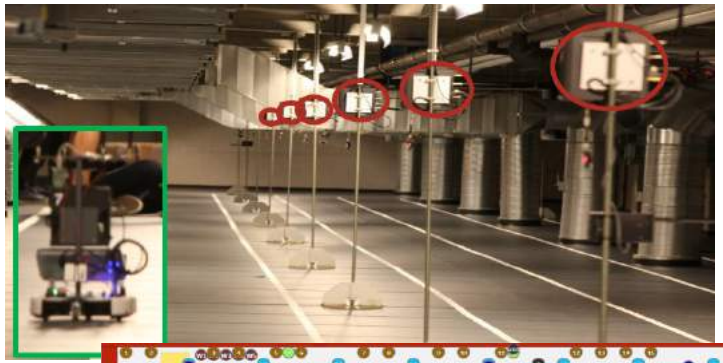
- w-iLab.1: datacenter with 44 embedded PCs (WiFi and sensor nodes)
- w-iLab.2: industrial room with 100 fixed +15 mobile nodes (WiFi, sensor, LTE, SDR)

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



4 RF-shielded boxes

https://wilab1.ilabt.iminds.be/inventory



https://inventory.wilab2.ilabt.iminds.be

imec IDLab UNIVERSITEIT GENT Universiteit Antwerpen

WILAB TESTBED

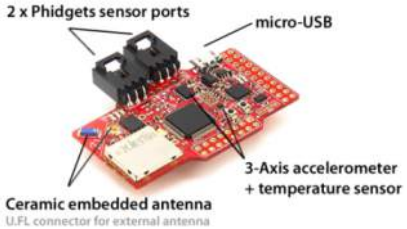
- w-iLab.1
  - **44 x NUC**: Intel dual core i5-4250U (2,6GHz), 8GB RAM, 1x 320GB disk, 1x 1Gb/s, 1x 802.11abgn+Bluetooth4.0, 1x 802.11ac, 2x 802.15.4 Zolertia Re-Mote (2.4GHz+sub-GHz) + temp sensor
  - **4 x Qosmotec** shielded boxes, connected by fully configurable attenuator patch panel
- w-iLab.2
  - **47 x ZOTAC**: Intel dual core Atom D525 (1.8GHz), 4GB RAM, 1x 160GB disk, 1x 1Gb/s, 2x 802.11abgn, Bluetooth 2.0, Environment Emulator + 802.15.4 RM090 sensor (2.4GHz)
  - **10 x DSS**: Intel dual core i5, 4GB RAM, 1x 60GB SSD, 2x 1Gb/s, 1x 802.11abgn, 1x 802.11ac, Bluetooth 2.0, Environment Emulator + 802.15.4 RM090 sensor (2.4GHz)
  - **42 x APU**: dual core AMD G T40E(1GHz), 4GB RAM, 1x 32GB SSD, 3x 1Gb/s, 2x 802.11ac, 1x 802.15.4 Zolertia Re-Mote (2.4GHz+sub-GHz)
  - **15 x MOBILE**: DSS node mounted on top of fully controllable mobile platform
  - **5 x SERVER5P:** 8x dual core Intel Xeon 5600, 12GB RAM, 1x 160GB disk, 6x 1Gbs/s
  - **7 x SERVER1G2X**: 8x dual core Intel Xeon1541(2.1GHz),16GB RAM,500GB disk, 2x1Gbs/s, 2x10Gb/s
  - **2 x LTE femto-cell, 7x USRP-N210, 2x USRP-x310, 4x USRP-B210, 4x USRP-B200, 3x WARP, 4x zc706 ZYNC SDR, 2x ZED zync SDR**
- Internal layer 2 interconnectivity (EU, US, Brazil, Asia)
- Images for Ubuntu, Debian
- Full root access so everything can be installed by yourself

