Summary of the work done with USRP at RMA

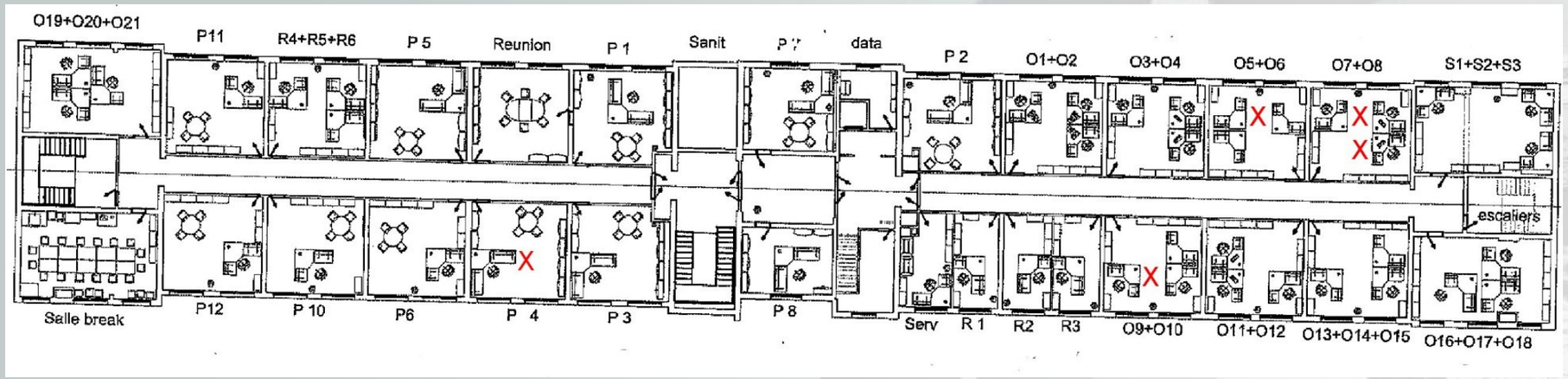
Dept. Communication, Information Systems & Sensors (CISS)
Royal Military Academy, Belgium

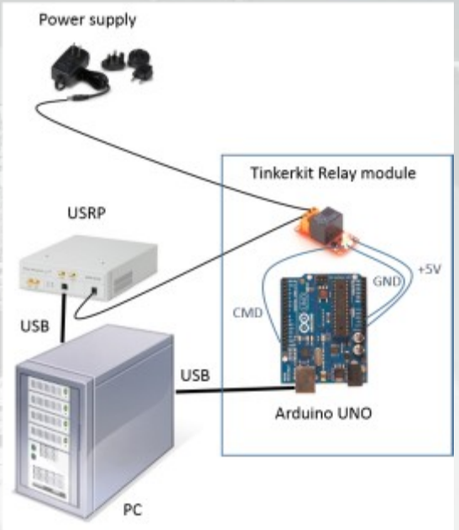
Outline

- Testbed at RMA
- Tools to Develop Applications
- The CogWave Framework
- Standardised Waveforms
- Spectrum Sensing Techniques
- Learning Techniques
- Summary

Testbed at RMA

- Acquisition of 3xUSRP1,1xUSRP2,5xB100,2xN210,1xB200 since 2009.
- Development of a USRP testbed (5xB100+1xN210) at CISS with a web server along with power switches for remote power on/off of USRPs based on Arduino UNO and tinkerkit relay modules (~30 euros).





