Performing cognitive radio experiments on the

LOG-a-TEC sensor network testbed

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CREW Training Days

15 January 2014

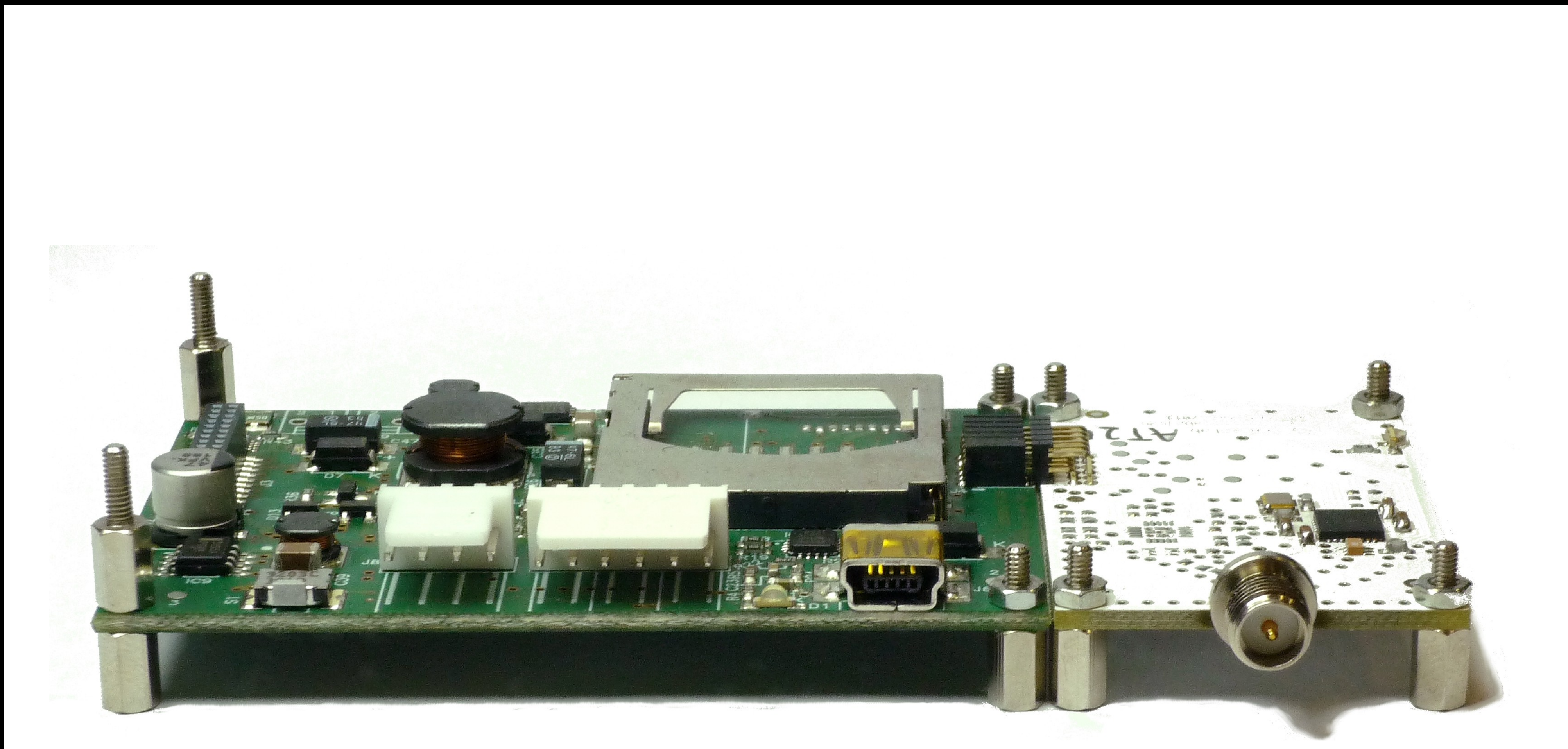
The research leading to these results has received funding from the European Union's Seventh Framework Programme (FP7/2007-2013) under grant agreement n°258301 (CREW project).

Overview

- Overview of the VESNA platform
  - hardware
  - software stack
- Overview of Log-a-tec testbed
  - how remote access works
- Building a basic experiment with Python
  - required software
  - step-by-step demonstration
- Conclusion and further references

VESNA

- “VErsatile platform for Sensor Network Applications”



VESNA

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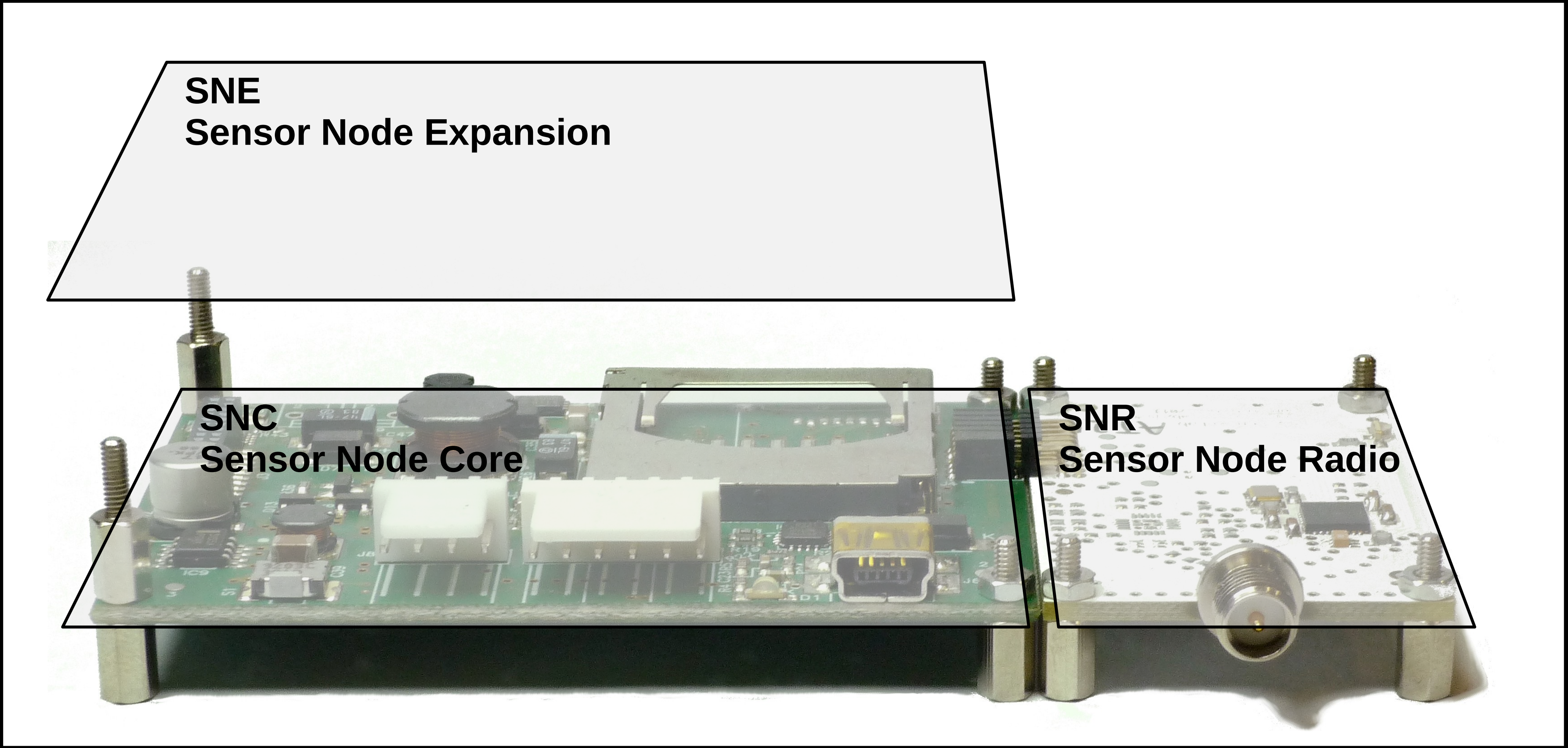
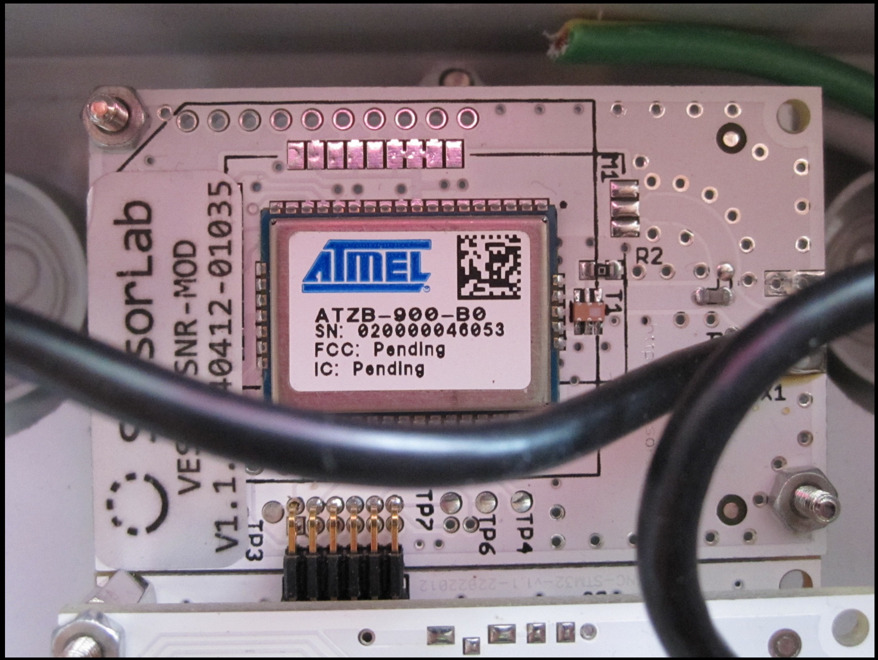


Sensor Node Core

- STM ARMv7 Cortex-M3
  - up to 72 MHz clock, 1 MB Flash, 96 kB RAM
- 3 x 1 MS/s ADC, w/ instrumental amplifier
- Non-volatile storage
  - 128 kB fast MRAM
  - SD or microSD
- Multi-purpose power supply
  - rechargeable, non-rechargeable battery, solar cell, external power
- USB 2.0, RS-232, I2C, SPI, UART, ...

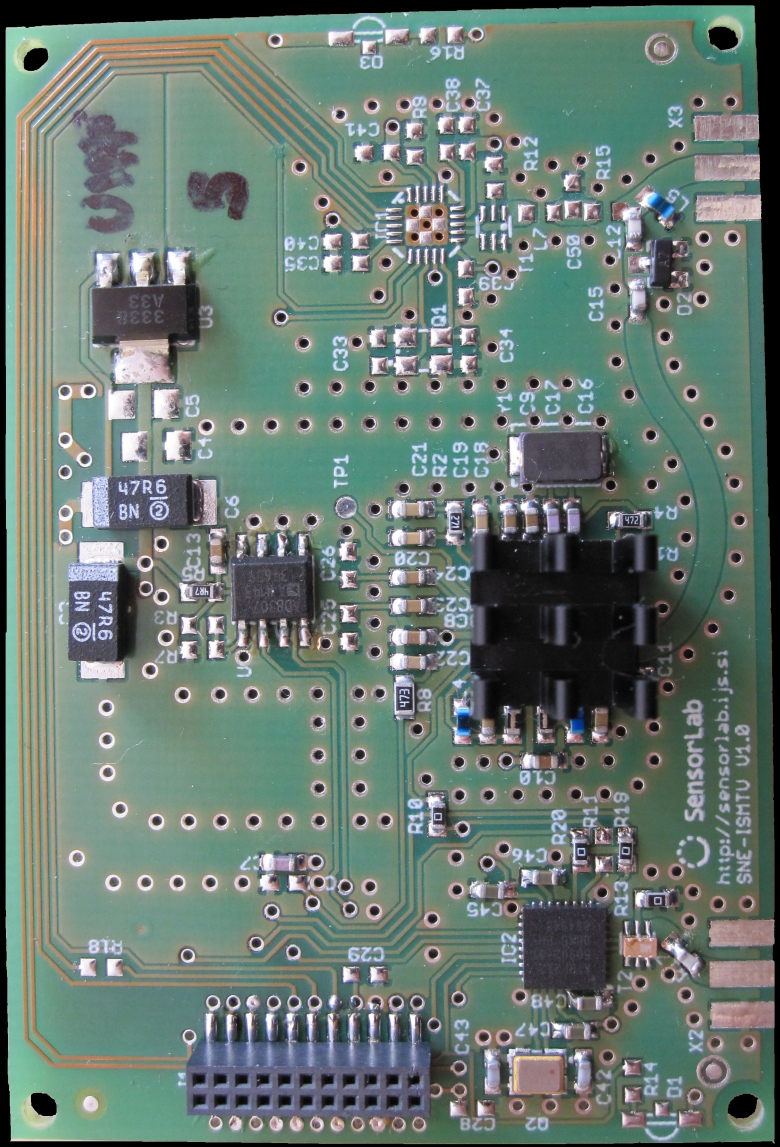
Sensor Node Radio

- Connect nodes into a wireless mesh network
  - 868 MHz European SRD band
  - 2.4 GHz ISM band
- IEEE 802.15.4
  - Atmel proprietary BitCloud / ZigBit / SerialNet
  - 6lowPAN
- Sensor node control and management



Sensor Node Expansion

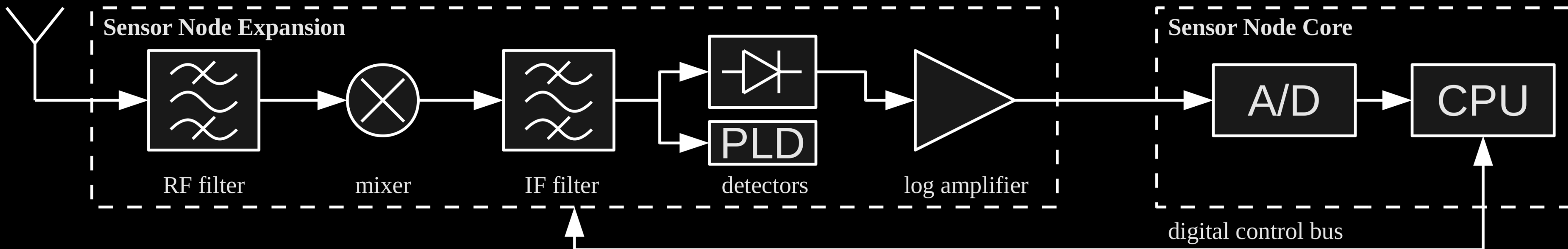
- SNE connector allows for application specific expansions
  - Data acquisition,
  - sensor interfaces,
  - wired/wireless communications,
  - extra power supply,
  - etc.