EMBEDDED PC'S

Feature	ZOTAC	APU 1d4	DSS/MOBILE	SERVER1P/SERVER5P	SERVER1G2X
CPU type	Intel Atom D525 (2cores, 1.8GHz)	AMD G series T40E APU (2cores, 1GHz)	Intel core i5	8x dual Intel Xeon Processor 5600 Series	Intel Xeon Processor D-1541 (2.1GHz, 8 cores, 16 threads)
RAM (GB)	4GB DDR2 800MHz PC2-6400 CL6	4GB DDR3 1066MHz	4GB DDR2 800MHz PC2-6400 CL6	12GB DDR2 800MHz PC2-6400 CL6	16GB DDR4 2133MHz
Hard disk	160GB (2.5", SATA, 7200RPM, 16MB)	32GB (SSD,mSATA)	60GB (2.5", SATA, SSD)	160GB (2.5", SATA, 7200RPM, 16MB)	500GB (3.5", SATA, 7200RPM, 64MB)
WiFi	2x802.11abgn	2x802.11ac	1x802.11abgn, 1x802.11ac	No WiFi cards/dongles	No WiFi cards/dongles
Sensor node	EE + RM090	Zolertia Re-Mote	EE + RM090	No EE/sensor node	No EE/sensor node
Bluetooth	USB 2.0 Bluetooth (Micro CI2-v3.0 EDR)	No Bluetooth	USB 2.0 Bluetooth (Micro CI2-v3.0 EDR)	No Bluetooth	No Bluetooth

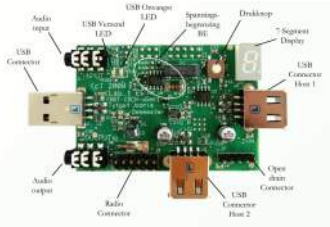
CONSTRAINED IOT DEVICES

- Zolertia Re-Mote
  - 2.4GHz / 868MHz
  - UWB-shield (in-house developed)
- Currently deployed:
  - Temperature sensors
  - Many other sensors possible

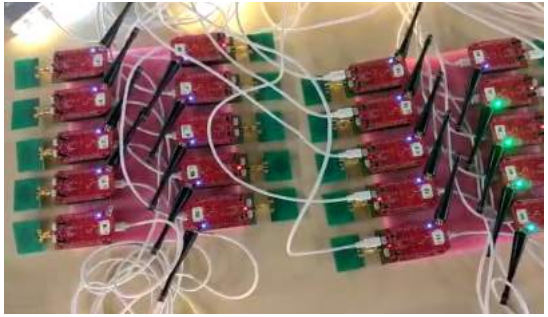


- Zolertia Z1
  - 2.4GHz

- RM090
  - 2.4GHz



- Environment Emulator
  - Battery emulation
  - 6KHz sample rate
  - Generate I/O events on DUT
    - RM090/Re-Mote



- UWB-shield
  - UWB radio, sub-cm accuracy

Nordic Semiconductor nRF52 DK
- BLE development kit

- Sparklan WPEA-251N(BT)
  - 802.11a/b/g/n
  - Bluetooth 4.0 LE/ 3.0 HS/ 2.1 EDR standard

W-ILAB.2 PLENUM CLEANROOM SPECIAL NODES AND PROXY USE

- some embedded nodes are used as proxy to connect to specialized hardware
- more powerful servers available for special purposes (16x 10Gbit interfaces)

2 x femtocell (ip.access)

+emulated core (SiRRAN)

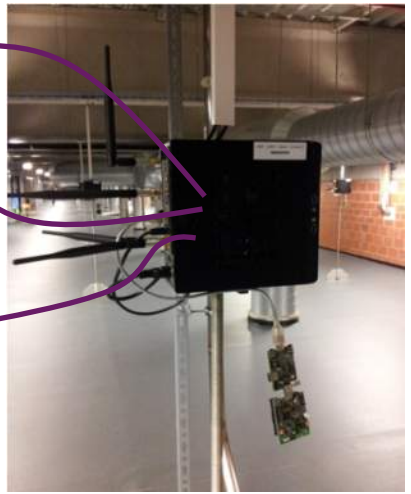
sensor nodes (RM090 with MSP430), environment emulator,...

+20 UE (Huawei)

USRP, WARP, IMEC SE SDR/cognitive

?

your custom hardware (e.g via USB, PoE, 220V, ethernet)



WILAB – NEW SDR EXTENSIONS

USRP x310 (x2)
10Gbps fiber to switch
10 Gbps Ethernet to server

USRP B210 (x4)
USRP B200 (x4)
USB3.0 to Intel NUC

ZC706 with Zync-7000 SoC (x3)
1Gbps Ethernet to APU
2 x USB (UART + JTAG)
APU
AMD G-series (1GHz)
Only for programming & debugging

Xilinx ZedBoard Zync-7000 SoC (x1)
2 x USB (UART + JTAG)