Tools to Develop Applications

- Universal Hardware Driver (UHD) C++ API
- Qt C++ API: a cross-platform application framework for developing application software with a graphical user interface (GUI)
  - Multithreading : subclass QThread and reimplement run()
- IT++: A C++ library of mathematical, signal processing and communication classes and functions
- Gstreamer C++ API : a pipeline-based multimedia framework for audio and video playback, recording, streaming and editing
- Flexibility to implement waveforms in C++ in real-time
- Example code: send samples of an IT++ complex vector with UHD C++ API

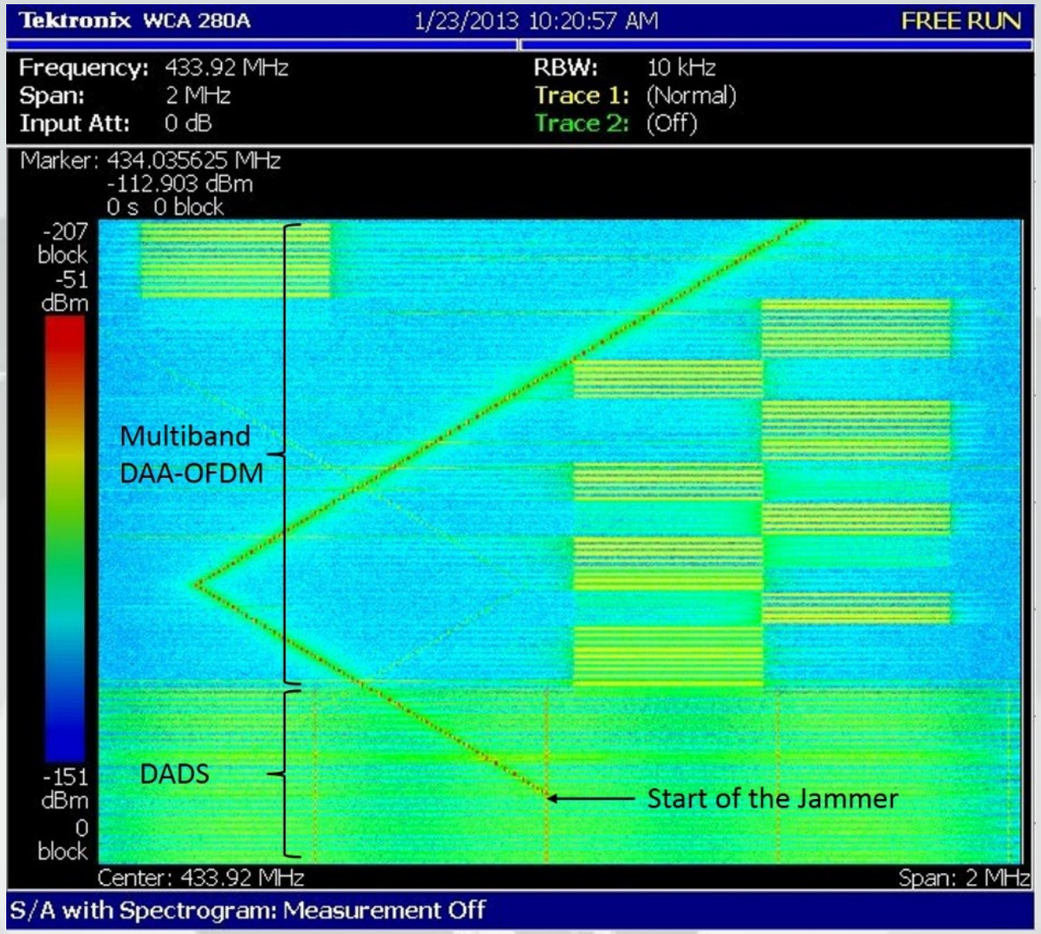
```
void UHDDevice::sendsamples(cvec tx_buff,double timestamp){

    double tx_rate=1.0e6;
    uhd::tx_metadata_t tx_md;
    tx_md.start_of_burst = true;
    tx_md.end_of_burst = true;
    tx_md.has_time_spec = true;
    tx_md.time_spec = uhd::time_spec_t(timestamp);
    tx_stream->send(&tx_buff(0), tx_buff.size(), tx_md, timestamp+tx_buff.size()/tx_rate);

}
```