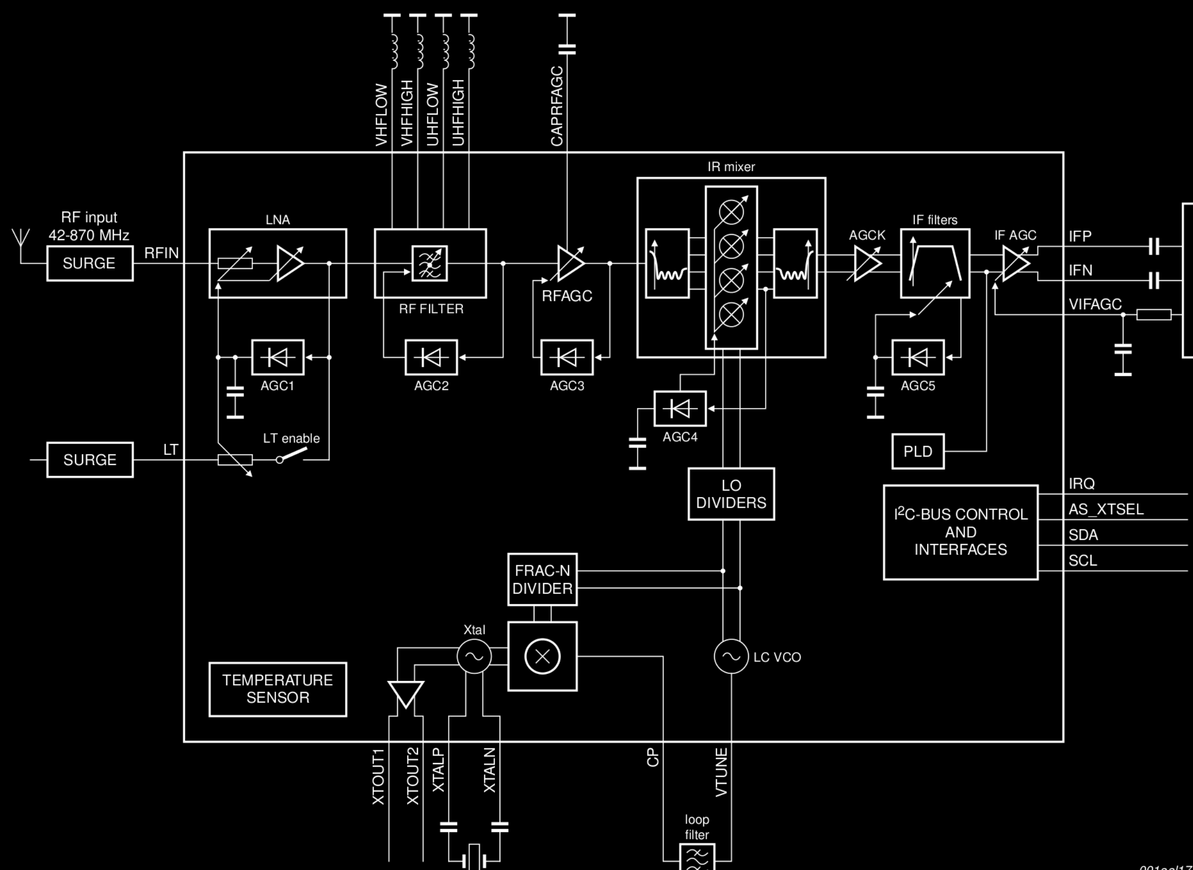


SNE-ISMTV

- Designed for spectrum sensing and cognitive radio applications
- Collection of radio-frequency hardware
  - UHF/VHF wide-band energy detection receiver
  - reconfigurable narrow-band sub-1 GHz transceiver
  - reconfigurable narrow-band 2.4 GHz transceiver
  - additional IEEE 802.15.4 radio (868 MHz)
- Independent of the testbed management network

SNE-ISMTV-UHF



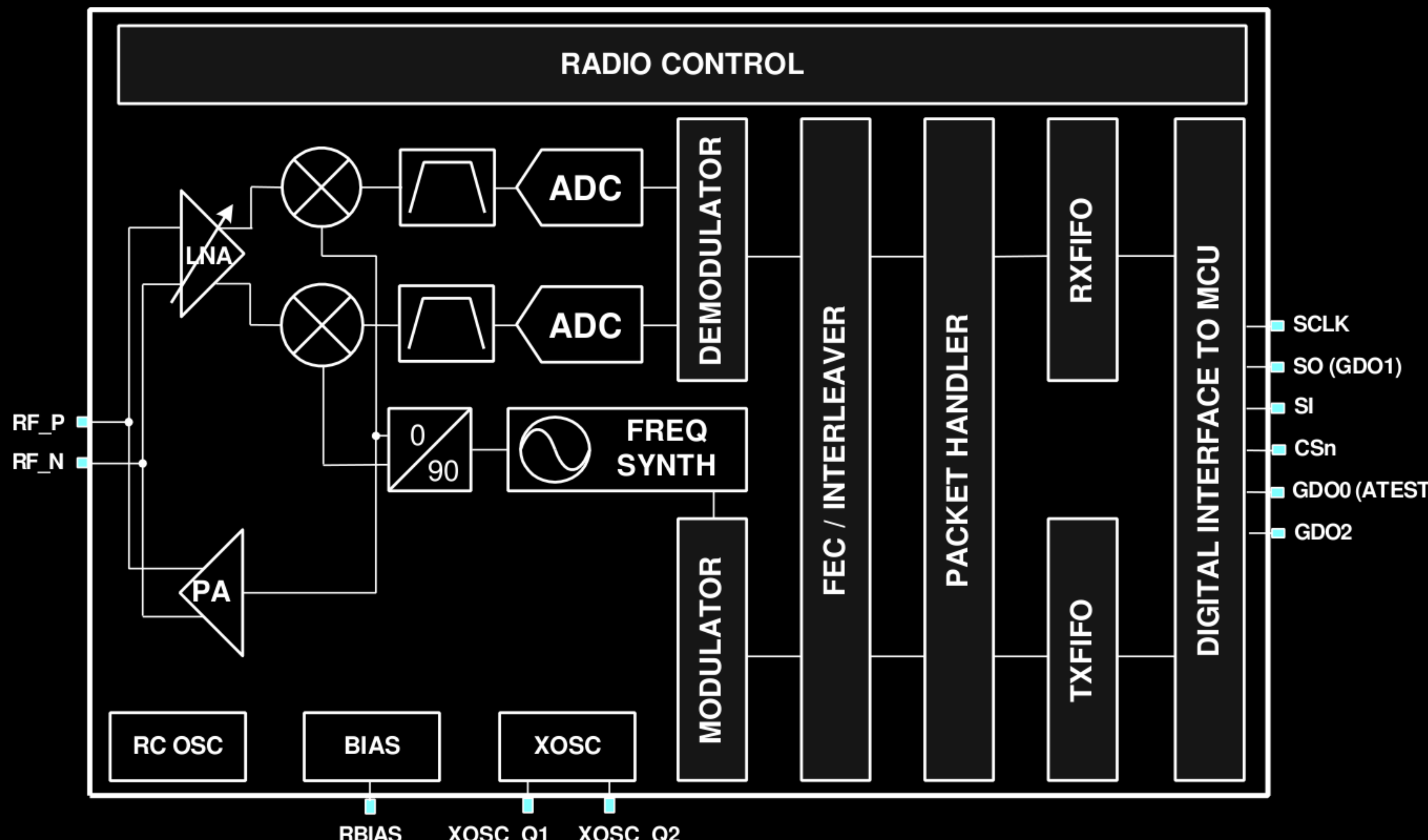


SNE-ISMTV-UHF

- Based on **NXP TDA18219** silicon tuner

• Frequency range	470 - 862 MHz
• Bandwidth	1.7 MHz, 8 MHz
• Power detector uncertainty	1.8 dBm
• Detector read-out time	50 ms / 1 µs
• Average noise level	-169 dBm (@ 1Hz)
• Dynamic range	60 dBm

Texas Instruments CCxxxx



SNE-ISMTV-TI868, TI2400

- Integrated tuner, modem, packet handling hardware
- Reception and transmission
  - FSK, MSK, ASK modulations
  - packet-based or continuous
- Energy detection measurements
- Test signal generation, interferer simulation
- Experiments with packet-based protocols

SNE-ISMTV-TI868

- Based on **TI CC1101** sub-1 GHz transceiver

- Frequency range 780 - 871 MHz
  - 868 MHz European SRD band
  - upper channels of the UHF band
- Bandwidth 50, 100, 200 kHz
- Power detector resolution 0.5 dBm
- Average noise level -150 dBm (@ 1Hz)
- Maximum TX power 12 dBm

SNE-ISMTV-TI24

- Based on **TI CC2500** 2.4 GHz transceiver

- Frequency range 2.40 – 2.48 GHz
  - 2.4 GHz ISM band
- Bandwidth 200, 400 kHz
- Power detector resolution 0.5 dBm
- Average noise level -159 dBm (@ 1Hz)
- Maximum TX power 0 dBm

