CREW

SEVENTH FRAMEWORK PROGRAMME

FIRE Workshop

LOG-a-TEC testbed: Cognitive Radio Networking Experimentation Using the VESNA Platform

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ibbt imec ctvr TU berlin TECHNISCHE UNIVERSITÄT DRESDEN THALES EADS IJS

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Outline

- Introduction
- LOG-a-TEC/JSI testbeds
- VESNA sensor nodes
- ISM spectrum sensing
- TV spectrum sensing
- Testbed reconfiguration
- Radio planning

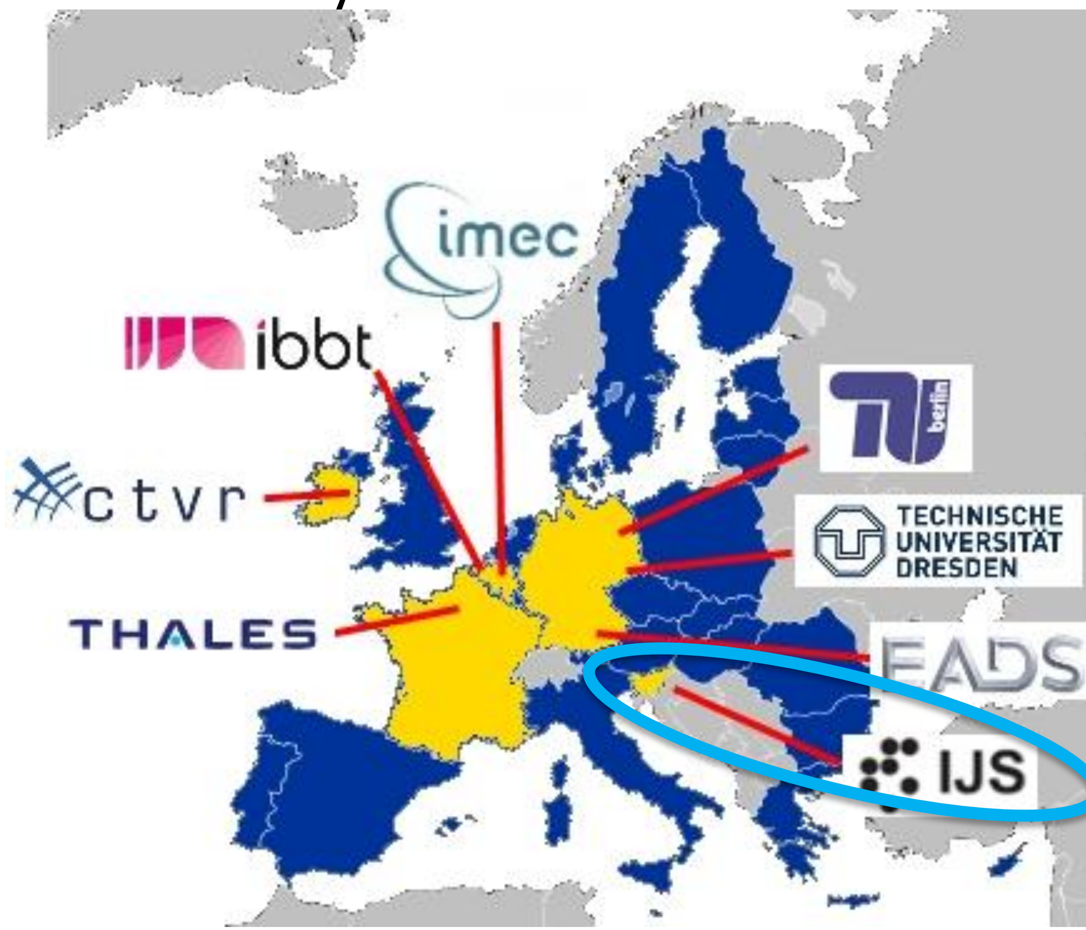
- CREW Open Call 2

- Cognitive networking
- Summary

Introduction

Who are we?

- Public research institute
- Based in Ljubljana, Slovenia
- Joined the CREW consortium in July 2011



Joseph/Jožef Stefan

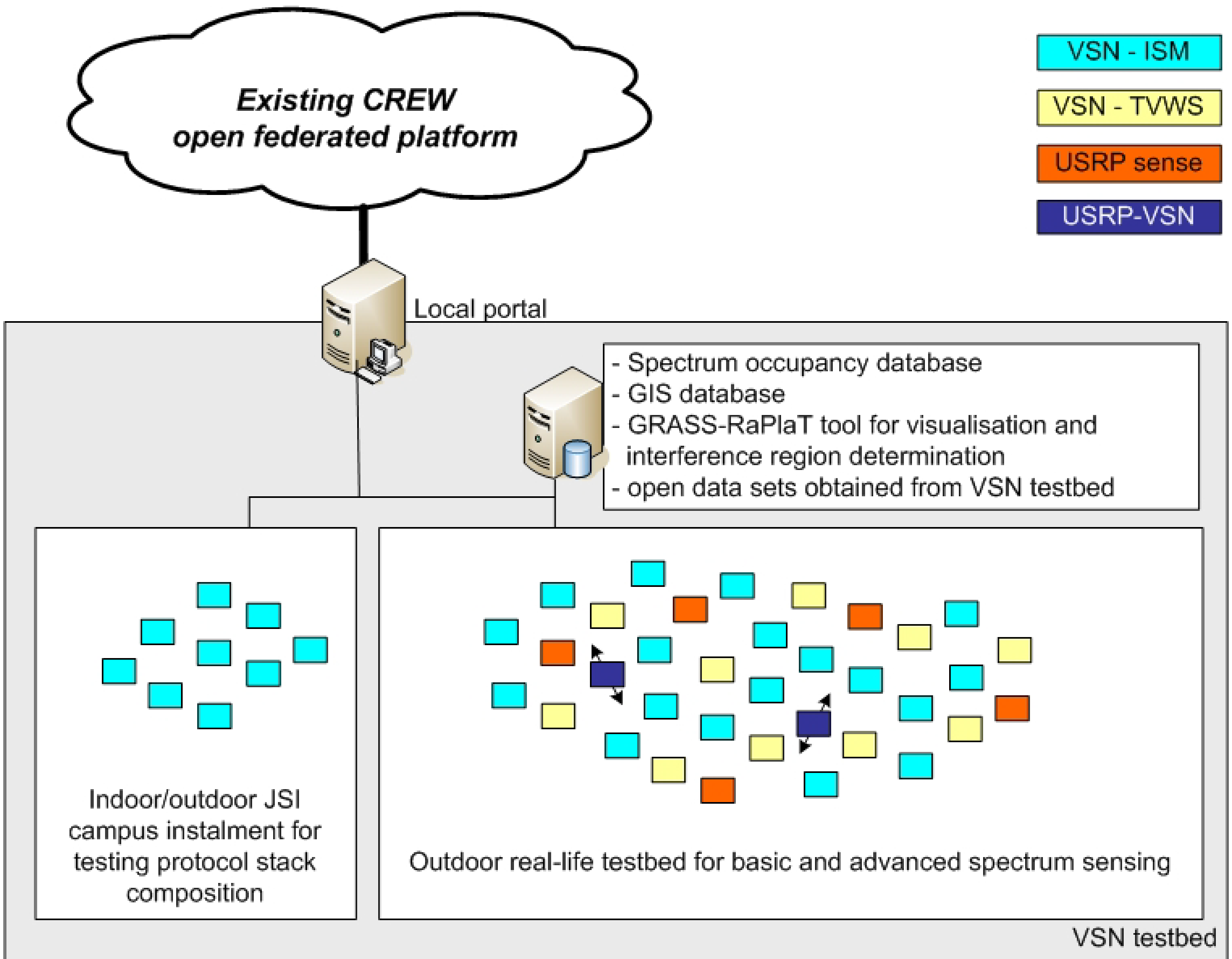
Jožef Stefan (1835-1893)	
Born	24 March 1835 St Peter (today in Klagenfurt am Wörthersee), Austrian Empire
Died	7 January 1893 (aged 57) Vienna, Austria-Hungary
Residence	Austria
Citizenship	Austrian Empire
Nationality	Slovene

Fields	Physicist
Institutions	University of Vienna
Alma mater	University of Vienna
Doctoral advisor	Andreas von Ettingshausen
Doctoral students	Ludwig Boltzmann Marian Smoluchowski Johann Josef Loschmidt
Known for	Stefan–Boltzmann law Stefan–Boltzmann constant σ Stefan problem Stefan's equation Stefan's formula Stefan flow Stefan number Maxwell–Stefan diffusion
Notable awards	Lieben Prize (1865)