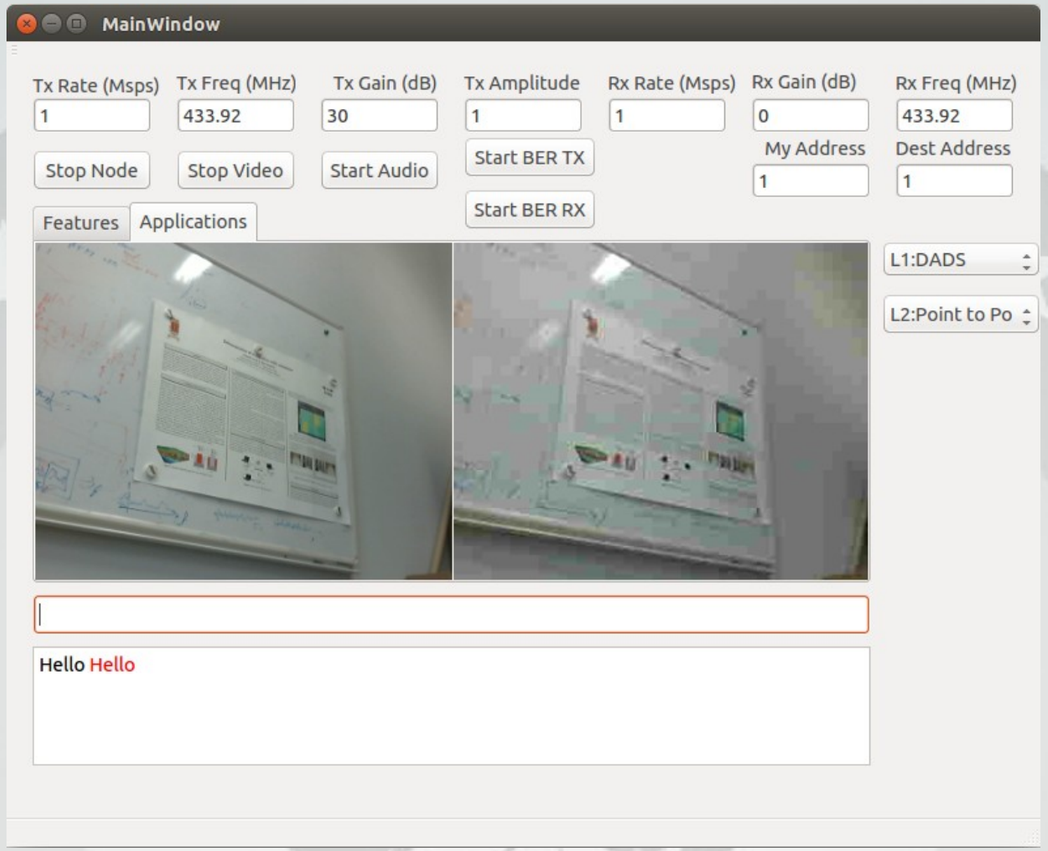
The CogWave Framework

- Implementation of a library of PHY modulation schemes and rules to switch between PHY modulation schemes during run-time in the General Purpose Processor (GPP):
  - Multichannel Detect and Avoid (DAA)-OFDM
  - Delay and Add Direct Sequence (DADS)
  - Other modulation schemes: BPSK, QPSK, GMSK, CPFSK, OFDM ported from the GNU Radio C++ API, EDA CORASMA (SC-FDM) and NATO NBWF (CPM).
- FDD and TDD modes for all modulations schemes.
- Frequency hopping for all modulation schemes based a predefined hopping sequence only known to the nodes.