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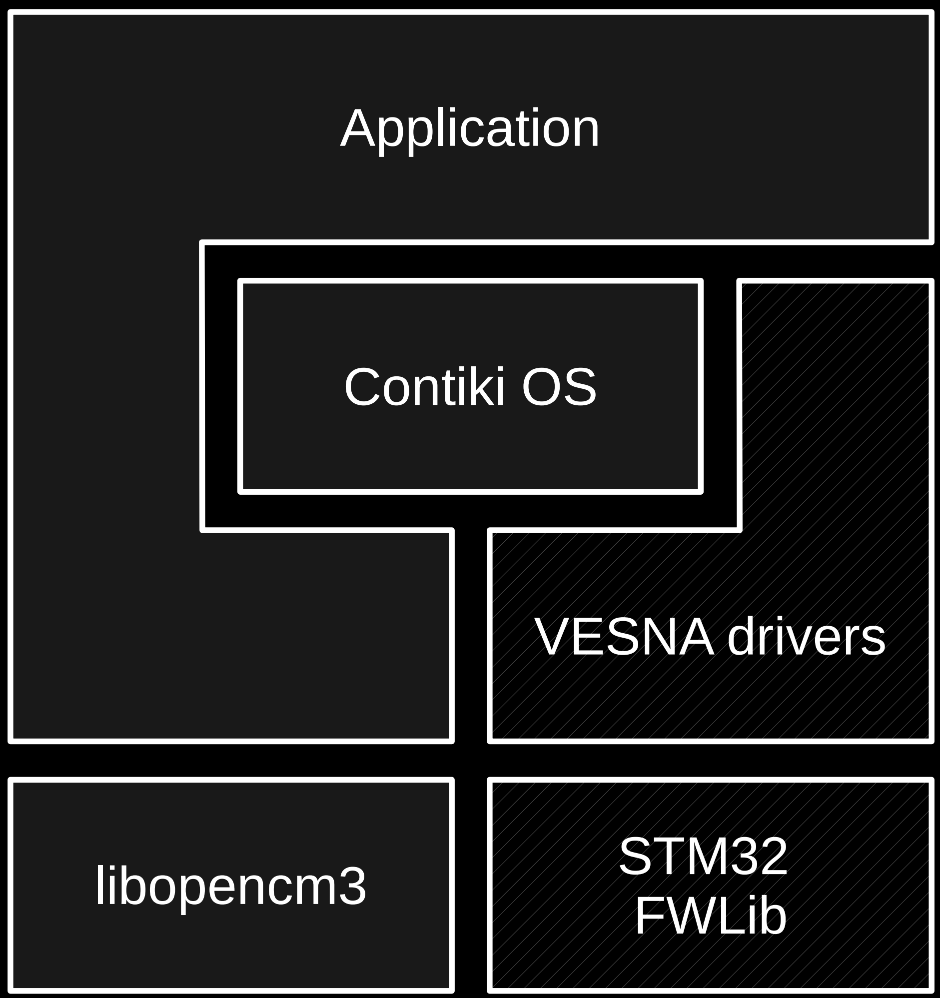
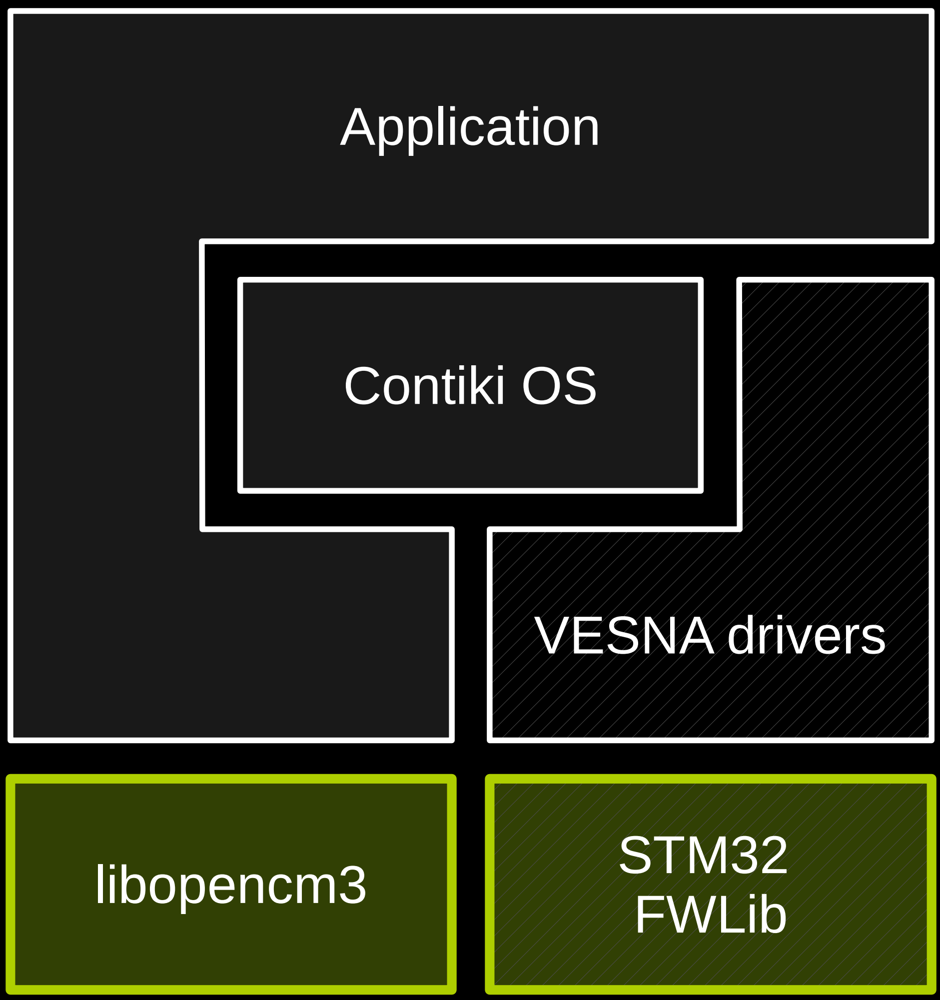
VESNA software stack

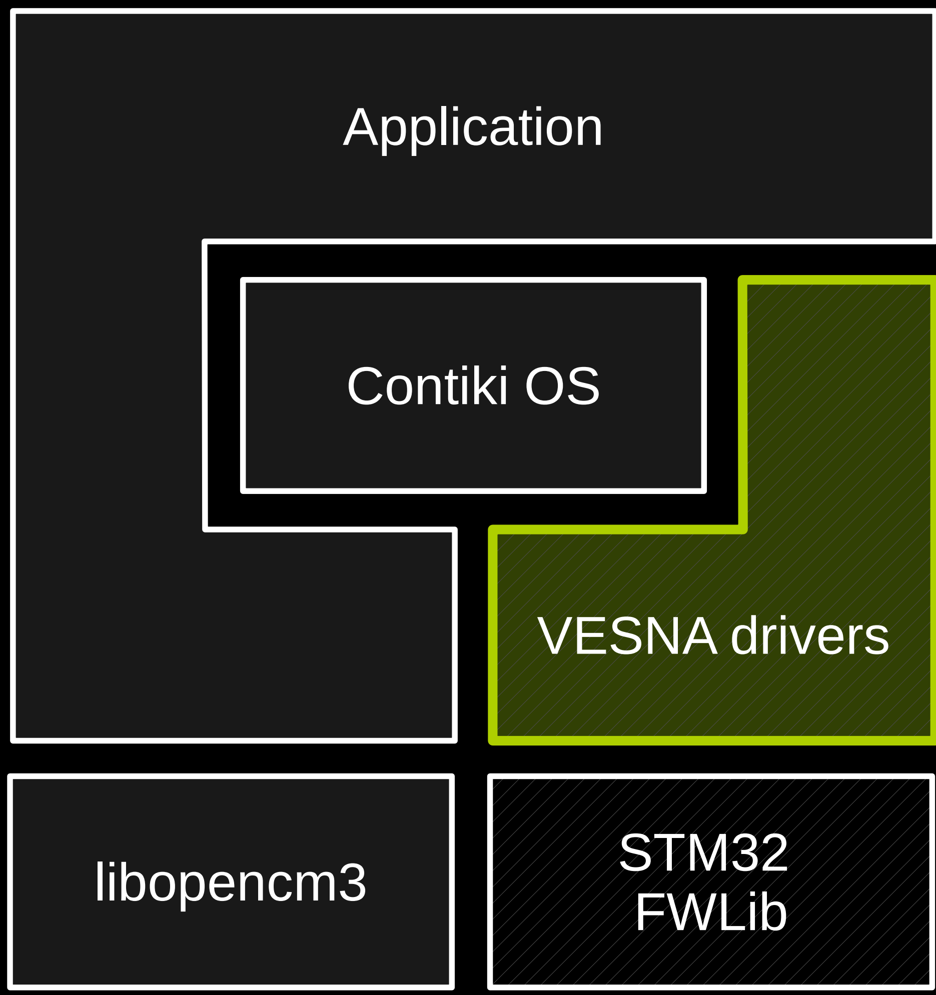


VESNA software stack



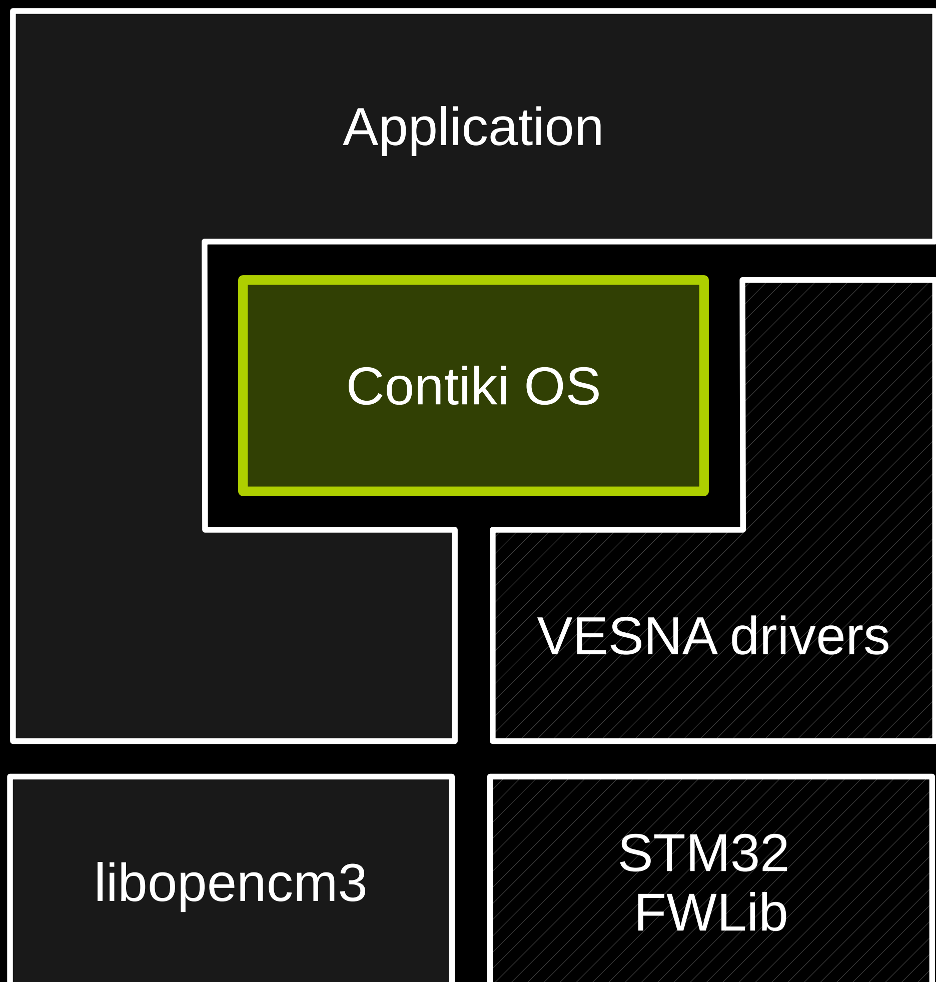
- Hardware register definitions
- Abstraction of MCU peripherals
- **libopencm3**
  - LGPL
- **STM32 FWLib**
  - open source, proprietary license

VESNA software stack



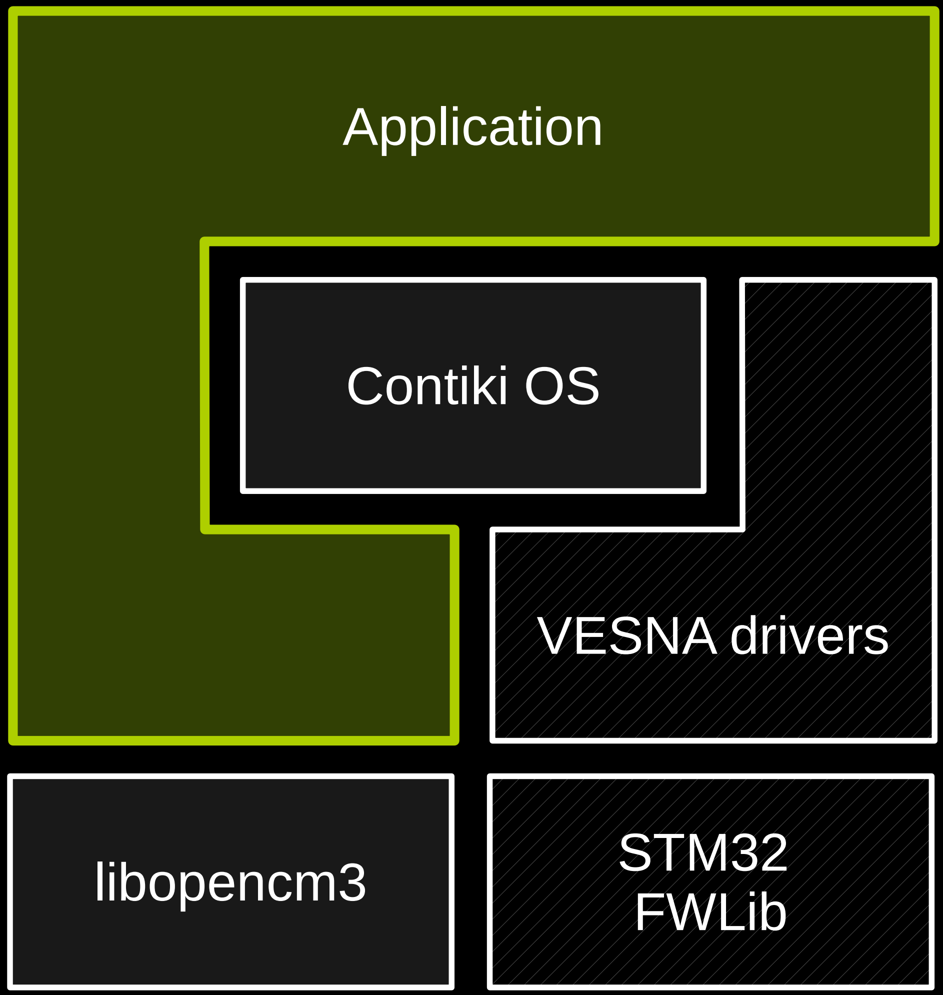
- High level abstraction
- Standard C library support
  - #include <stdio.h>
- Device drivers
  - storage, sensors, radio, SNE support, ...
- Networking
- Convenience functions

VESNA software stack



- Embedded operating system
- Cooperative multi-tasking
- Networking
  - IPv4, IPv6, 6lowPAN, RPL, CoAP
- Permissive BSD-style license