JSI – Jožef Stefan Institute

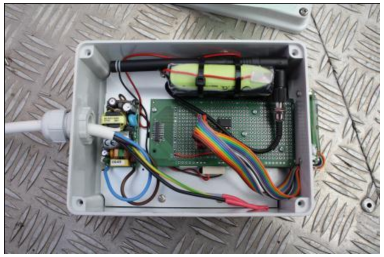
- **Jožef Stefan Institute, founded in 1949, is the leading Slovenian national research organization in the areas of natural sciences and technology:**
  - information and communication technologies & electronics
  - physics
  - chemistry, biochemistry & nanotechnology
  - environment
  - nuclear technology
- **> 600 researchers (total staff ~1000)**
- **> 200 on-going international projects including many funded in the frame of FP6 (5 still running), FP7 (~75) and EURATOM (24)**

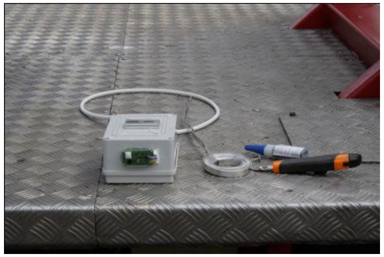
The conceptual VESNA-based testbeds



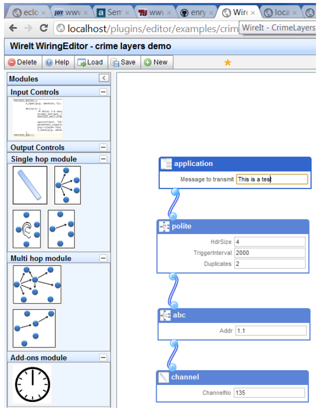
LOG-a-TEC/JSI testbeds

- **LOG-a-TEC site (50 VESNAs):**
  - outdoors site in the city of Logatec, Slovenia (installed on public infrastructure, e.g. light poles, etc.)
  - used for spectrum sensing and cognitive radio experiments



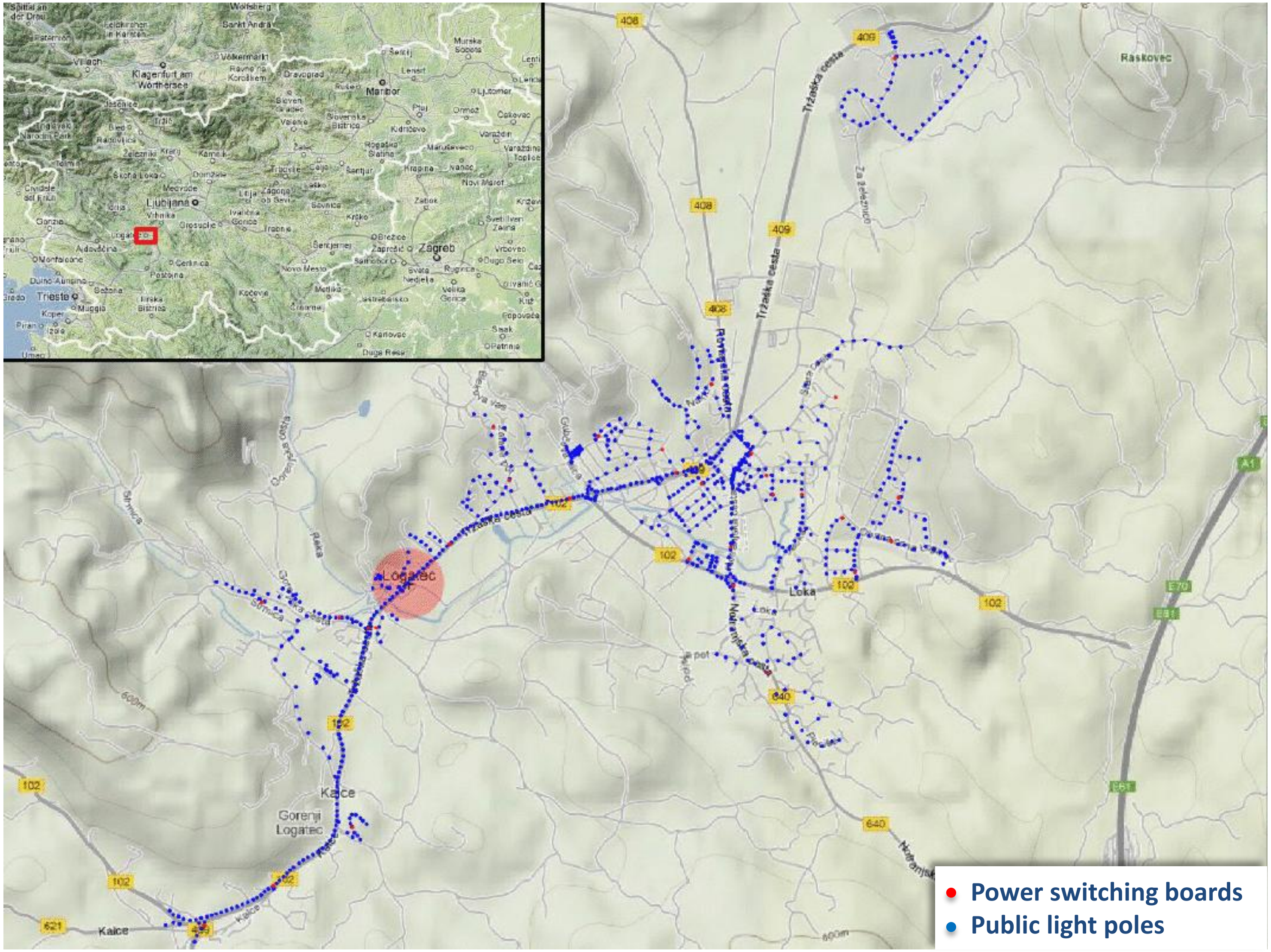
- **JSI sites (~2 x 20 VESNAs):**
  - two combined indoor and outdoor installations at JSI campus
    - one used for spectrum sensing and cognitive radio experimentation – meant as test site for LOG-a-TEC
    - one used for cognitive networking experimentation

Logatec test bed at a glance

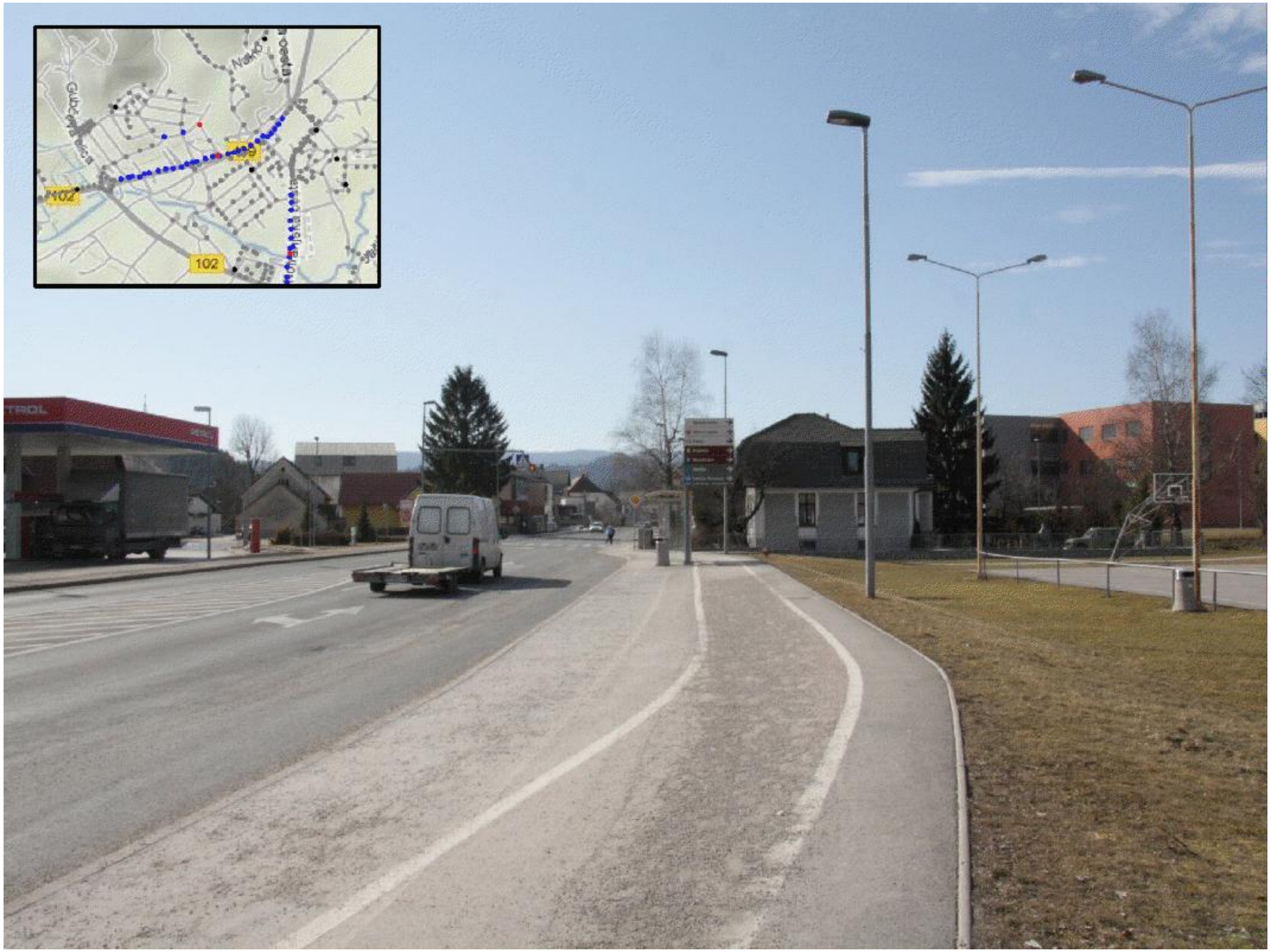
- **Wireless sensor network containing approx. 50 nodes in three clusters**
  - Industrial zone, city center
  - All nodes are VESNA
- **Communication via Atmel ZigBit modules ATZB-900-B0 on a VESNA radio board**
  - 802.15.4/ZigBee mesh network @ 868 MHz
- **Spectrum sensing with VESNA SNE-ISMTV**
  - ISM: CC1101 for sub GHz and CC2500 for 2.4 GHz bands
  - TV (VHF+UHF): NXP TDA18219HN (42 – 870 MHz)