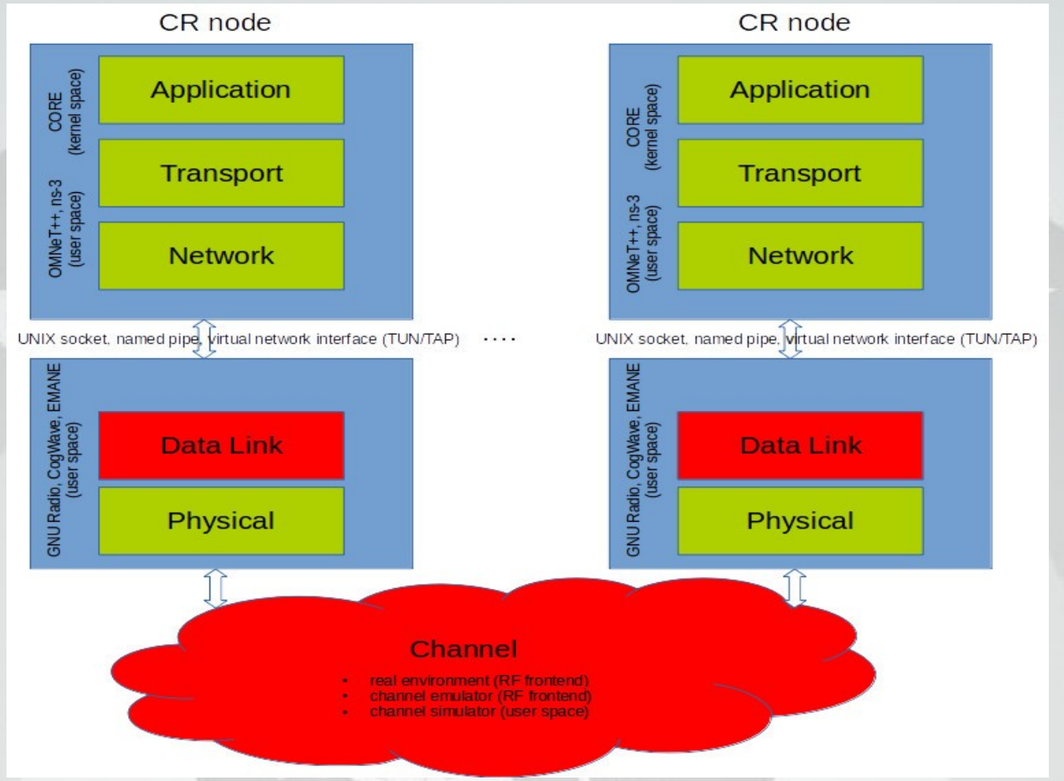
The CogWave Framework

- Implementation of a library of MAC protocols (Point-to-Point TDD, Point-to-Point-FDD, Aloha, non-persistent CSMA, 1-persistent CSMA, p-persistent CSMA, TDMA, OFDMA) in the GPP
- Implementation of a library of hardware interfaces (USRP, HackRF) and software interfaces (virtual for emulation, simulator for high fidelity simulation of high number of nodes) with realistic channel models (free space, COST 207, ITU, SUI) in the GPP
- Implementation of several applications for video transmission (M-JPEG), audio transmission (MP3, AMBE2+, MELPe), BER calculation, text message, IP traffic in the GPP