VESNA software stack



- Application can
  - Run on Contiki OS
  - Run without OS using VESNA drivers
  - Run without OS using libopencm3
- Depends on licensing, complexity

Overview

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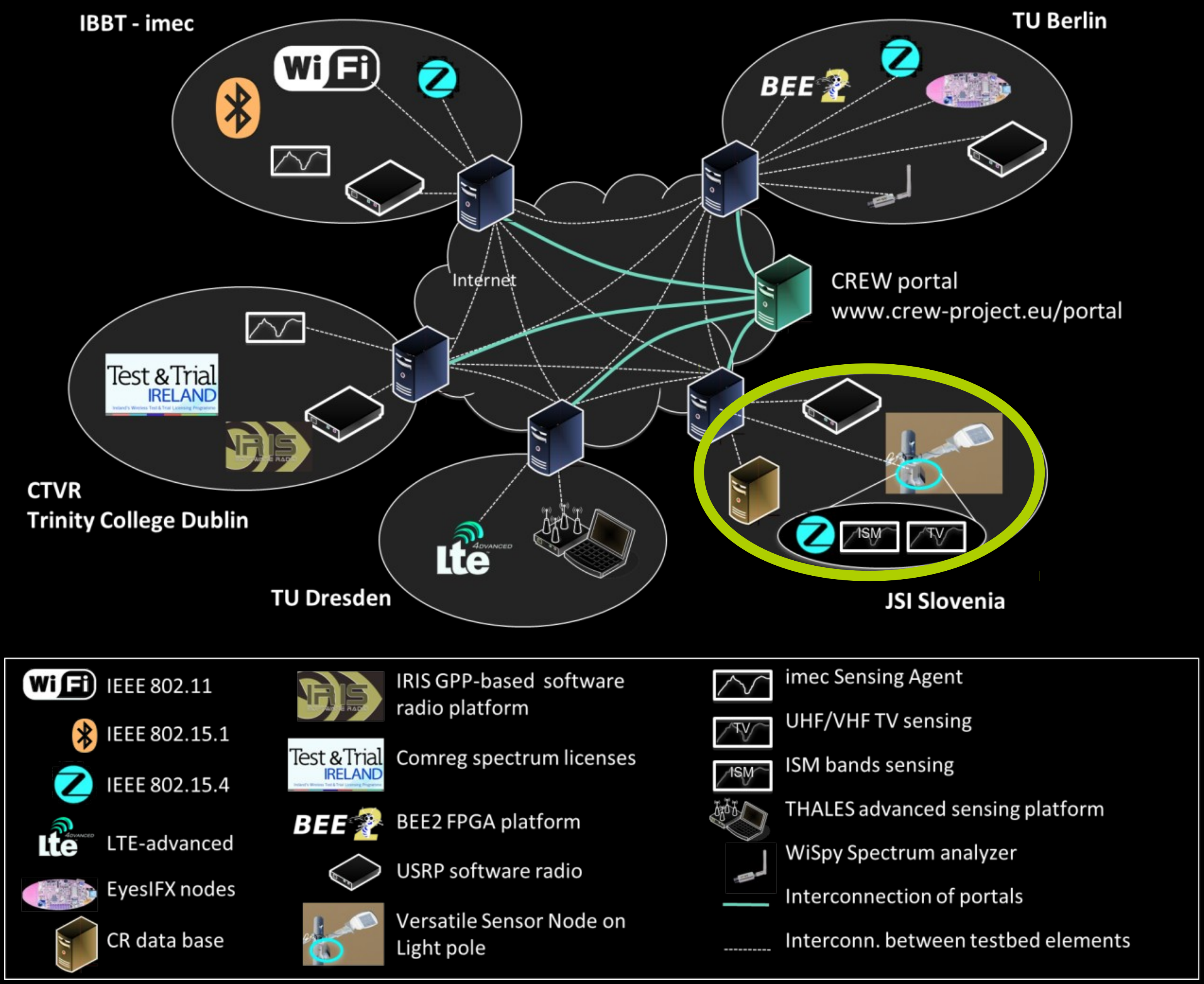
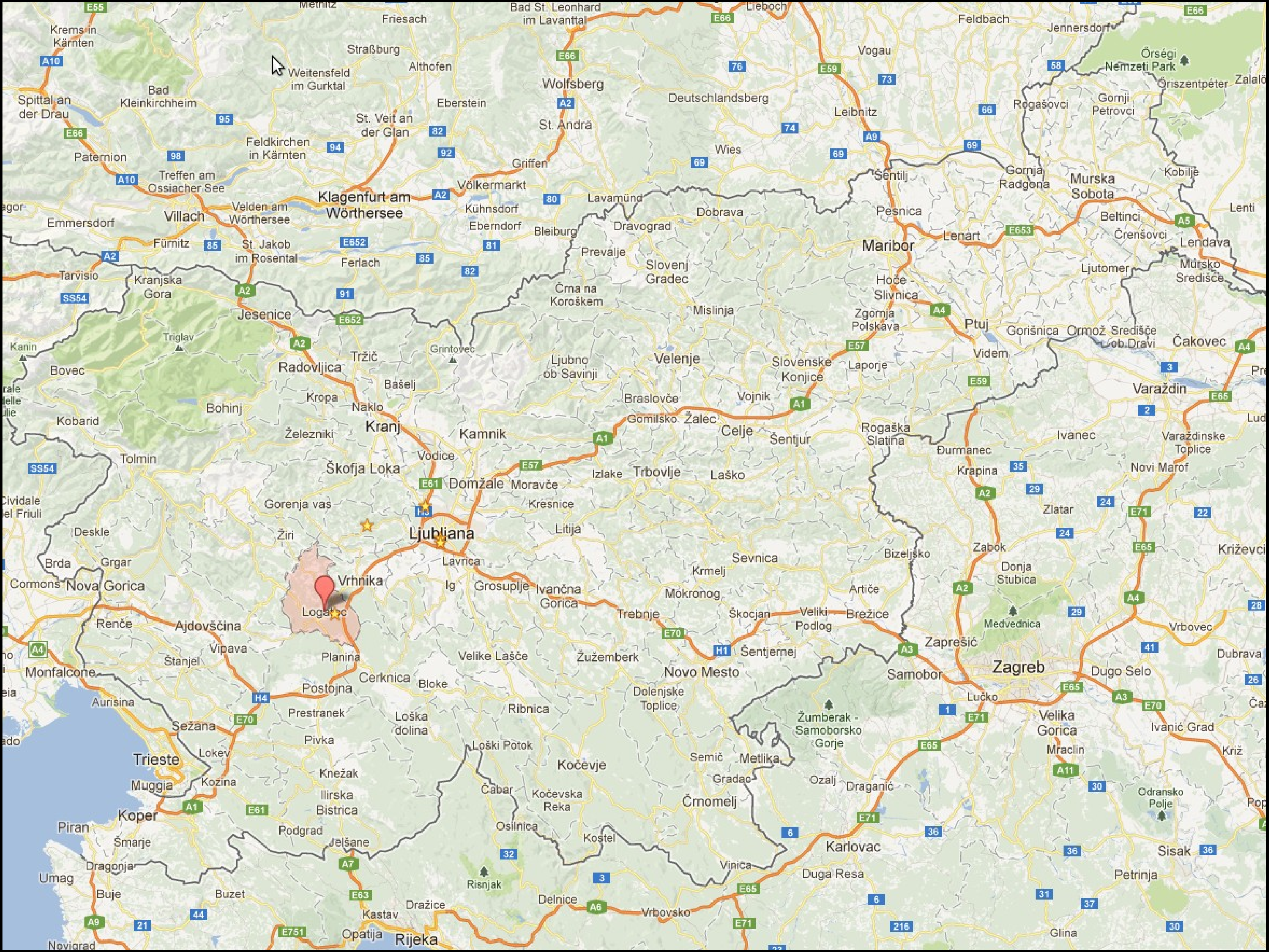
Log-a-tec testbed



Log-a-tec testbed

- 51 VESNA wireless sensor nodes
  - mostly mounted on street lights, some on rooftops
  - 32 x SNE-ISMTV-TI24
  - 11 x SNE-ISMTV-TI868
  - 5 x SNE-ISMTV-UHF w/ low-gain antenna
  - 3 x SNE-ISMTV-UHF w/ high-gain antenna
- Two clusters in municipality of Logatec
  - industrial zone (23 nodes)
  - city center (28 nodes)


Krems in Kärnten
Friesach
Bad St. Leonhard im Lavanttal
Lieboch
Feldbach
Jennersdorf
Straßburg
Weitensfeld im Gurktal
Althofen
Wolfsberg
Vogau
Örségi Nemzeti Park
Őriszentpéter
Bad Kleinkirchheim
Spittal an der Drau
Eberstein
Deutschlandsberg
Leibnitz
Rogašovci
Gornji Petrovci
St. Veit an der Glan
St. Andrä
Paternion
Feldkirchen in Kärnten
Wies
Griffen
Šentilj
Gornja Radgona
Murska Sobota
Kobilje
Treffen am Ossiacher See
Völkermarkt
Lavamünd
Klagenfurt am Wörthersee
Kühnsdorf
Dobrava
Pesnica
Lenti
Villach
Velden am Wörthersee
Eberndorf
Dravograd
Beltinci
Emmersdorf
Bleiburg
Lenart
Črenšovci
Fürnitz
St. Jakob im Rosental
Ferlach
Prevalje
Maribor
Lendava
Tarvisio
Kranjska Gora
Slovenj Gradec
Ljutomer
Mursko Središće
Hoče - Slivnica
Črna na Koroškem
Jesenice
Mislinja
Zgornja Polskava
Ptuj
Gorišnica
Ormož
Središće ob Dravi
Čakovec
Kanin
Triglav
Tržič
Grintovec
Velenje
Videm
Bovec
Radovljica
Ljubno ob Savinji
Slovenske Konjice
Laporje
Varaždin
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Kropa
Naklo
Braslovče
Vojnik
Bohinj
Kobarid
Gomilsko
Žalec
Celje
Rogaška Slatina
Kranj
Kamnik
Železniki
Šentjur
Ivanec
Varaždinske Toplice
Tolmin
Vodice
Đurmanec
Škofja Loka
Izlake
Trbovlje
Laško
Krapina
Novi Marof
Domžale
Moravče
Cividale del Friuli
Gorenja vas
Kresnice
Zlatar
Deskle
Litija
Ljubljana
Žiri
Zabok
Križevci
Lavrica
Sevnica
Bizeljsko
Brda
Grgar
Krmelj
Donja Stubica
Cormons
Nova Gorica
Vrhnika
Ig
Grosuplje
Ivančna Gorica
Mokronog
Artiče
Medvednica
Logatec
Renče
Ajdovščina
Trebnje
Škocjan
Veliki Podlog
Brežice
Vrbovec
Zaprešić
Vipava
Planina
Velike Lašče
Žužemberk
Šentjernej
Dubrava
Monfalcone
Štanjel
Cerknica
Novo Mesto
Samobor
Zagreb
Dugo Selo
Postojna
Bloke
Dolenjske Toplice
Aurisina
Prestranek
Ribnica
Loška dolina
Lučko
Velika Gorica
Sežana
Žumberak - Samoborsko Gorje
Ivanić Grad
Pivka
Loški Potok
Trieste
Lokev
Semič
Metlika
Mraclin
Kočevje
Knežak
Kriż
Muggia
Kozina
Ilirska Bistrica
Gradac
Ozalj
Draganić
Čabar
Kočevska Reka
Odransko Polje
Koper
Črnomelj
Piran
Podgrad
Osilnica
Šmarje
Jelšane
Kostel
Karlovac
Sisak
Dragonja
Risnjak
Vinica
Umag
Duga Resa
Petrinja
Buje
Buzet
Delnice
Kastav
Dražice
Vrbovsko
Novigrad
Opatija
Rijeka
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A9
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A2
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E652
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81
SS54
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C-047
C-044
C-028
C-033
C-048
C-046
C-042
C-052
C-031
C-029
C-030


HITACHI


C-009
C-009

Vilharjeva ulica
Miklavžev vrtec
Pavšičeva ulica
Tilova ulica
Pavšičeva ulica
Kraigherjeva ulica
Kidričeva ulica
Partizanska ulica
Partizanska ulica
Knjižnica Logatec
Republika Slovenija upravna enota Logatec
Kamnoseštvo Oblak Peter Oblak sp
Tržaška cesta
Tržaška cesta
Tržaška cesta
Logatec
Logatec
Vodovodna cesta
Čevica
Čevica
Čevica
PGD
Tovarniška cesta
Cankarjeva cesta
Cankarjeva cesta
Pošta
Guesthouse Jersin
Notranjska cesta
Notranjska cesta
Poštni Vrt
Poštni Vrt
Zdravstveni dom Logatec
Glasbena šola Logatec
Šolska pot
Grič
Osnovna šola 8 talcev Logatec
Dimnikarstvo Kraner Vincencij Kralj sp
Nova vas
Nova vas
Prešernova ulica
Gregorčičeva ulica
Levstikova ulica
Krpanova ulica
Potoška cesta
Potoška cesta
Brod
Brod
Brod
Šušteršič krovstvo
Cesta talcev
Cesta talcev
Cesta talcev
"Strojno ključavničarstvo in izdelovanje kovinskih Predmetov" Zvonimir Maček sp
BS
408
409
102
100 m