Logatec on the map



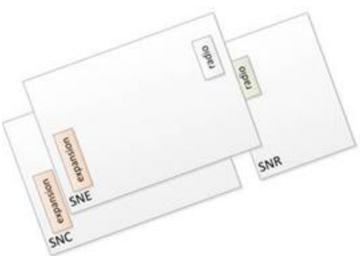
Logatec industrial zone

Logatec central area



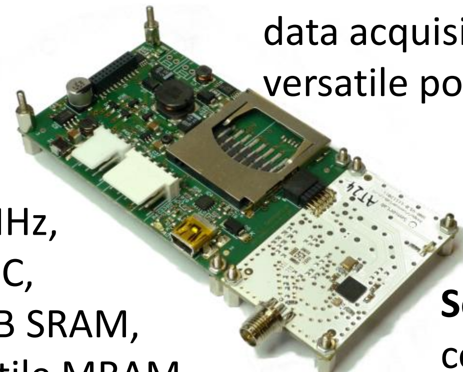
VESNA sensor nodes

- **Modular concept (sandwich like hardware)**



Expansion connector
for application
specific circuits

Sensor Node Core (SNC)
data acquisition and processing,
versatile power supply



ARM Cortex-M3
clock up to 72 MHz,
1 MHz 12-bit ADC,
1 MB flash, 96 kB SRAM,
128 kB non-volatile MRAM,
SD or micro SD card slot
USB 2.0 and RS-232 interface

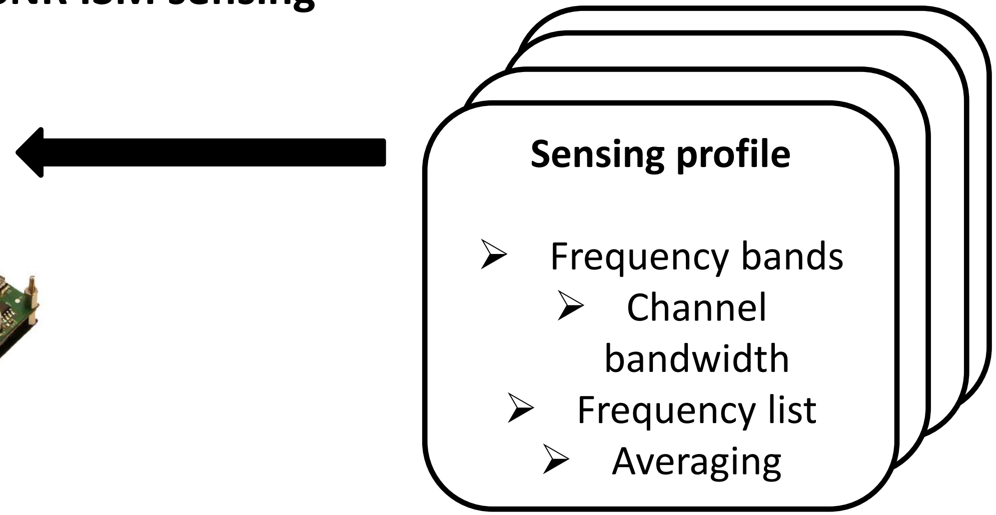
Sensor Node Radio (SNR)
communication within
the sensor network

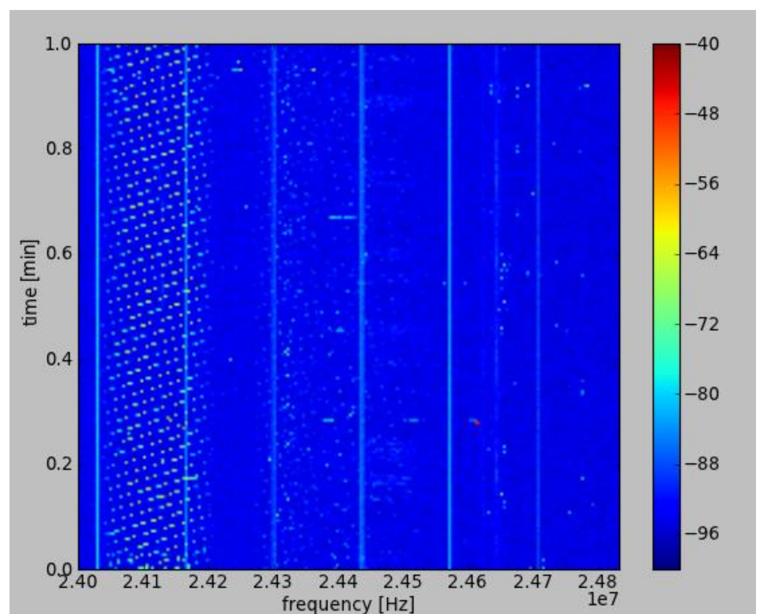
- **Modules:**
  - Core (SNC)
  - Radio (SNR)
  - Extensions (SNE)

ISM spectrum sensing

- There is a list of pre-prepared sensing profiles
- One profile is selected and VESNA is configured according to it
- VESNA performs the spectrum sensing according to specifications
- Results are saved locally on the SD card and sent in batches to the server

VESNA-SNC +
SNR ISM sensing

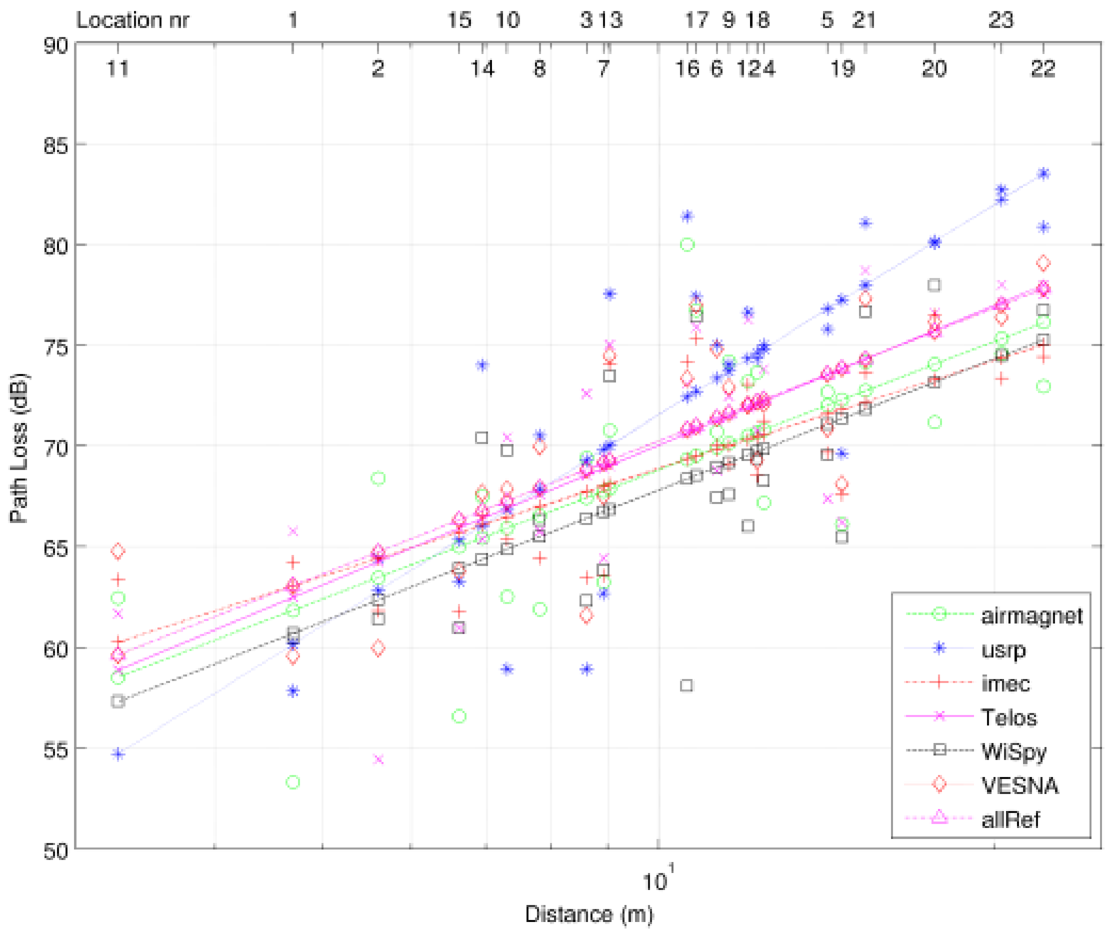




VESNA spectrum sensing application source is released under GPL.
https://github.com/sensorlab/vesna-spectrum-sensor