SERVER
Intel Xeon
Only for programming & debugging

SERVER (x7)
Intel Xeon Processor D-1541
(2.1GHz, 8 cores, 16 threads)
16GB DDR4 RAM

NUC (x8)
Intel Core i5-4250U
(3M Cache, up to 2.60 GHz)
8GB DDR3 RAM

RFNoC Ettus Research

GNURadio THE FREE & OPEN SOFTWARE RADIO ECOSYSTEM

SRS LTE open-source 4G from handset to core

imec iLab.t documentation

TABLE OF CONTENTS

- Virtual Wall
- Wireless Testlab and OfficeLab
  - Overview
  - Getting started
  - Tutorials and howto's

https://doc.ilabt.imec.be/ilabt/wilab/index.html

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BLIC

WILAB – 802.11AX

Source: Cisco.com

cisco

Ruckus WIRELESS

UBIQUITI NETWORKS

Intel
802.11ax
2x2 MIMO
2.4Gbps

Compex
802.11ac Wave 2
4x4 MIMO
1.73Gbps

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WILAB – 802.11AX

Cisco Catalyst 9117

802.11ax
8x8 MU-MIMO
5Gbps backbone

Ubiquiti Unifi XG

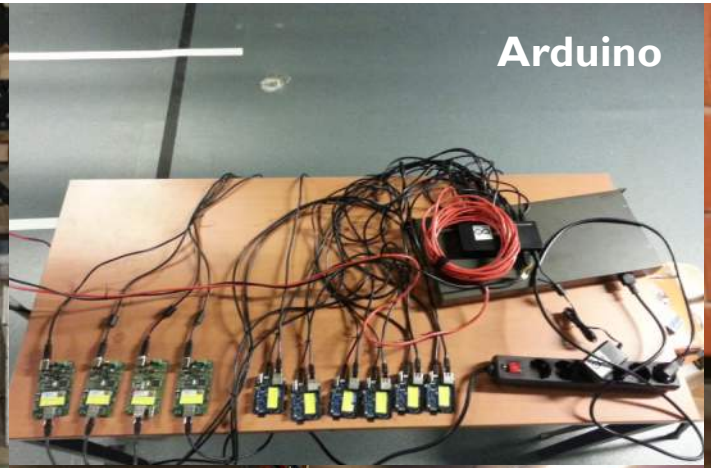
802.11ac Wave 2
4x4 MU-MIMO
10Gbps backbone

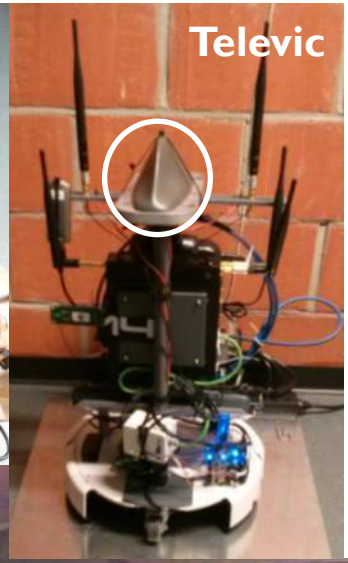
Ruckus Zoneflex R730

802.11ax
8x8 MU-MIMO
5Gbps backbone

Will be added to testbed as non-imageable devices

THIRDPARTY HARD- AND SOFTWARE TESTS





IOT - OFFICELAB

44 Intel NUC

8GB RAM / 320GB HDD
802.11a/b/g/n + BT 4.0
802.11ac (3x3)

OFFICELAB

Office environment with 110 embedded PCs spread over 3 office floors

Use cases: wireless, sensor, networking, 3rd party hardware, indoor localization (UWB)