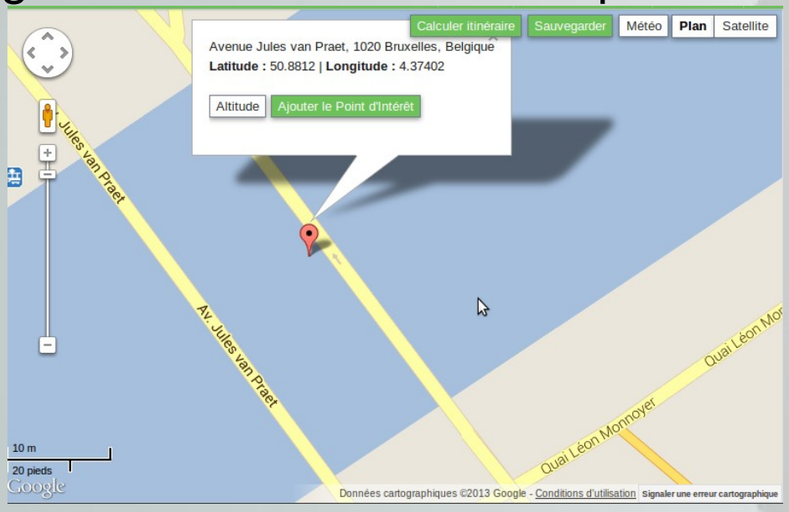
The CogWave Framework

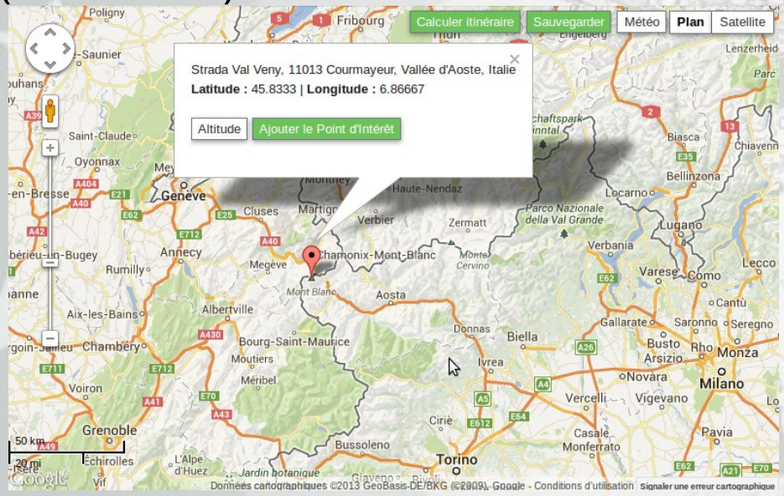
- Combination between the CogWave framework and network simulators (**OMNeT++, ns-3**) at the network layer via **TUN/TAP interface**
- PHY and MAC provided by CogWave, NET and above provided by OMNeT++, ns-3 (Routing: OSPF, AODV, OLSR. Network: IPv4, IPv6; ARP. Transport: TCP, UDP, RTP. Application: HTTP, DHCP, Voice, P2P)
- The combination of the CogWave framework with network simulators (OMNeT++, ns-3) has been tested by executing different protocols (e.g. routing protocols, TCP, UDP) and applications (e.g. ping application, client-server application) for high fidelity simulation, emulation and connection with RF hardware.



Standardised Waveforms

- Automatic Information System (AIS) is an automatic tracking systems used on ships and vessel traffic services for identifying and locating vessels by electronically exchanging data with other nearby ships, AIS base stations and satellites.
- Implementation of a real-time AIS transponder (receiver and transmitter) application in the GPP with USRP :
  - Two VHF maritime channels (161.975 MHz and 162.025 MHz)
  - 9.6 kbps GMSK modulation in 25 kHz channel
  - Self-Organized Time Division Multiple Access (SOTDMA)