Vrhnika-Logatec
Tržaška cesta
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408
Termoflor
GRC Zapolje
IOC Zapolje III
IOC Zapolje IV
IOC Zapolje I
Industrijsko obrtna cona Zapolje
IKSPORT doo
Za železnico
Stara cesta
TV 18
TV 19
TV 20
868 7
868 8
868 9
868 10
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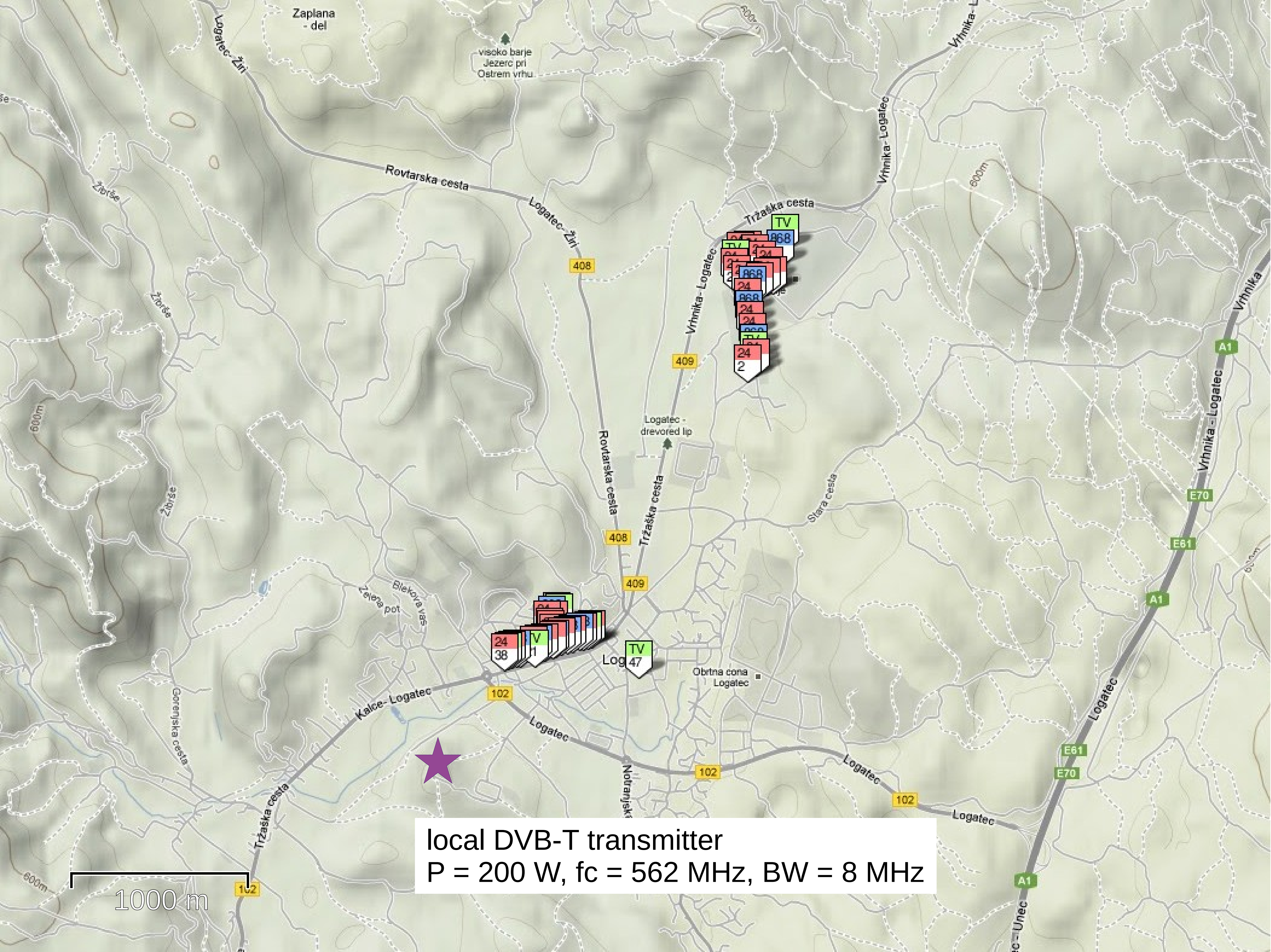
24 26
200 m


local DVB-T transmitter
P = 200 W, fc = 562 MHz, BW = 8 MHz
1000 m
Zaplana - del
visoko barje Jezerc pri Ostrem vrhu
Rovtarska cesta
Logatec-Žiri
Tržaška cesta
Vrhnika-Logatec
Logatec - drevored lip
Kalce-Logatec
Obrtna cona Logatec
Logatec
Notranjska
Gorenjska cesta
Stara cesta
Žibrše
Blekova vas
Zelena pot
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E61
E70
600m
TV
868
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38
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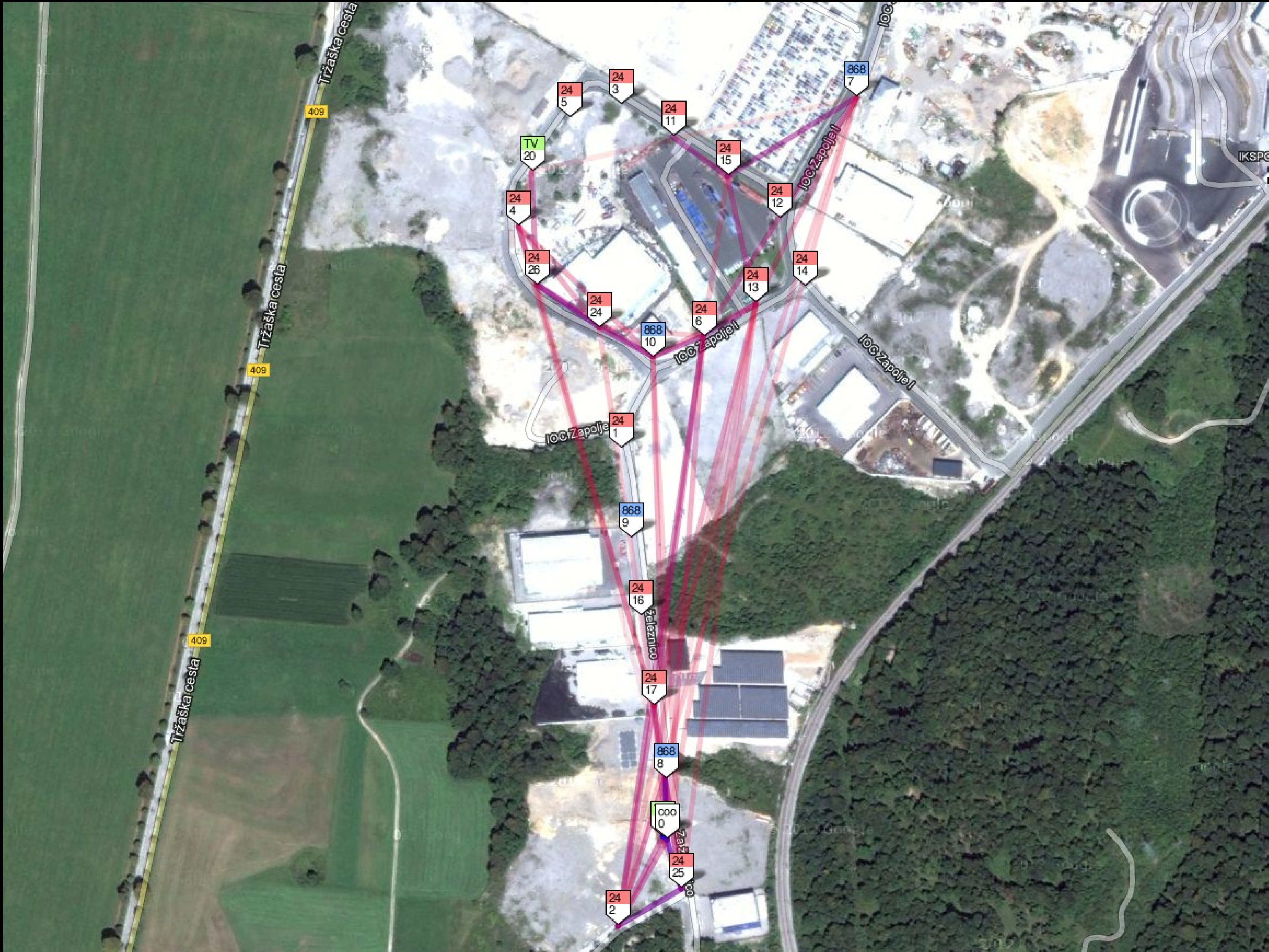
2



Tržaška cesta
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IOC Zapolje I
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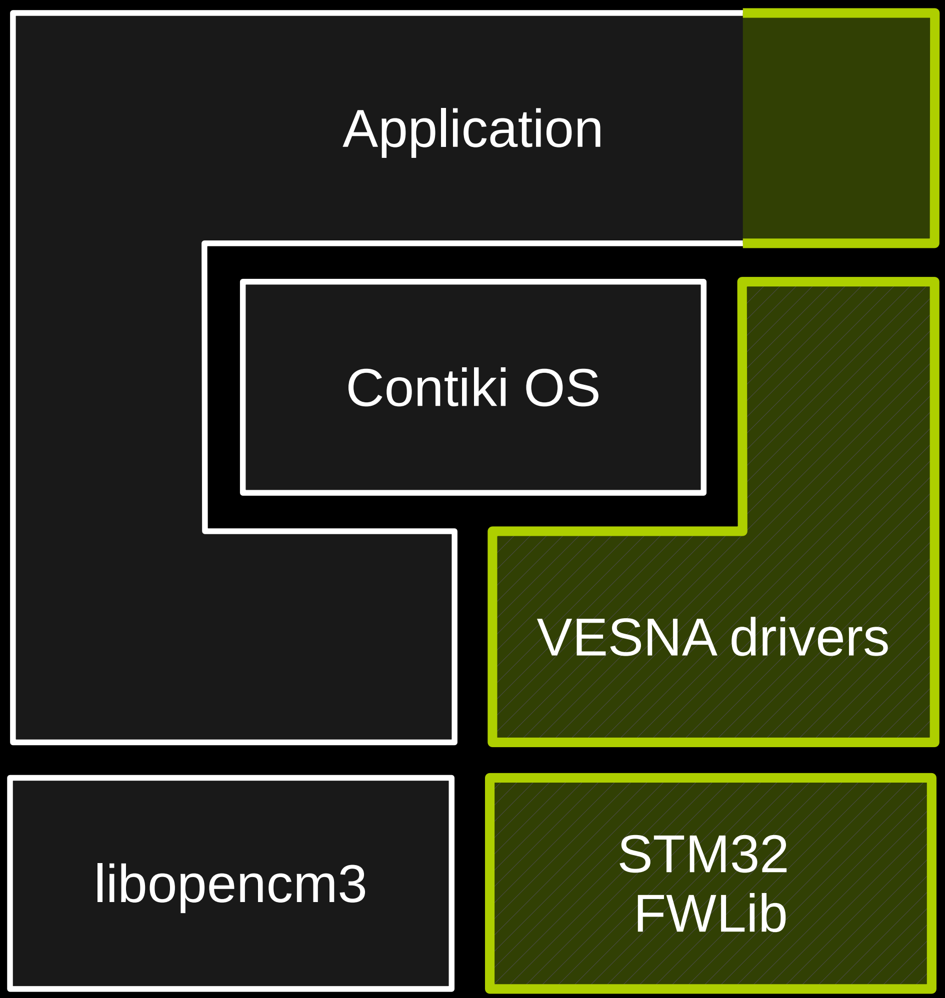
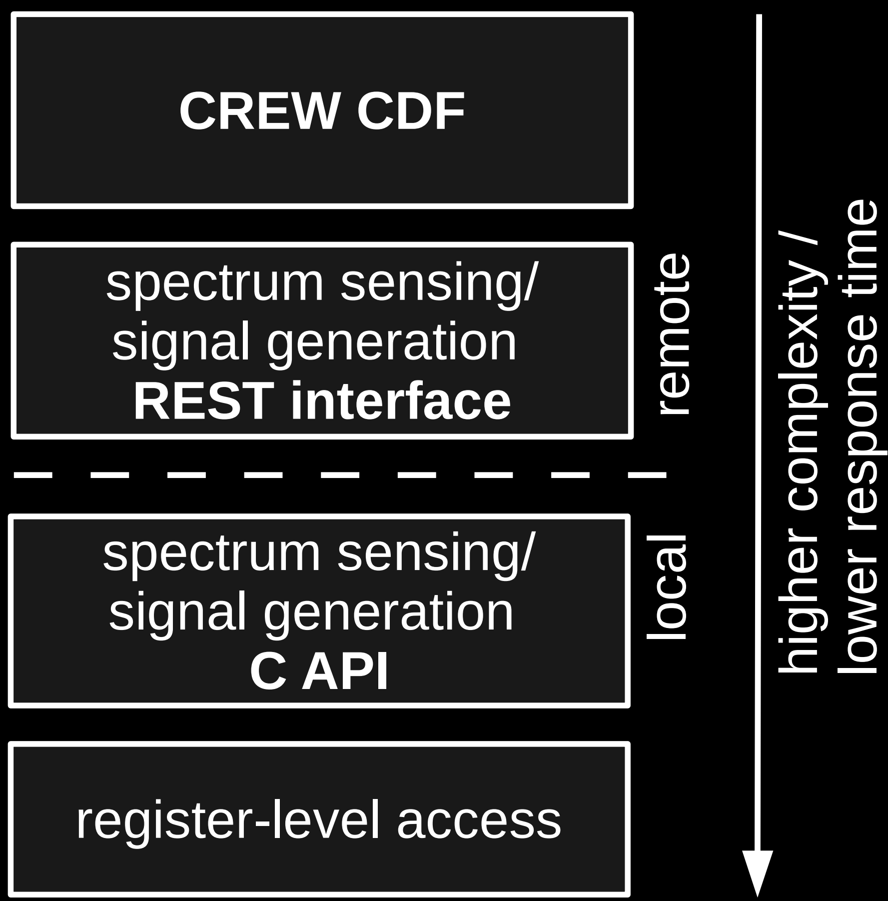
Log-a-tec VESNA application