Least squares regression for individual devices

- Markers - the RSSI from a constantly transmitting signal generator as a function of distance.
- The lines - estimated path loss when a very simple propagation model is applied to the measurement results. (PL = k1 + k2 * log (D), where k1, k2 are parameters of the model)
- The model has been applied to the collected data points; the total of squared error between data points and the lines is minimal.
- It can be seen that the path loss line of VESNA is very close to the reference value's line, and to the "bulk" of the line, and to the "bulk" of the other devices. The errors are quantified in the next slide.



Van Wesemael, P., W. Liu, M. Chwalisz, J. Tallon, D. Finn, Z. Padrah, S. Pollin, S. Bouckaert, I. Moerman, and D. Willkomm, "Robust distributed sensing with heterogeneous devices", Future Network & Mobile Summit, 07/2012.

Mean Squared Error per device

Device Name	MSE Compared to devRef	MSE Compared to allRef
allRef		19.9883
Airmagnet	31.8376	20.7657
USRP	33.9482	28.8005
imec	14.8554	21.5957
Telos	28.5254	20.1824
WiSpy	25.9246	23.2951
VESNA	15.6993	20.4692

Demo

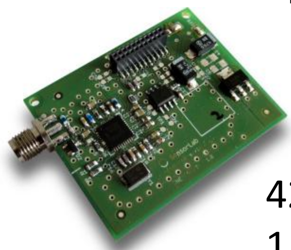
Van Wesemael, P., W. Liu, M. Chwalisz, J. Tallon, D. Finn, Z. Padrah, S. Pollin, S. Bouckaert, I. Moerman and D. Willkomm, "Robust distributed sensing with heterogeneous devices", Future Network & Mobile Summit, 07/2012.

TV spectrum sensing

NXP TDA18219HN silicon tuner
integrated RF tracking filter,
image-rejection mixer,
IF selectivity,
gain control,
low-IF output

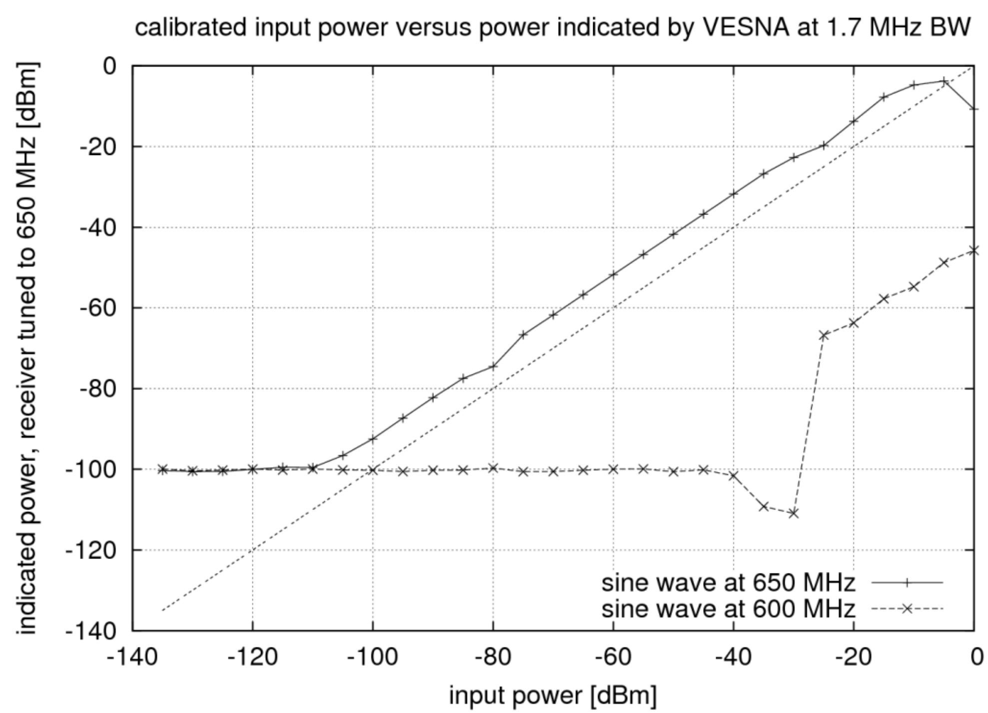
VESNA SNE-CREWTV

- UHF spectrum sensing expansion for CREW



42 – 870 MHz RF input
1.7, 6, 7, 8, 10 MHz channel
5.9 dB noise figure

Analog devices AD8307 demodulating logarithmic amplifier
±1 dB linearity
92 dB dynamic range

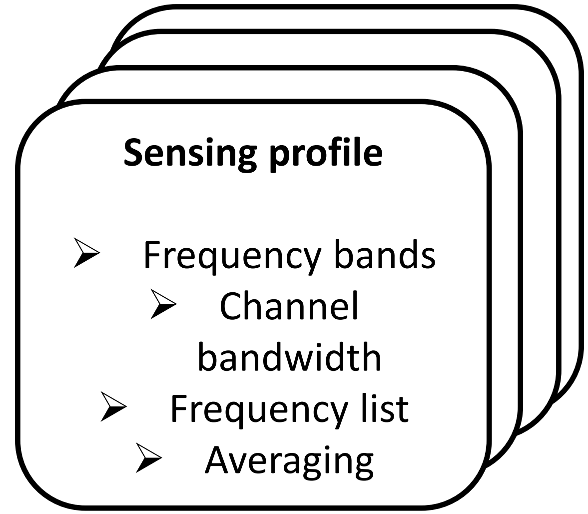


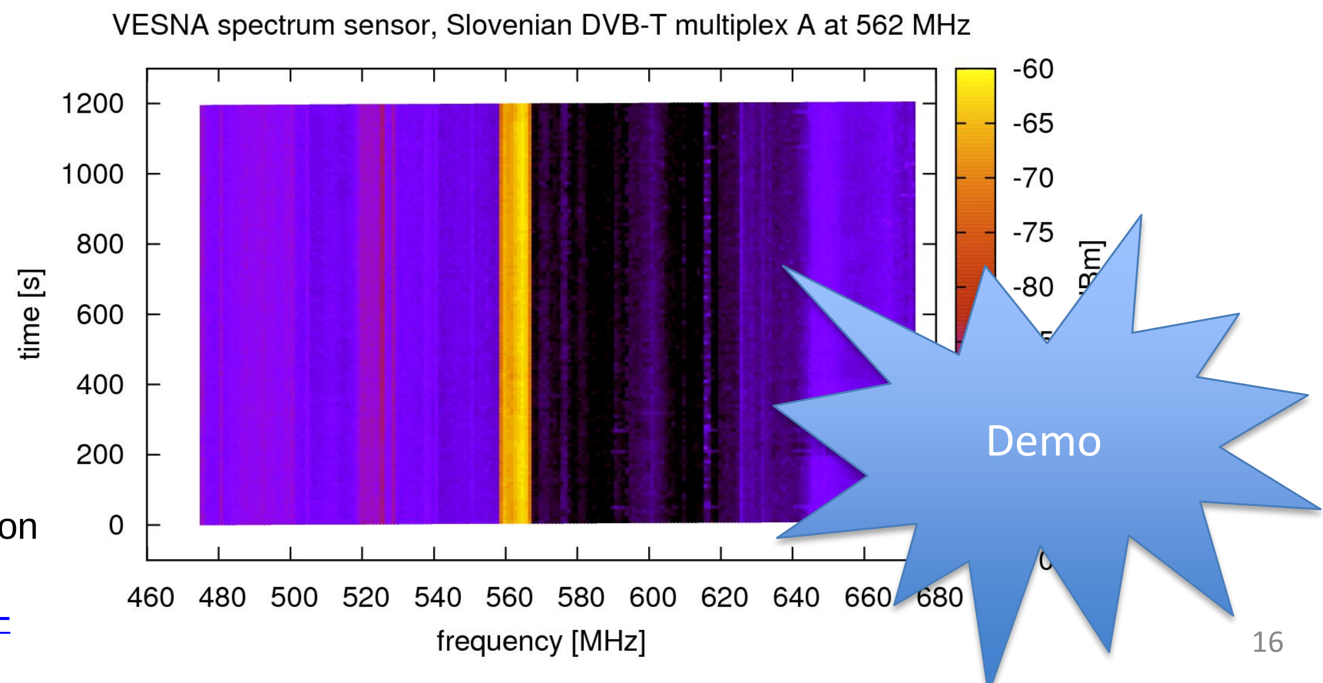
http://www.tablix.org/~avian/blog/archives/2012/04/spectrum_sensing_in_a_nutshell/