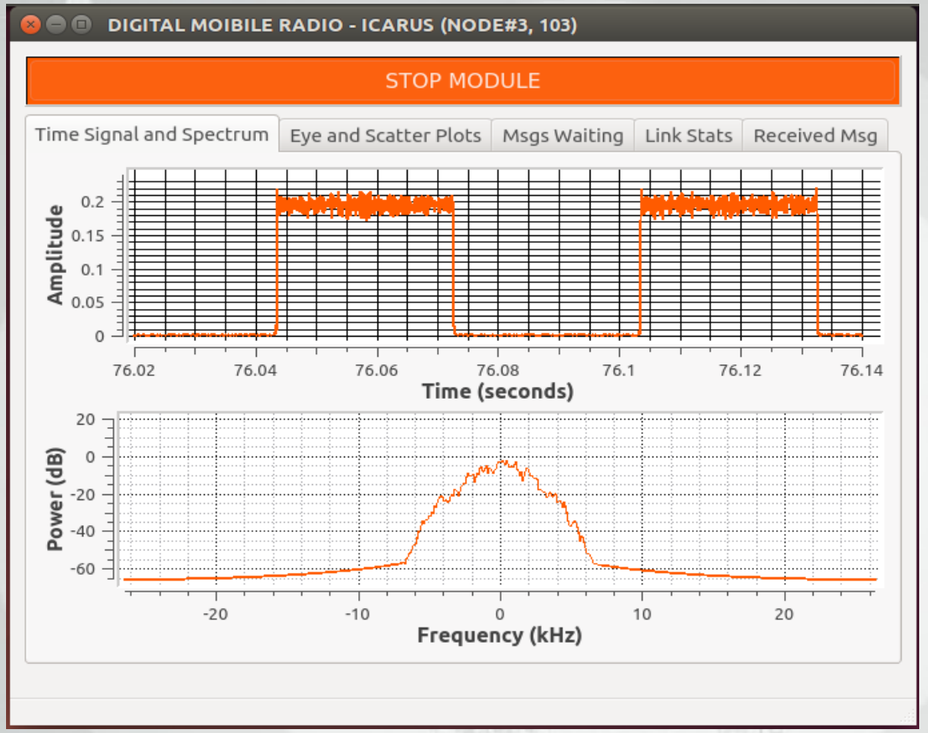


Standardised Waveforms

- Digital Private Mobile Radio (dPMR) is an open, non-proprietary standard that was developed by the European Telecommunication Standards Institute (ETSI)
- Implementation of a real-time dPMR receiver and transmitter application in the GPP with USRP (C++ and LabView) :
  - Licence-free UHF band 446.1-446.2 MHz
  - 4.8 kbps 4-FSK modulation in 6.25 kHz channel
  - Frequency Division Multiple Access (FDMA)