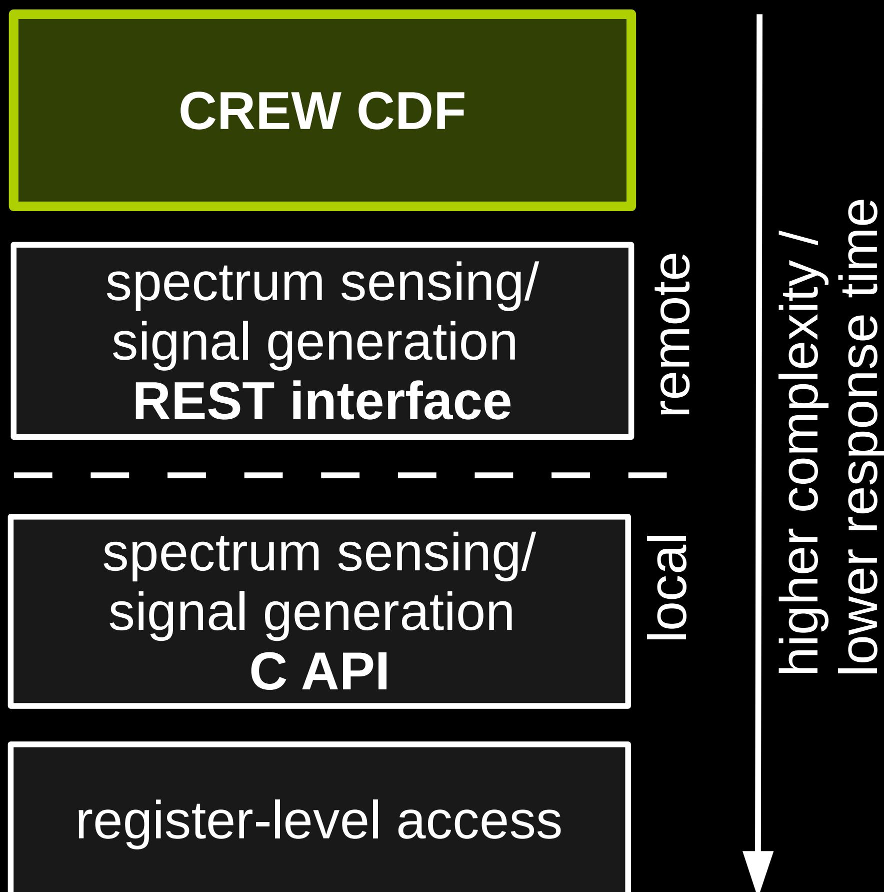


- REST interface for remote experiments
- Native code for local experiments
- Test bed Management
  - OTA reprogramming
  - monitoring

Controlling the SNE-ISMTV

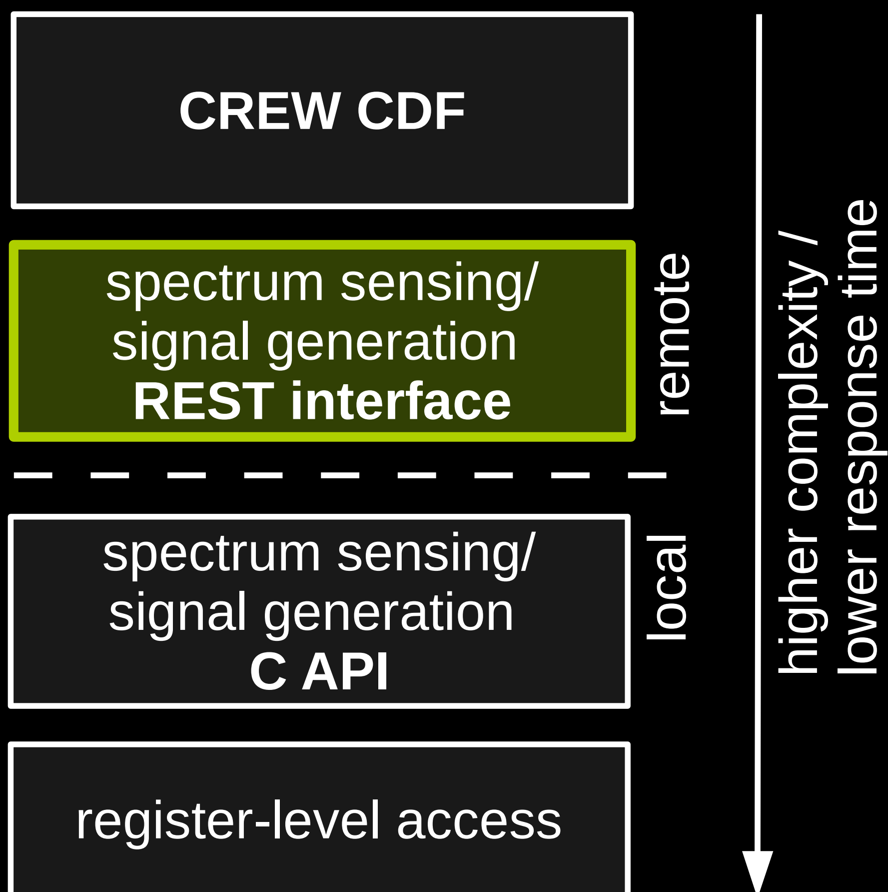


Controlling the SNE-ISMTV



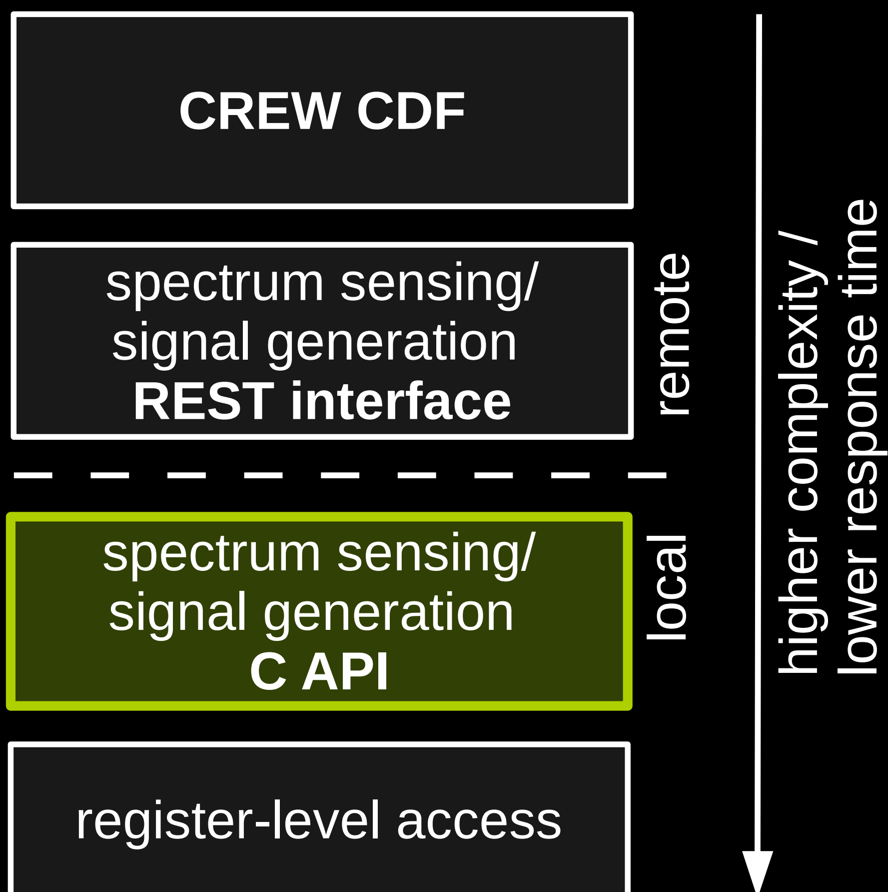
- Spectrum sensing setup
- Meta-data in XML
  - hardware setup,
  - frequency band,
  - date, author, ...
- Data in CSV or MatLab format
  - spectrum sensing results
  - (time, frequency, power)

Controlling the SNE-ISMTV



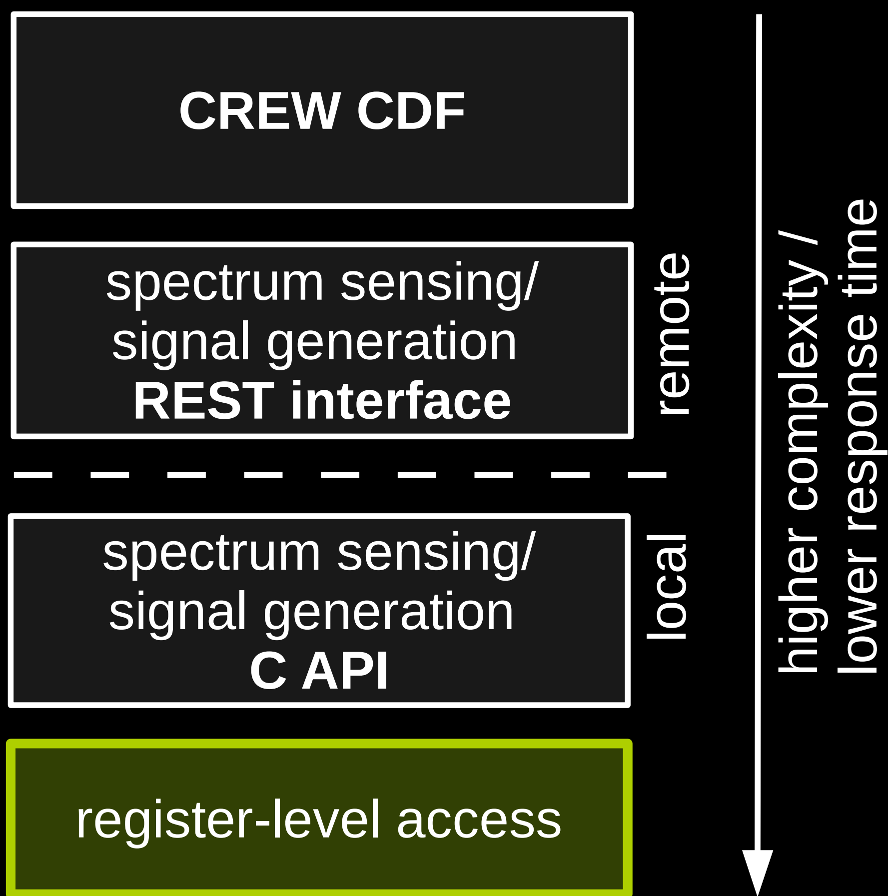
- High-level abstraction of hardware
- Spectrum sensing
  - sense band *B* at time *T* using device *D* and method *M*
- Signal generation
  - transmit at frequency *F* and power *P*

Controlling the SNE-ISMTV



- Direct access to the API from native code
- Removes network round-trips
  - lower latency
  - data processing on the sensor node
  - no interference on 868 MHz band

Controlling the SNE-ISMTV



- Directly programming radio hardware
  - CC1101, CC2500, TDA18219
- Exploit full capabilities of available hardware
- Time consuming testing required

REST interface

- Each node has a 16-bit network address
- Nodes act as a servers on the network
  - expose various resources
  - resources addressed by name
    e.g. “**sensing/deviceStatus**”
  - GET and/or POST method
- Experimenter's computer acts as a client
  - issues requests to nodes and receives responses
  - **only one request at a time**

REST interface

- **GET method**
  - retrieve data from the node
    (e.g. measurement results, status messages, ...)
  - doesn't change state