https://wilab1.ilabt.iminds.be/inventory

http://doc.ilabt.imec.be

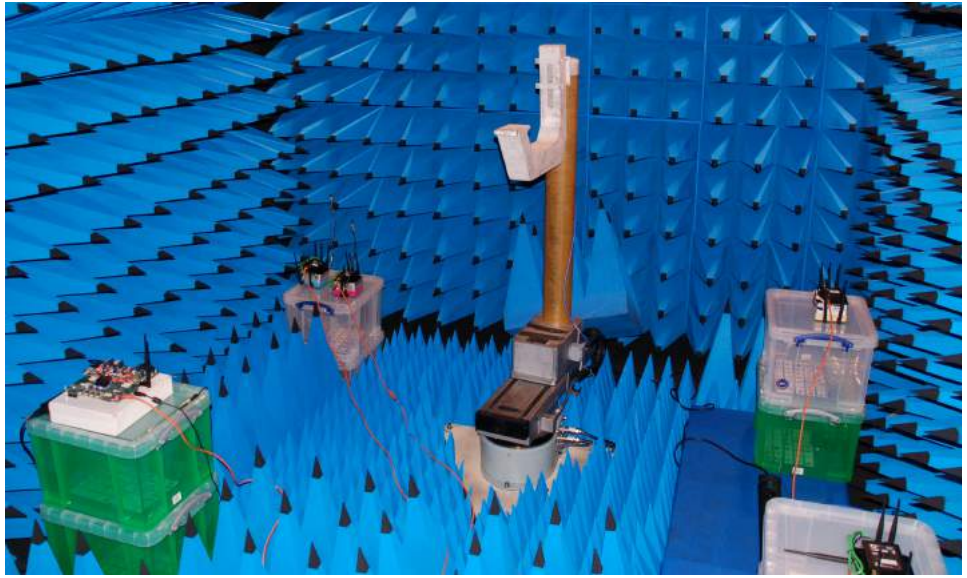
OFFICELAB

- **iGent building**: floor 9, 10, 11
- **110 x NUC**: Intel dual core i5-4250U (2,6GHz), 8GB RAM, 1x 320GB disk, 1x 1Gb/s,
  - 1x 802.11abgn+Bluetooth4.0
  - 1x 802.11ac
  - BLE development kit (only floor 11)
  - 1x 802.15.4 Zolertia Re-Mote (2.4GHz + sub-GHz) with temperature sensor
    - Extendable with many other sensors (light, motion, gas, noise, …)
  - Indoor localization with Zolertia Re-Mote + UWB shield (on floor 11)
- Internal layer 2 interconnectivity (EU, US, Brazil, Asia)
- Images for Ubuntu, Debian
- Full root access so everything can be installed by yourself
- IoT-toolkit for management of large sensor experiments

PORTABLE TESTBED

Portable wireless test infrastructure with 15 embedded PCs (WiFi/sensor) & SDR equipment. Easily extendable with 3rd party hardware.

Use cases: wireless, sensor, networking, on-site testing, rapid deployment



http://doc.ilabt.imec.be

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PUBLIC

PORTABLE TESTBED

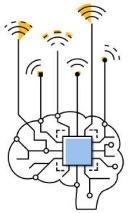
- **15 x NUC**: Intel dual core i5-4250U (2,6GHz), 8GB RAM, 1x 320GB disk, 1x 1Gb/s,
  - 1x 802.11abgn+Bluetooth4.0
  - 1x 802.11ac
- **USB extensions** (depending on needs):
  - 802.15.4 Zolertia Re-Mote (2.4GHz + sub-GHz) with temperature sensor
  - SDR hardware: USRP B200/B210-mini, USRP B200/B210
- **Network extensions**:
  - SDR hardware: USRP x310, ZYNC zc706
- Integrate 3rd party hardware by connecting to testbed nodes over USB or Ethernet
- Standalone server & network able to work offline or even server-less
- Battery packs can power NUC up to 10 hours
- Images for Ubuntu, Debian
- Full root access so everything can be installed by yourself

CITYLAB

IDLAB ANTWERP

CITYLAB APPLICATIONS

WIRELESS + EDGE AI



Multi-radio Connectivity

- Test wireless multi-technology coexistence in unlicensed spectrum
- Enabling multi-technology orchestration and collaboration to improve performance