TV spectrum sensing

- There is a list of pre-prepared sensing profiles
- One profile is selected and VESNA is configured according to it
- VESNA performs the spectrum sensing according to specifications
- Results are saved locally on the SD card and sent in batches to the server

VESNA-SNC + SNR Communication + SNE-CREWTV





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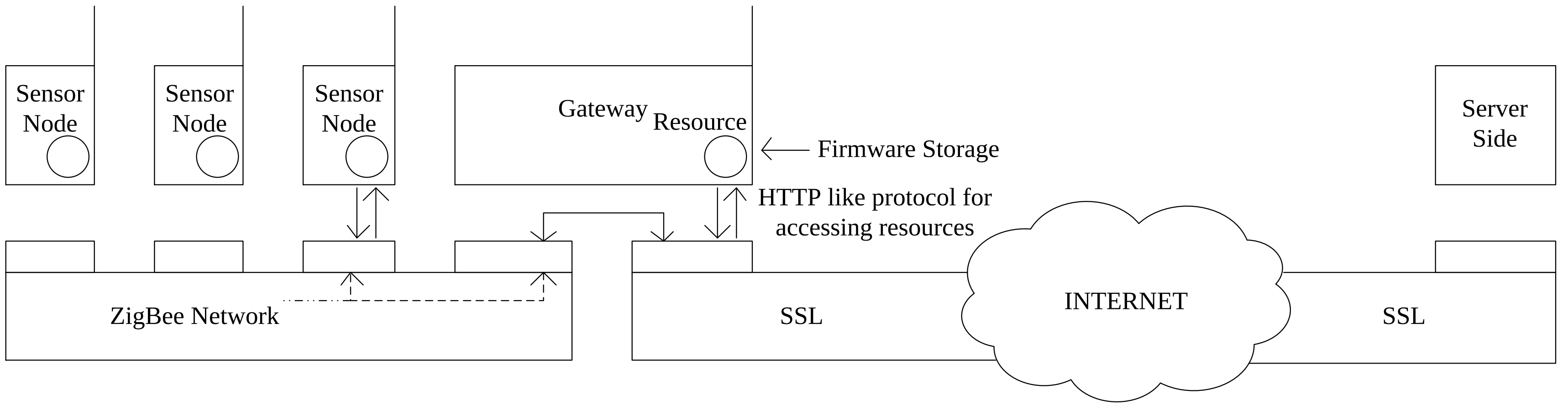
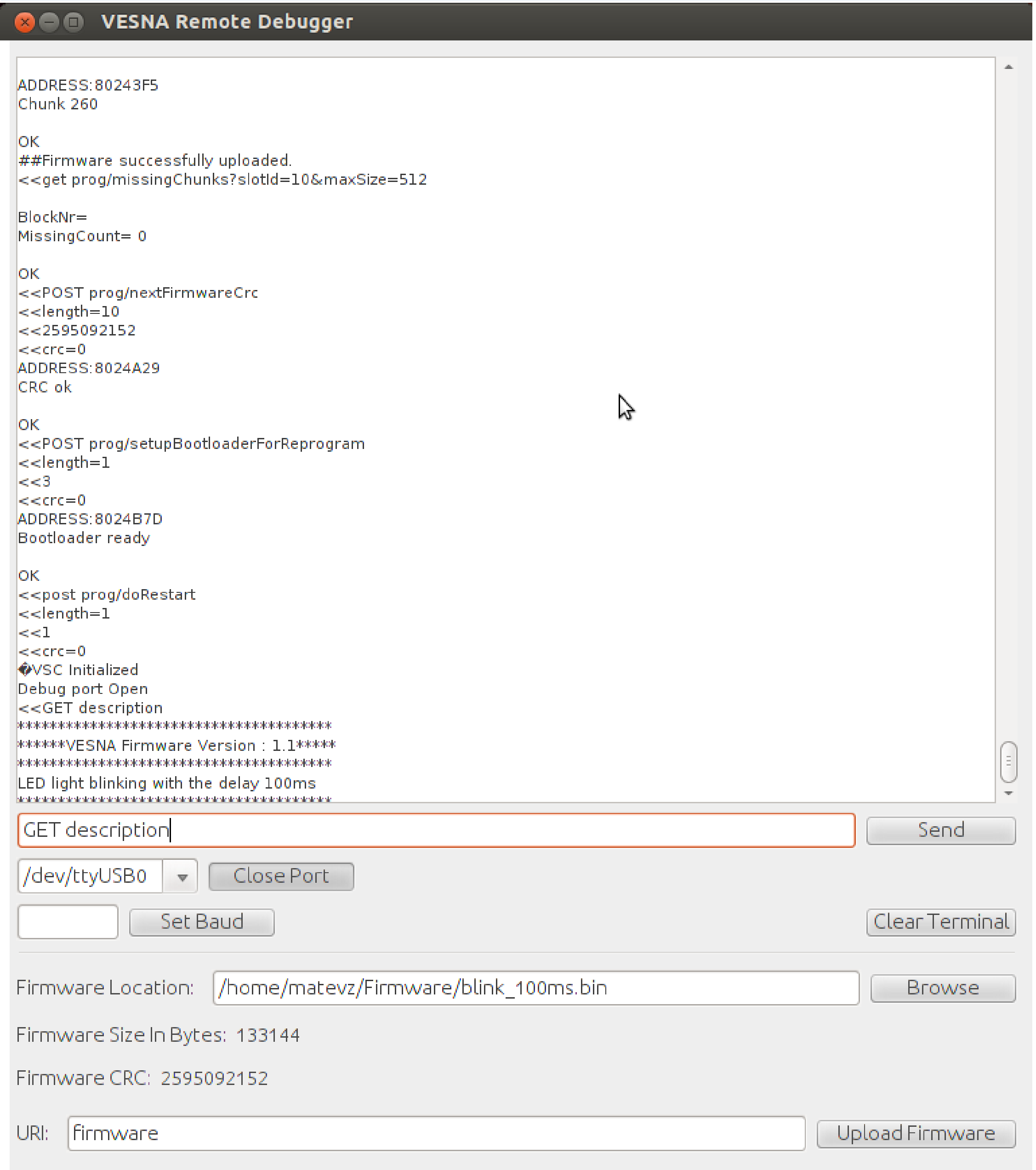
Reprogramming and reconfiguration

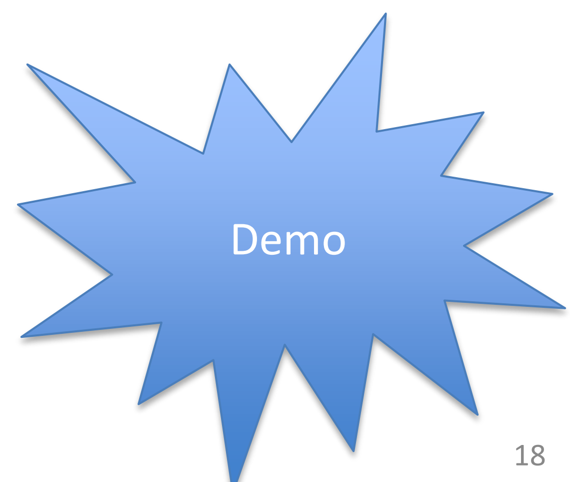


- The server sends the firmware to the gateway over SSL using a custom protocol inspired by HTTP
- The gateway implements a simple which can handle GET and POST requests
- The gateway stores the firmware in chunks of 512 bytes image on the SD card
- After the firmware transfer, the CRC of the image is checked
- A message is sent from the server to the bootloader on the gateway telling it that next time it restarts, it should boot from the part of the SD card where the new image was stored
- Then a message for restart is sent, on restart the new image will be running
- If error on restart it boots from the first slot of the SD card reserved for the safe mode of the firmware
- Reprogramming nodes done via multicast through the coordinator in similar way