GET sensing/slotInformation?id=1

method — resource name — arguments

REST interface

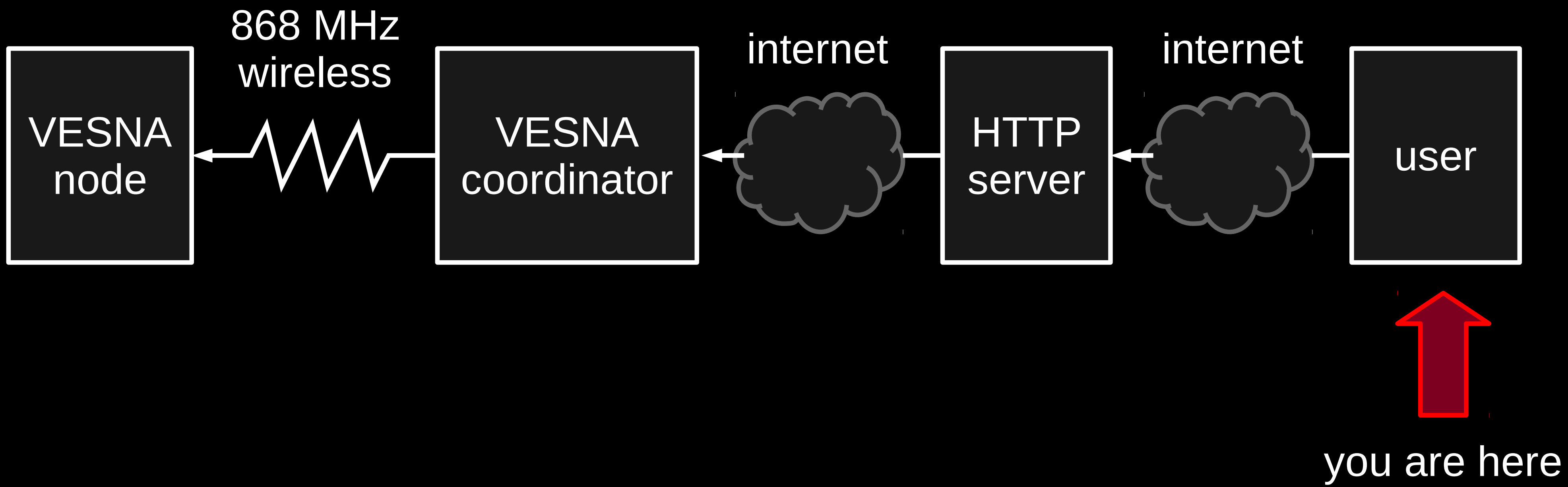
- **POST method**
  - send data to the node
    (e.g. configuration parameters, trigger events, ...)
  - changes state

method | resource name | arguments

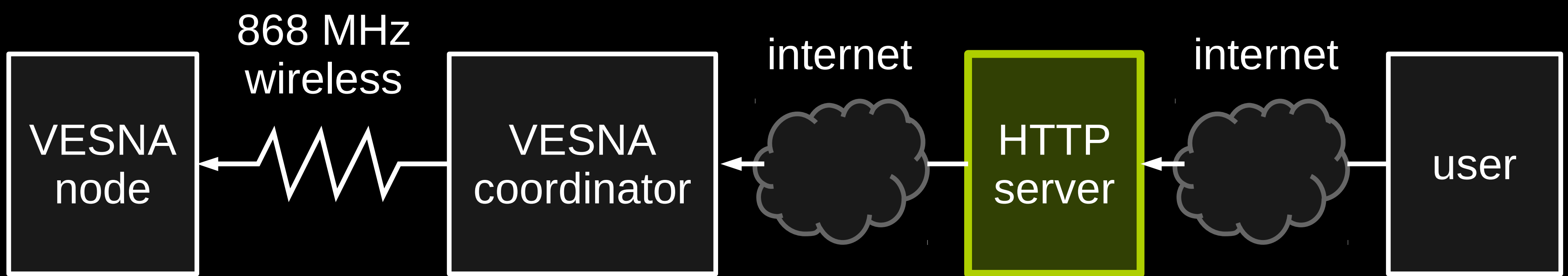
```
POST generator/program?

in 1 sec for 10 sec with dev 0
conf 0 channel  0 power 0
```

data

Network overview

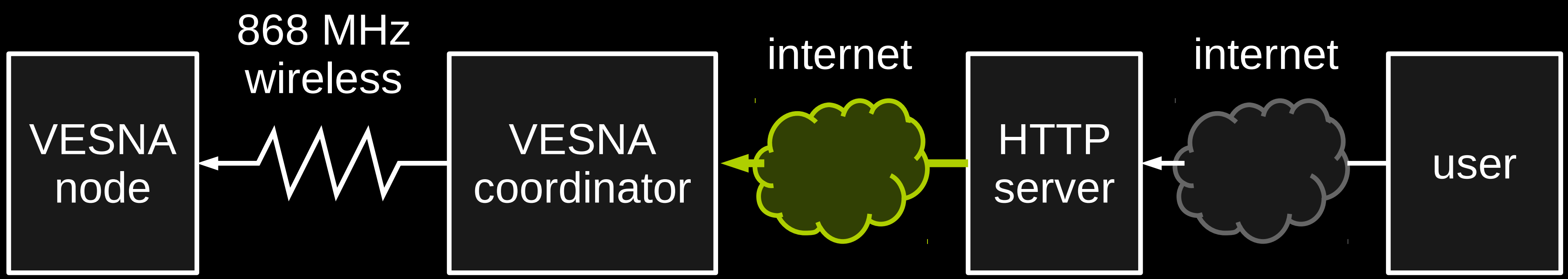


Log-a-tec web portal

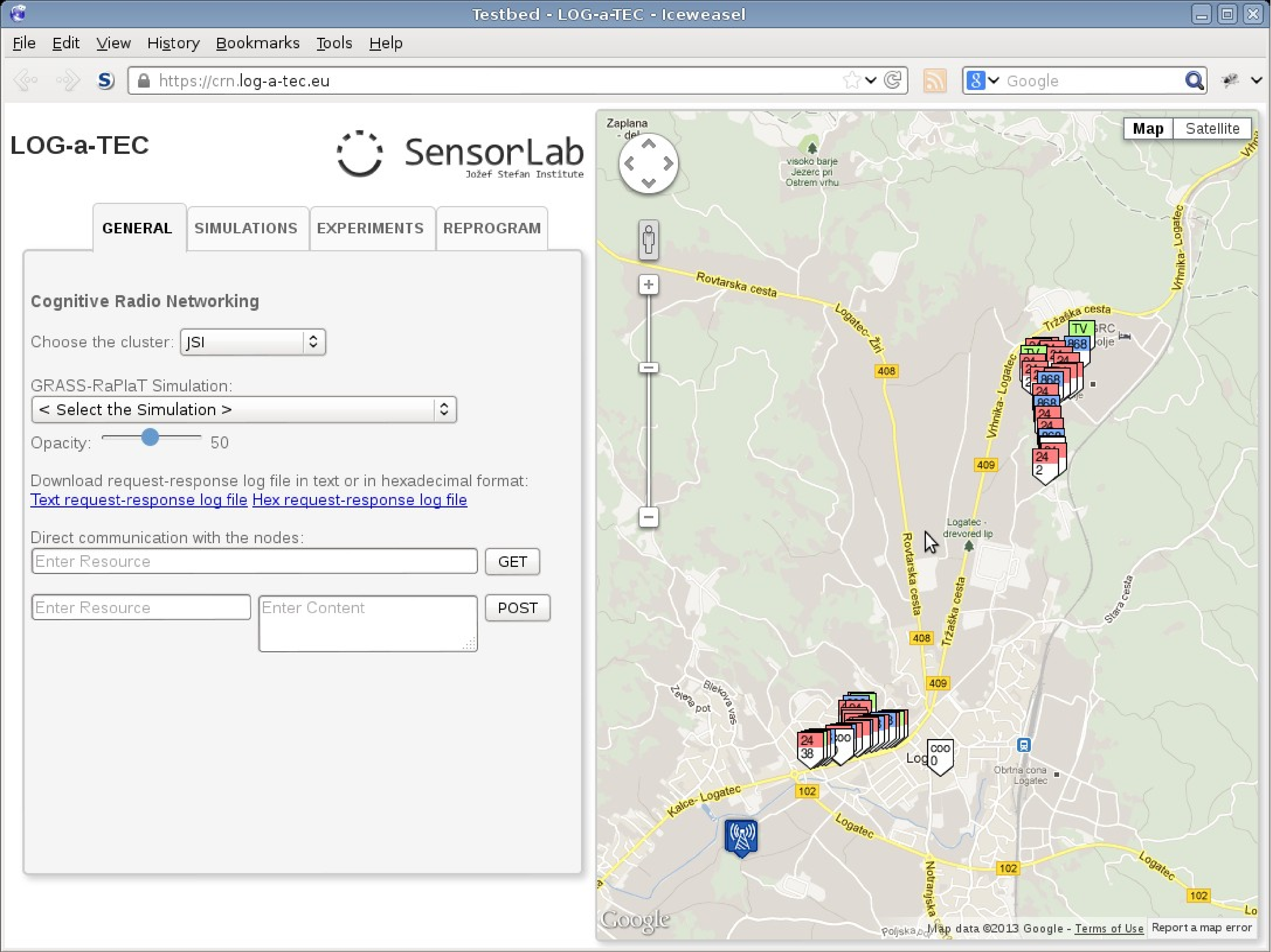


- Web portal
  - map with locations of VESNA nodes
  - manually issue GET and POST requests
  - simulations with GRASS-RaPlaT
- HTTP API end-point
  - programmatic access to VESNA REST interface

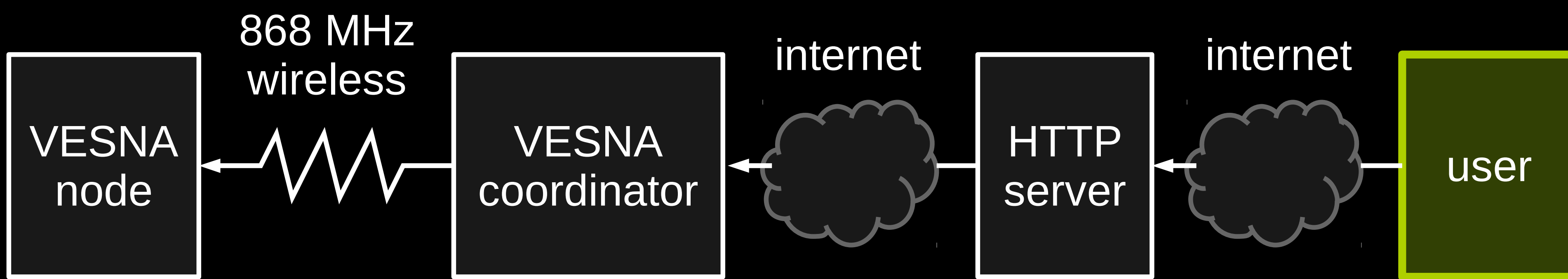
Accessing the coordinator



- HTTP server forwards GET & POST requests to coordinator
- Simple HTTP-like (LCSP) protocol over SSL tunnel
- One coordinator per cluster
  - coordinator identified by cluster ID


Testbed - LOG-a-TEC - Iceweasel
File Edit View History Bookmarks Tools Help
https://crn.log-a-tec.eu
Google
LOG-a-TEC
SensorLab
Jožef Stefan Institute
GENERAL
SIMULATIONS
EXPERIMENTS
REPROGRAM
Cognitive Radio Networking
Choose the cluster: JSI
GRASS-RaPlaT Simulation:
< Select the Simulation >
Opacity: 50
Download request-response log file in text or in hexadecimal format:
Text request-response log file Hex request-response log file
Direct communication with the nodes:
Enter Resource
GET
Enter Resource
Enter Content
POST
Map
Satellite
Zaplana
visoko barje Jezerc pri Ostrem vrhu
Rovtarska cesta
Logatec - Žiri
408
Tržaška cesta
Vrhnika - Logatec
409
Logatec - drevored lip
Rovtarska cesta
Stara cesta
Zelena pot
Blekova vas
Kalce - Logatec
102
Logatec
Obrtna cona Logatec
Notranjska
Map data ©2013 Google - Terms of Use
Report a map error

Python libraries



- `https://crn.log-a-tec.eu/communicator?cluster=10001&method=get&resource=hello`

- We provide a Python module to communicate with VESNA nodes

Overview

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- ~~Overview of Log-a-tec testbed~~
  - ~~how remote access works~~
- Building a basic experiment with Python
  - required software
  - step-by-step demonstration
- Conclusion and further references

Installing Python libraries

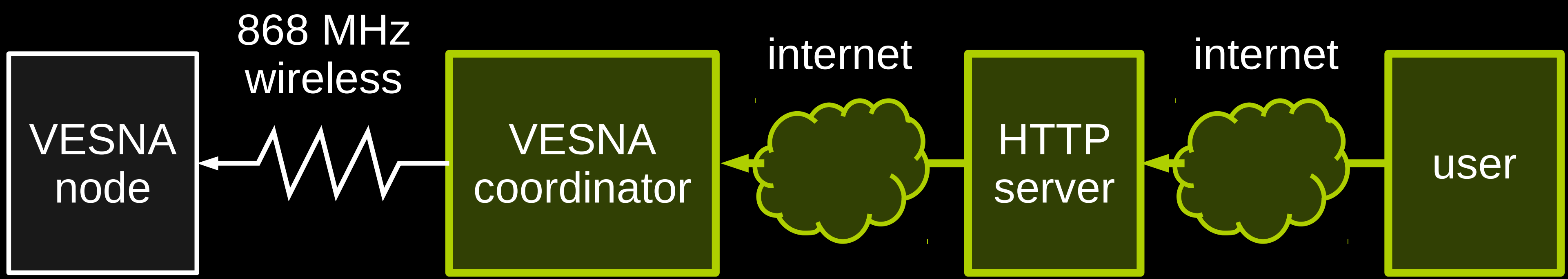
- set $**`PYTHONPATH`**
  - add to `~/.bashrc`:
    `export PYTHONPATH=~/local/lib/python`
- install vesna-alh-tools
  - `git clone https://github.com/sensorlab/vesna-alh-tools`
  - `$ python setup.py install --home=~/local`
- install vesna-spectrum-sensor
  - `git clone https://github.com/sensorlab/vesna-spectrum-sensor`
  - `$ cd python`
  - `$ python setup.py install --home=~/local`