AI Edge computing

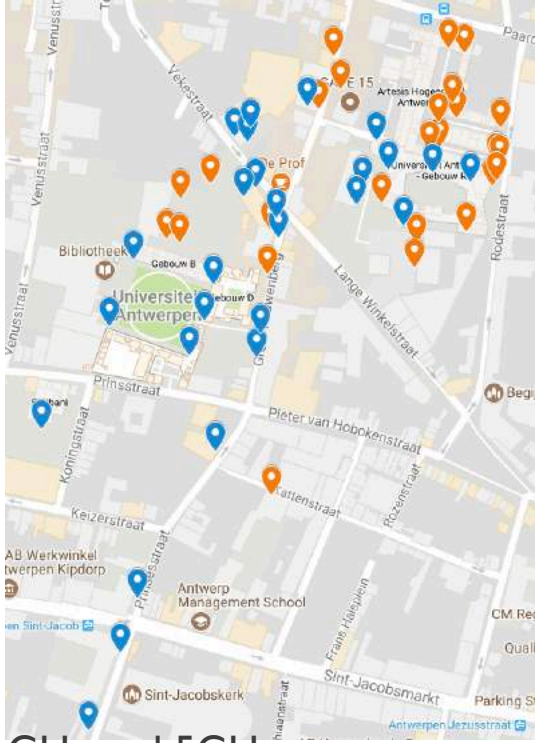
- Taking advantage of speed/latency at the edge
- Enabling computing, AI and orchestration in a distributed fashion

Outdoor, flexible multi-technology

CITYLAB: A CONNECTIVITY INFRASTRUCTURE

MULTI-TECHNOLOGY CONNECTIVITY

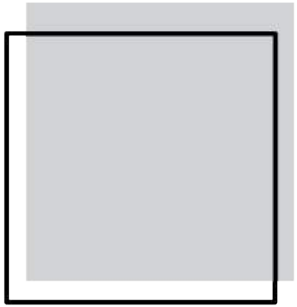
- Large deployment operational outdoor
  - 35 CityLab gateways in City Campus
  - 15 additional gateways pending
  - 15 in Smart Zone for connectivity services
- Focus on coexistence testing in unlicensed spectrum and edge computing
  - Outdoor edge computing
  - Supporting WiFi, 802.15.4, Bluetooth and sub-GHz
  - Backed up by commercial LPWAN backends (LoRa, SigFox, NB-IoT)

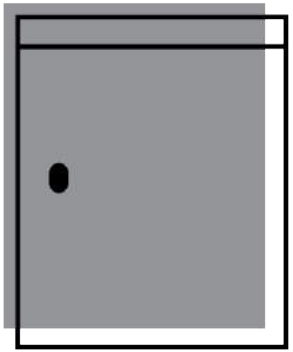


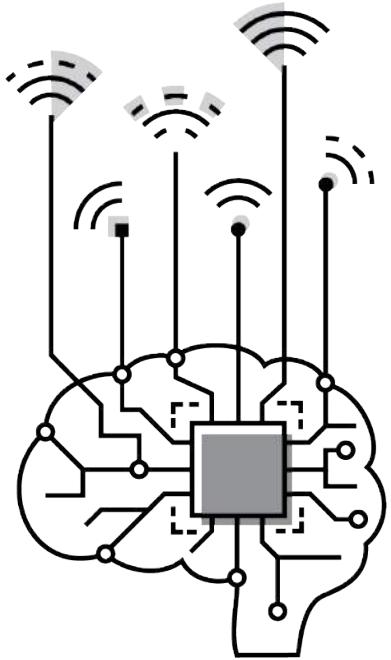
WiFi 802.11ac on 2.4 GHz and 5GHz
WiFi 802.11n on 2.4 GHz and 5GHz
Bluetooth 4.0
IEEE 802.15.4 on 2.4 GHz and IEEE 802.15.4g on 868MHz
DASH7 on 433MHz and 868MHz
LoRaWAN on 868MHz (client only)