Reprogramming and reconfiguration



- Send firmware
- On success, check CRC
- Specify new boot slot
- Invoke restart
- Inquire about new firmware



Measuring communication link quality

- Needed for selecting the locations for the sensor nodes
- The aim is to determine sites with low packet loss
- Key factor in
  - reconfiguration/reprogramming
  - measurement collection

obrtnacona_coordinator

zapolje_coordinator

logatec_coordinator

logatec_location6
Link to coordinator: RSSI [dBm]: max -70, min -92, avg -77 LQI: max 247, min 236, avg 247 RTT [ms]: max 205, min 103, avg 110 packet loss: 5 %

logatec_location7
Link to coordinator: RSSI [dBm]: max -73, min -87, avg -74 LQI: max 247, min 247, avg 247 RTT [ms]: max 117, min 103, avg 109 packet loss: 0 %

logatec_location4
Link to coordinator: RSSI [dBm]: max -61, min -82, avg -72 LQI: max 247, min 247, avg 247 RTT [ms]: max 118, min 103, avg 109 packet loss: 0 %

logatec_location5
Link to coordinator: RSSI [dBm]: max -67, min -87, avg -74 LQI: max 247, min 247, avg 247 RTT [ms]: max 123, min 103, avg 110 packet loss: 1 %

logatec_location2
Link to coordinator: RSSI [dBm]: max -45, min -73, avg -58 LQI: max 247, min 247, avg 247 RTT [ms]: max 127, min 103, avg 110 packet loss: 0 %

logatec_location3
Link to coordinator: RSSI [dBm]: max -52, min -81, avg -67 LQI: max 247, min 247, avg 247 RTT [ms]: max 193, min 104, avg 110 packet loss: 0 %

logatec_location1
Link to coordinator: RSSI [dBm]: max -43, min -49, avg -47 LQI: max 247, min 247, avg 247 RTT [ms]: max 115, min 103, avg 109 packet loss: 0 %

logatec_location16
Link to coordinator: RSSI [dBm]: max -70, min -89, avg -74 LQI: max 247, min 246, avg 247 RTT [ms]: max 119, min 103, avg 109 packet loss: 0 %

logatec_location8
Link to coordinator: RSSI [dBm]: max -73, min -85, avg -74 LQI: max 247, min 247, avg 247 RTT [ms]: max 117, min 103, avg 108 packet loss: 0 %

logatec_location9
Link to coordinator: RSSI [dBm]: max -73, min -91, avg -83 LQI: max 247, min 242, avg 247 RTT [ms]: max 140, min 103, avg 111 packet loss: 11 %

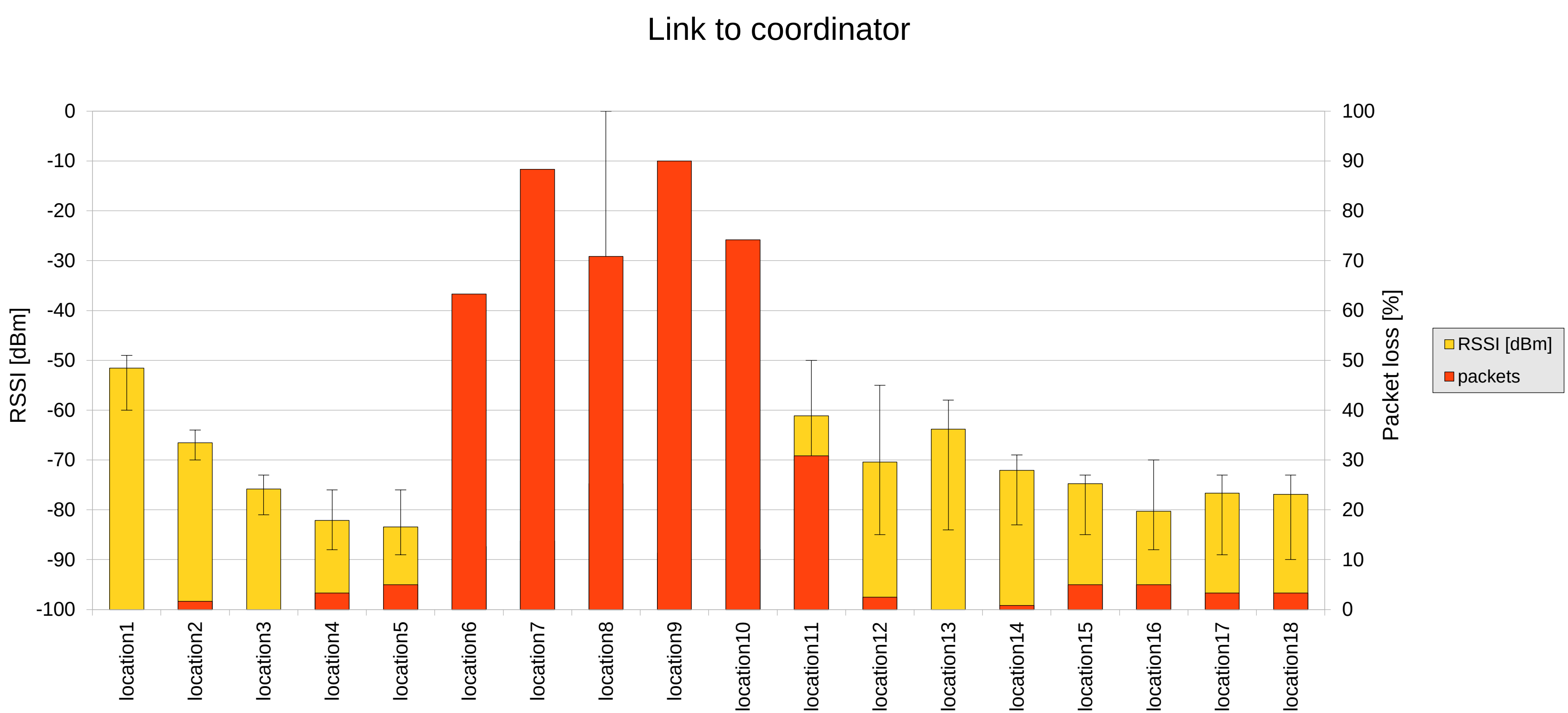
obrtnacona_location2
Link to coordinator: RSSI [dBm]: max -73, min -89, avg -78 LQI: max 247, min 238, avg 247 RTT [ms]: max 181, min 103, avg 112 packet loss: 8 %

obrtnacona_location5
Link to coordinator: RSSI [dBm]: max -67, min -85, avg -78 LQI: max 252, min 247, avg 249 RTT [ms]: max 116, min 104, avg 110 packet loss: 13 %

logatec_location34
Link to location25: RSSI [dBm]: max -58, min -80, avg -64 LQI: max