Installing Python libraries

- set authentication details
  - create `~/.alhrc` with:

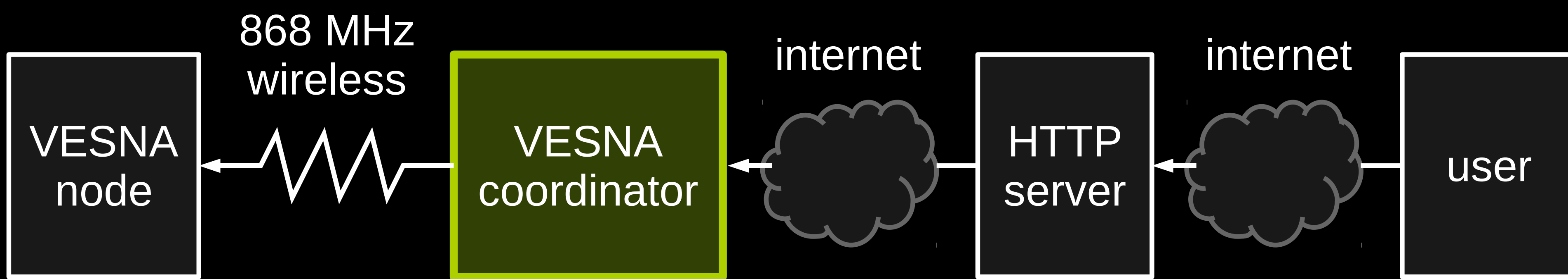
```
Host crn.log-a-tec.eu
User <username>
Password <password>
```

Demo



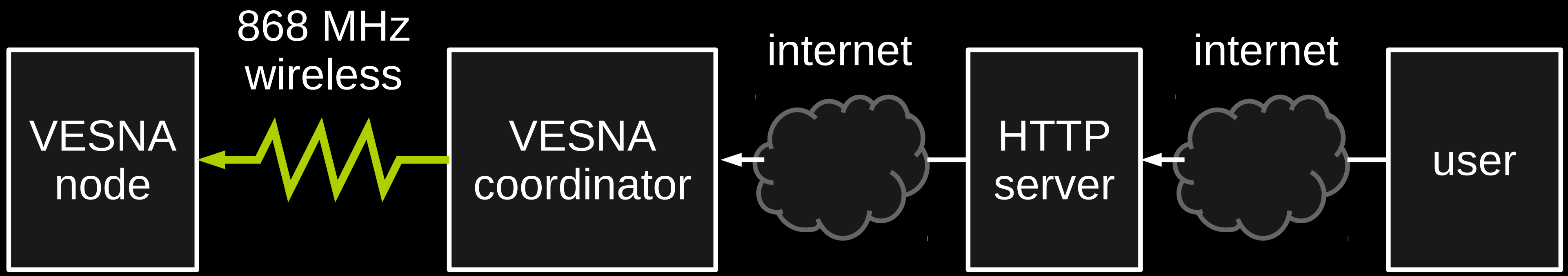
01-hello.py

Coordinator proxy



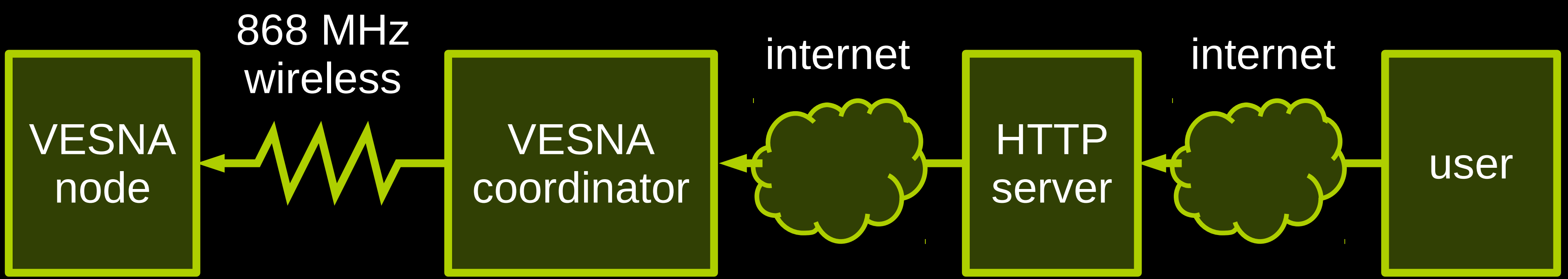
- Coordinator can proxy GET & POST requests to nodes over the management network
- GET nodes?19/sensor/mcuTemp
  issues
  GET sensor/mcuTemp
  to node 19

VESNA networking



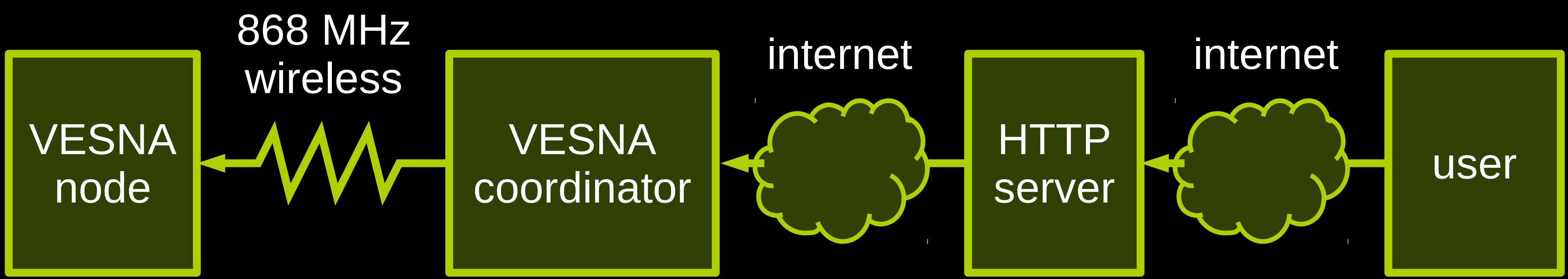
- management mesh network
- 868 MHz (European SRD band)
- typical bulk transfers ~ 300 bytes/s
- typical round-trip times ~ 600 ms
- HTTP-like protocol over IEEE 802.15.4 mesh

Demo



02-proxy.py

Demo



manage.py interactive session

Spectrum sensing interface

- Hardware abstraction
  - each node has one or more physical devices
  - each device has one or more configurations
- Device configuration determines
  - usable frequency range
  - channel number → central frequency relation
  - settle time required after channel change
  - channel bandwidth
  - averaging / post processing parameters (if any)

Demo

03-spectrum-sensing-devices.py

Spectrum sensing interface

- class **SpectrumSensor**
  - wrapper around **ALHProxy** for convenience methods
- class **ConfigList**
  - describes possible hardware device configurations
- class **SweepConfig**
  - describes frequency sweep
  - hardware configuration, start, stop, step frequency
- class **Sweep**
  - results of spectrum sensing sweep (timestamp, frequency, power)

Demo

04-single-sweeps.py

Signal generation interface

- Hardware abstraction
  - each node has one or more physical devices
  - each device has one or more configurations
- Device configuration determines
  - usable frequency, power range
  - channel number → central frequency relation
  - transmitted waveform

Signal generation interface

- class **SignalGenerator**
  - wrapper around **ALHProxy** for convenience methods
- class **ConfigList**
  - describes possible hardware device configurations
- class **TXConfig**
  - describes signal transmission
  - hardware configuration, frequency, power
- class **SignalGeneratorProgram**
  - Transmission configuration, start time, duration

Demo

05-signal-generation.py

Spectrum sensing interface

- class **SpectrumSensorProgram**
  - frequency sweep, start time, duration
  - SD card slot to write results to
- **SpectrumSensor.program()**
  - send task to the node
- **SpectrumSensor.is_complete()**
  - check if task complete
- **SpectrumSensor.retrieve()**
  - retrieve results from the SD card
- class **SpectrumSensorResult**
  - collection of sweeps

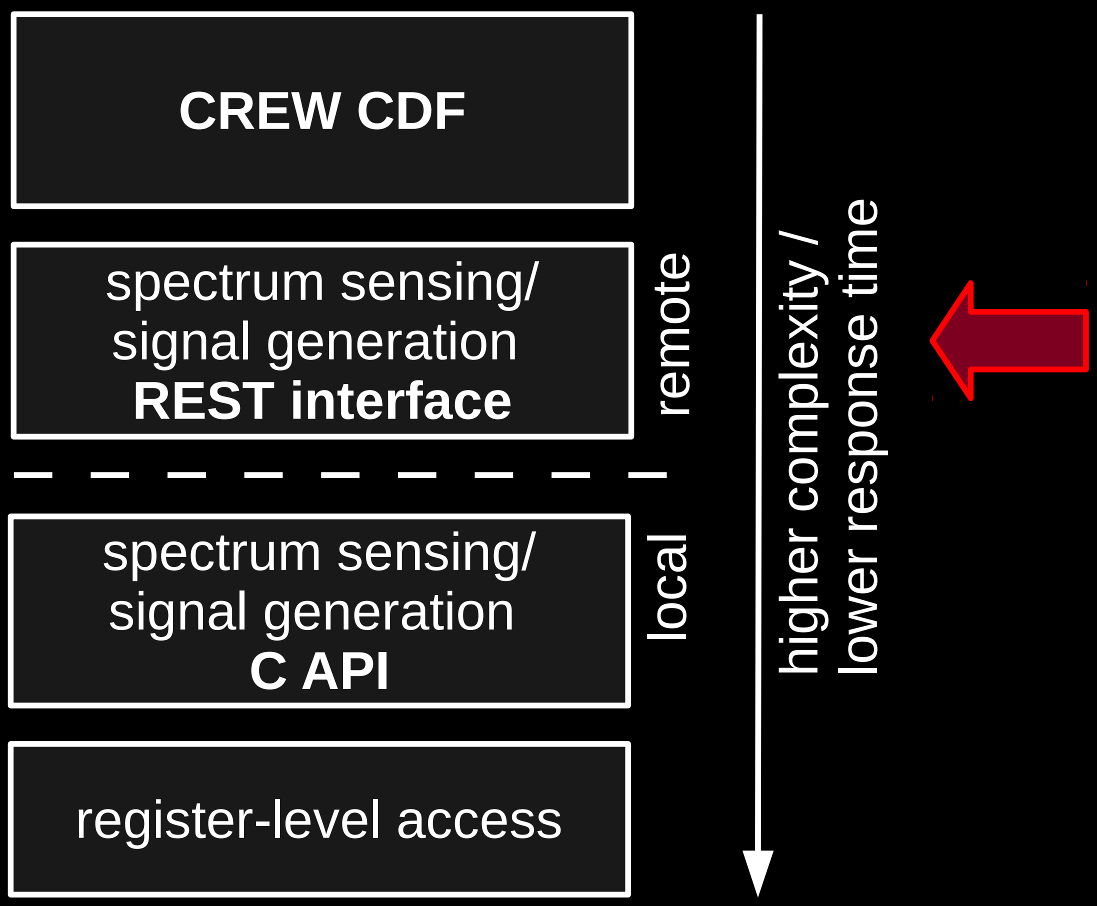
Demo

06-programmed-tasks.py

Overview

- ~~Overview of the VESNA platform~~
  - ~~hardware~~
  - ~~software stack~~
- ~~Overview of Log-a-tec testbed~~
  - ~~how remote access works~~
- ~~Building a basic experiment with Python~~
  - ~~required software~~
  - ~~step-by-step demonstration~~
- Conclusion and further references

Controlling the SNE-ISMTV



Developing VESNA applications

- Setup manual for Linux based development
  - `http://sensorlab.github.com/vesna-manual`
- Spectrum sensing and signal generation C API
  - see CREW deliverable 3.2
- Overview
  - add code to Logatec application
  - review & testing by JSI
  - over-the-air upload to nodes
  - communicate with the application over REST

Register level access

- See reference documentation for SNE-ISMTV receiver, transceiver ICs
  - TDA18219, CC1101, CC2500 datasheets
  - (SNE-ISMTV datasheet - WIP)
- read_reg(), write_reg(), interrupts
- Usually extensive testing required
  - tuners have bugs, unexpected features
  - for new RF front-end configurations calibration required if accurate RSSI measurements / TX power levels are desired

Questions?

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