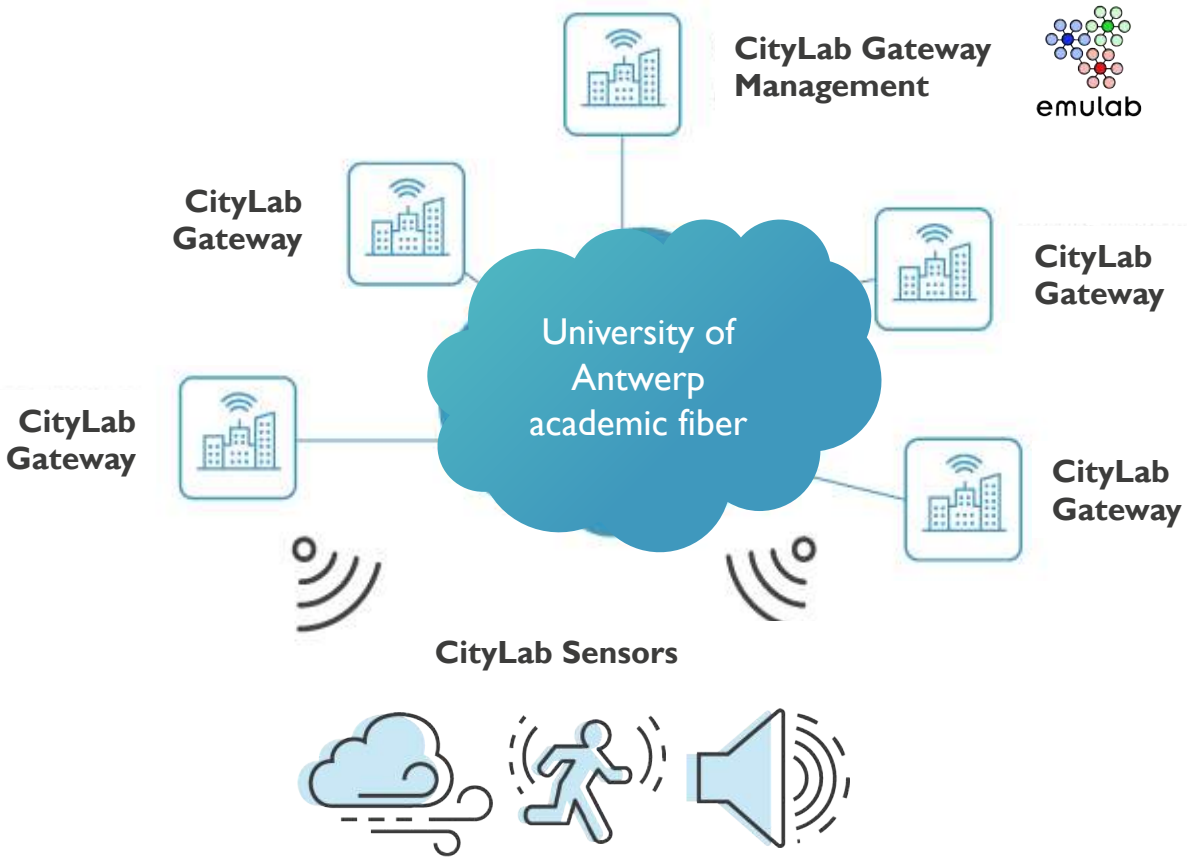
CITYLAB GATEWAYS

THREE BOXES








CityLab Gateway Management
emulab
CityLab Gateway
CityLab Gateway
CityLab Gateway
CityLab Gateway
University of Antwerp academic fiber
CityLab Sensors

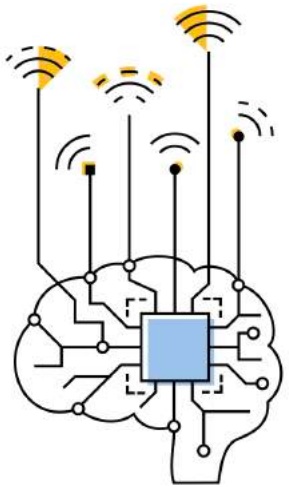
TYPICAL EXPERIMENT: FED4QOE

HOW TO DETERMINE QOE IN A WIRELESS ENVIRONMENT

- Fed4FIRE+ open call experiment by Allbesmart (PT)
  - How to translate wireless network characteristics into QoE
  - Validated their QoE measurement framework remotely

CITYLAB FUTURE: TOWARDS A SMART INFRASTRUCTURE

SMART CITY SENSORS – MULTI-RADIO CONNECTIVITY – EDGE COMPUTING



Going towards MEC, air quality + PIR + noise sensors and virtualization

CITYLAB FUTURE: TOWARDS A SMART INFRASTRUCTURE

SMART CITY SENSORS – MULTI-RADIO CONNECTIVITY – EDGE COMPUTING

- NIC switch
  - replace ath10k gradually with ath9k
- MEC
  - Implement edge orchestration framework
- Virtualization
  - allocation of radios instead of full nodes, with sharing and load management
- Antwerp-Ghent connectivity
  - GRE tunnel
- Cameras
  - Strongly considering introducing cameras for AI research ground truth, work in progress for privacy
- Sensors:
  - considering deployment of air quality – PIR – noise sensors with NFV-like control, TBC
- Licensed technologies:
  - considering the introduction of licensed technologies, with portable testbed and considering industry partnerships

embracing a better life