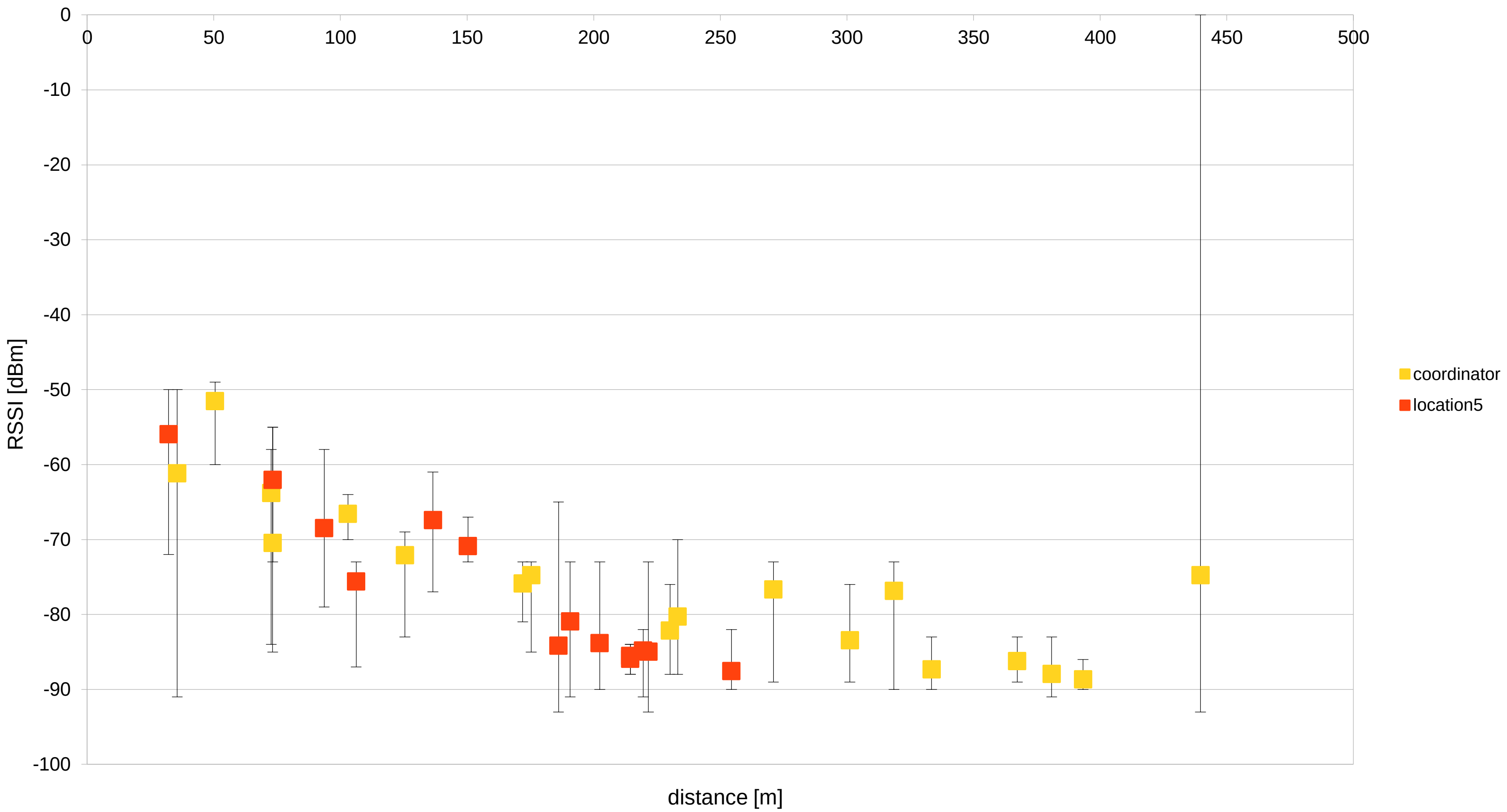
http://g.co/maps/5qt3w

The link quality to the coordinator



We consider 10% packet loss a good link.

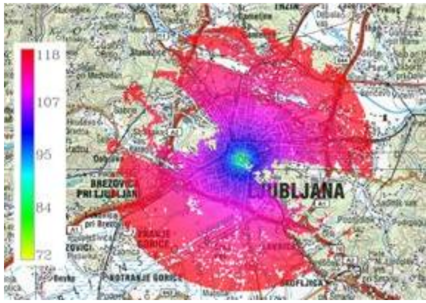
The link quality to the coordinator

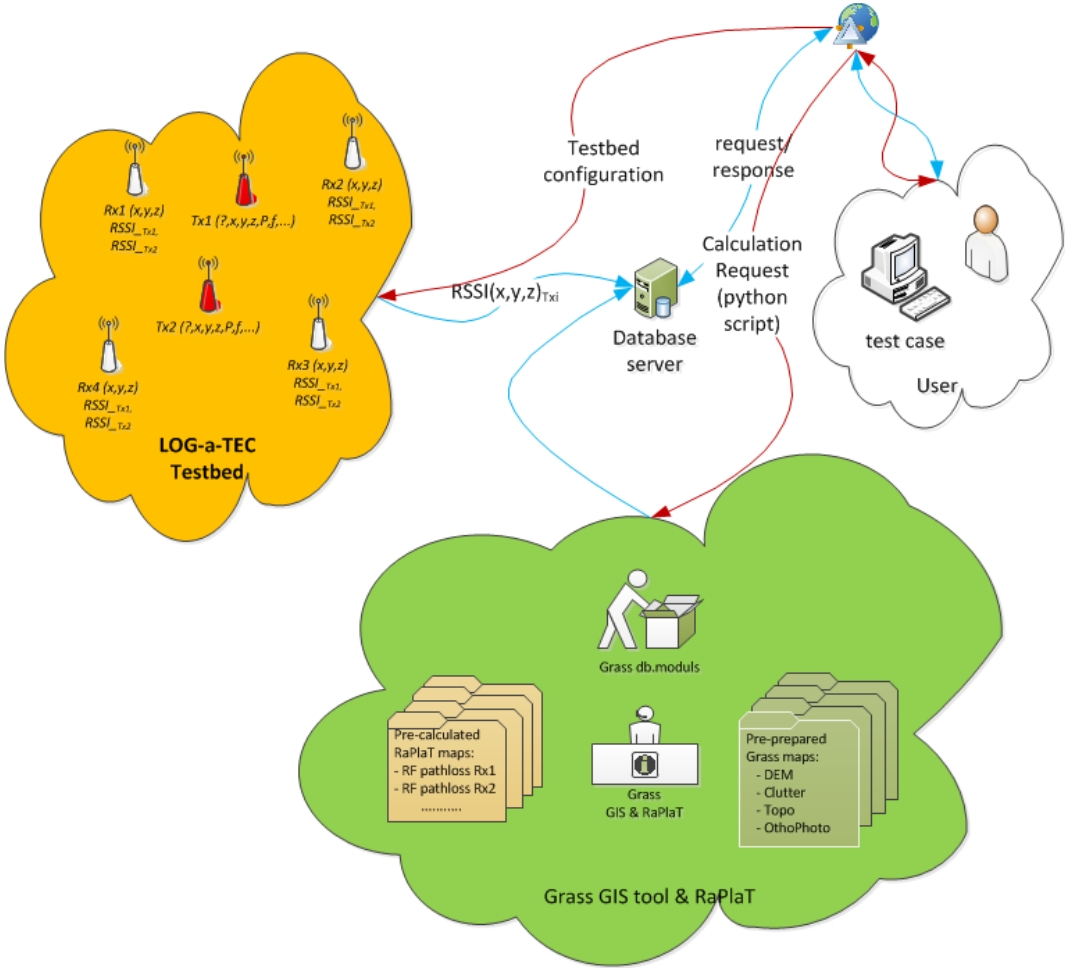


ATZB-900-B0: „100 kbps, outdoor range 6 km“

Radio planning tool

- for storing GIS data
- as a tool for conversion of GIS data to the data form appropriate for visualization via the web interface
- for calculating radio environmental maps (REM) and preparation for their visualization
- in the **inverse channel modeling for interference region determination and collaborative hidden node detection**.





The tool is freely available at:
http://www-e6.ijs.si/en/software/grass-raplat

CREW Open Call 2 - Portal

Portal containing all relevant information and functionality for experimenters (currently just initial mock-up)

VESNA (code)

Location:

- Logatec, Slovenia, Europe
- GPS coordinates

Configuration:

SNCv1.1

SNRv2.1 (TI24 CC2500)

SNE-CREW

Firmware: SLLibv3.45

SLLibv3.45
Contiki2.5 RIME
Contiki2.5 uIPv6
Contiki2.5 6LowPAN

Parameters:

Frequency band: 2.425 - 2.475 MHz

Sensing band: 10 MHz

10
20
30
50

Reconfigure

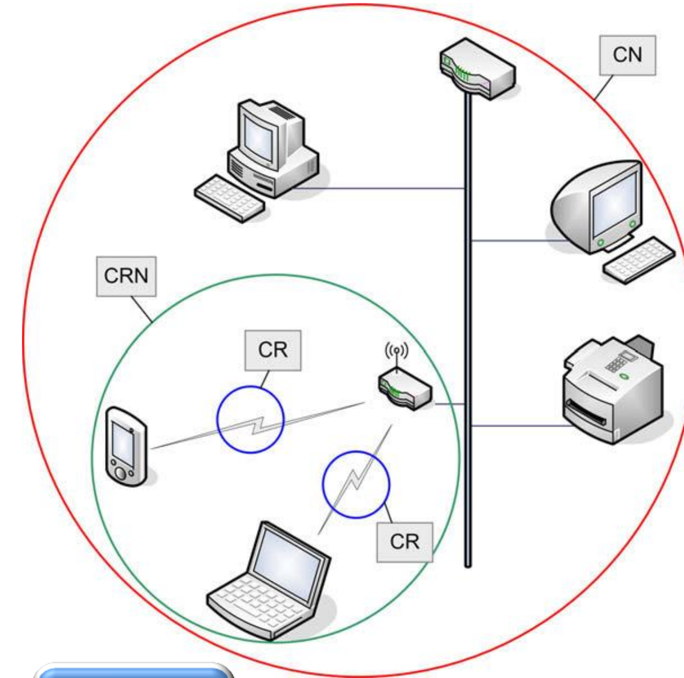
CREW Open Call 2 - Functionality

You will be able to order:

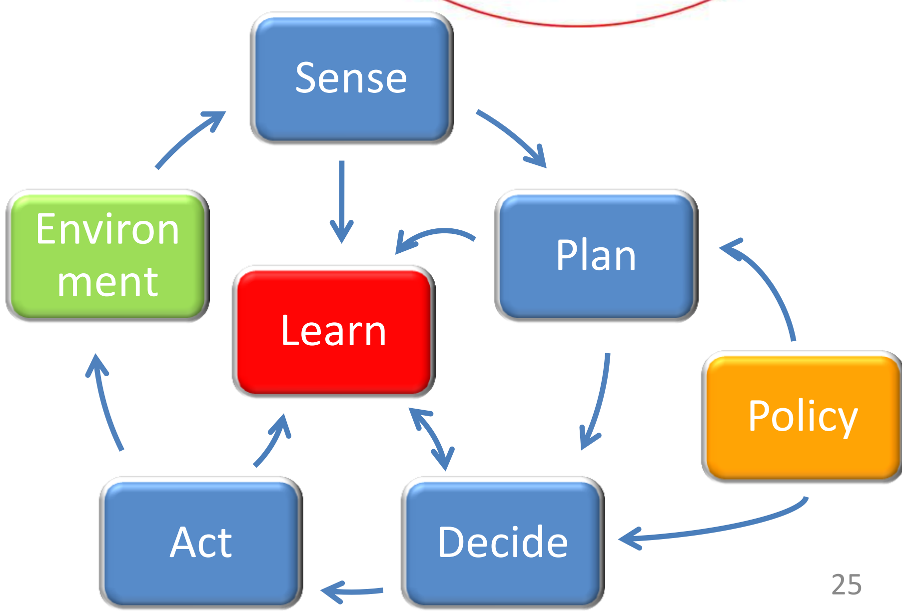
- **Sensing**
  - Have nodes at locations A, B, C, ... perform energy detection from time T1 to time T2 over frequencies between F1 and F2, using B_res resolution bandwidth and sweep time T_sweep.
  - The result is a collection of power matrices, as specified in the CREW common data format (time vs. frequency vs. received signal power).
  - There will be some **fixed combinations of frequency spans, resolution bandwidths and sweep times, as defined by our hardware in the "sensing profiles“ as could be seen in the demos**.
- **Transmission**
  - transmit signal (specify characteristics) on frequency F (inside the ISM bands).

Cognitive networking

- **Scope**
  - CR – wireless link
  - CRN – AP to wireless terminals
  - CN – wired + wireless



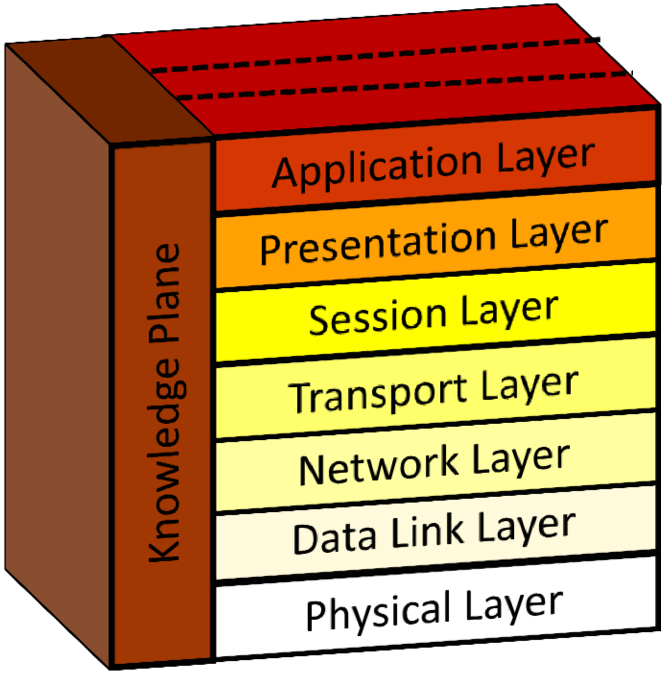
- **CN elements**
  - A representation of relevant knowledge about the scope (device, homogenous network, heterogeneous network, etc.).
  - A cognition loop which uses AI techniques inside its states (learning techniques, decision making techniques, etc.).



C. Fortuna, M. Mohorcic, Trends in the development of communication networks: Cognitive Networks, Computer Networks 53 (2009) 1354–1376

Cognitive networking

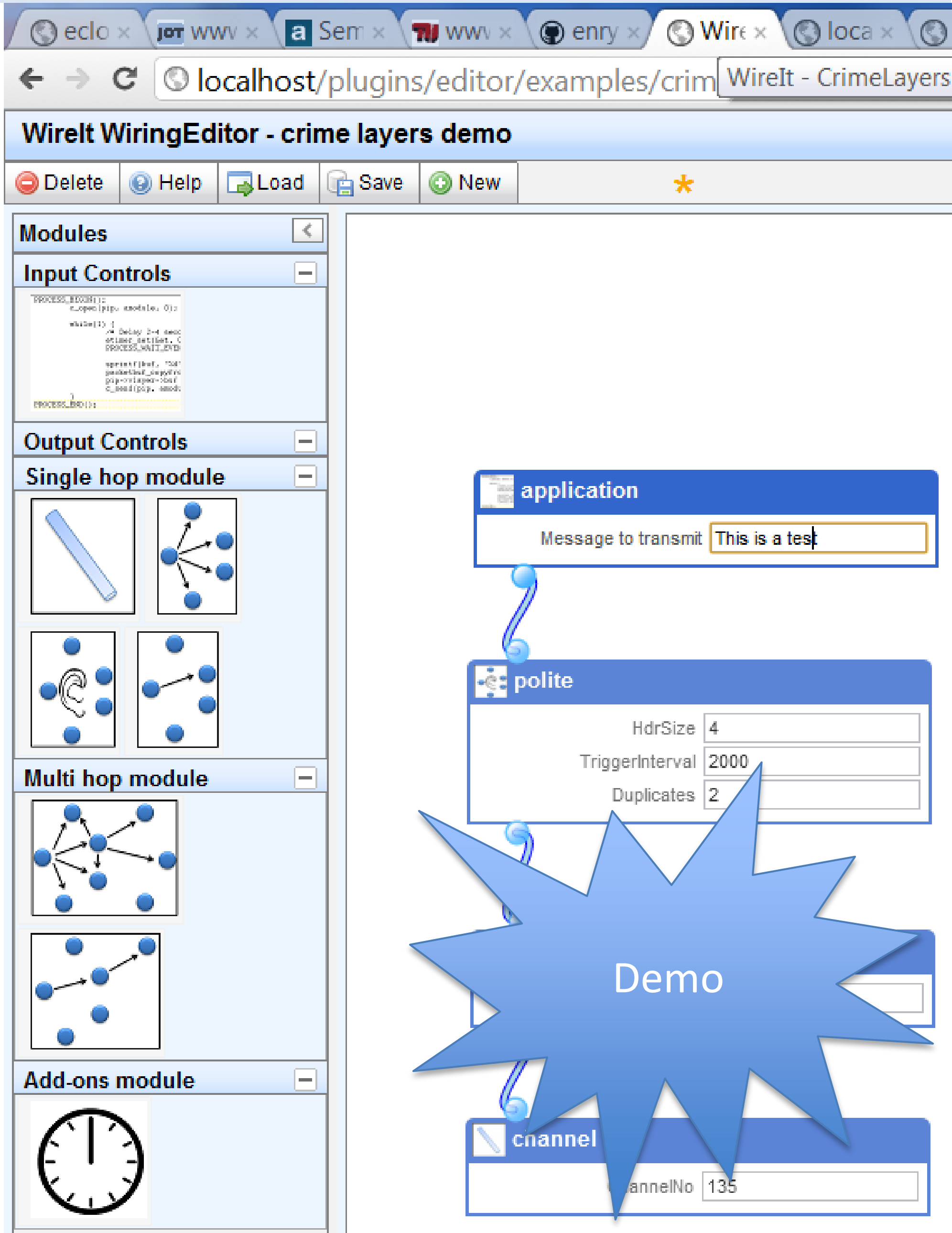
- Possible implementation: the Knowledge Plane (can be seen as smarter cross layer design)



D.D. Clark, C. Partrige, J.C. Ramming, J.T. Wroclawski, A knowledge plane for the internet, in: Proceedings of the SIGCOMM 2003, Karlsruhe, Germany, August 25–29, 2003.

Cognitive networking

- Remote composition, reconfiguration and reprogramming of protocol stacks for cognitive networking research.
  - Contiki OS with Configurable RIME (C-RIME) stack
  - Custom reprogramming protocol
  - Sesame store for storing consistency rules
  - Java server side (Jetty + VESNA server) and WireIt (Javascript/HTML5) user interface



Summary

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- VESNA sensor nodes
- ISM spectrum sensing
- TV spectrum sensing
- Testbed reconfiguration
- Radio planning

- CREW Open Call 2

- Cognitive networking

Acknowledgements: all colleagues from SensorLab, especially Tomaz x 2 and Zoli who contributed slides.

Questions / Discussion

http://www.crew-project.eu/

http://sensorlab.ijs.si/

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