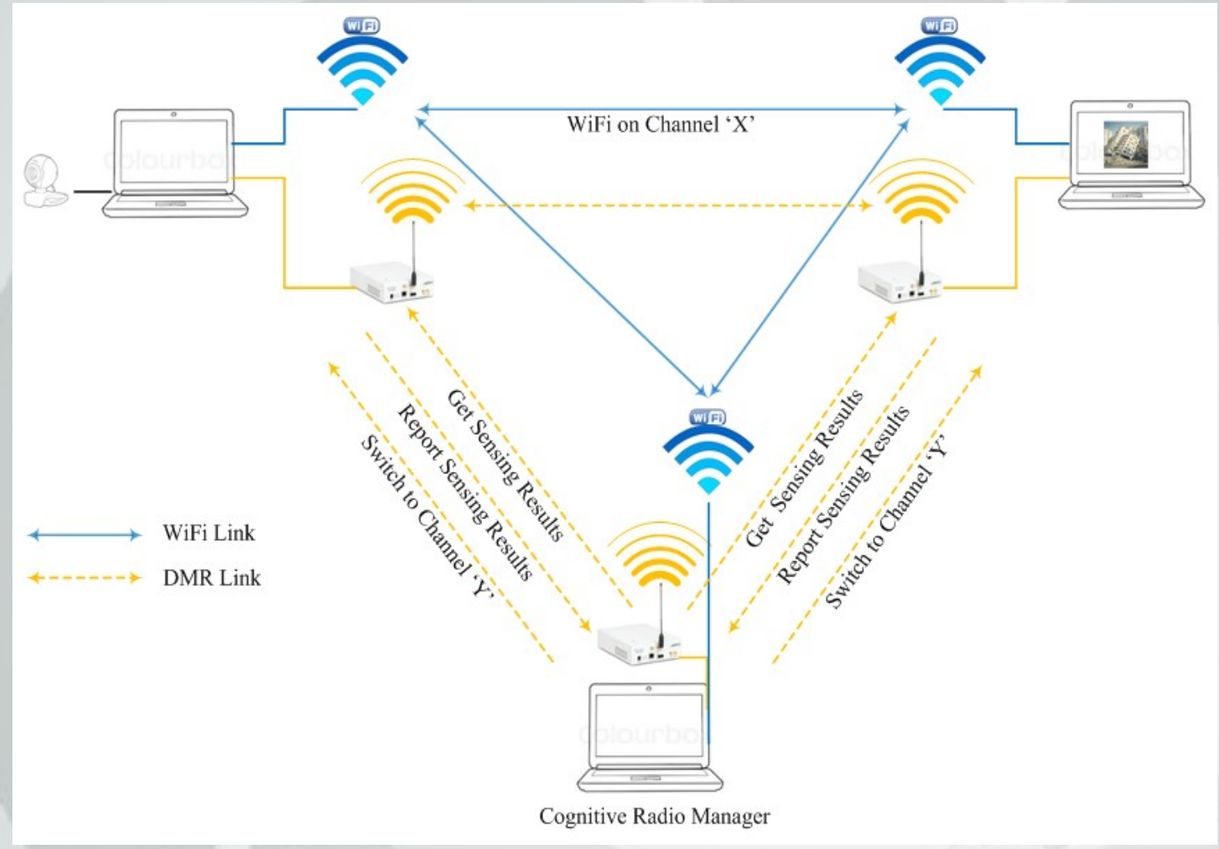
Standardised Waveforms

- Digital Mobile Radio (DMR) is an open digital mobile radio standard defined in the European Telecommunication Standards Institute (ETSI) and used in commercial products around the world.
- Implementation of a real-time DMR receiver and transmitter application in the GPP with USRP (C++)
  - Licence-free UHF band 446 MHz, Licenced from 66-960 MHz
  - 9.6 kbps 4-FSK modulation in 12.5 kHz channel
  - Two-slot Time Division Multiple Access (TDMA)



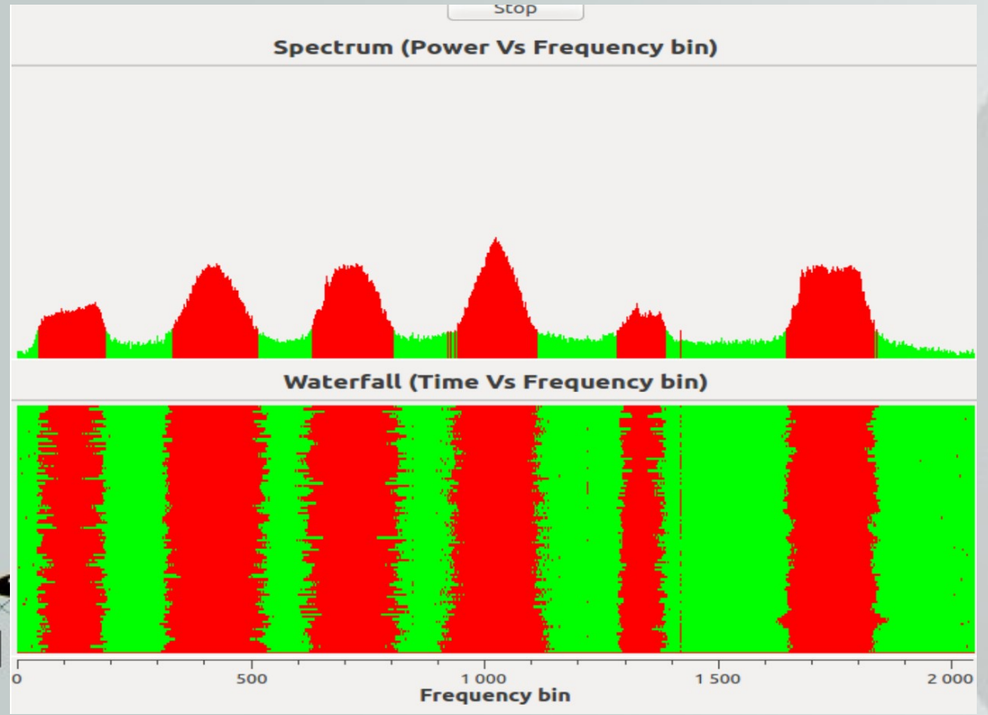
DMR Use in ICARUS

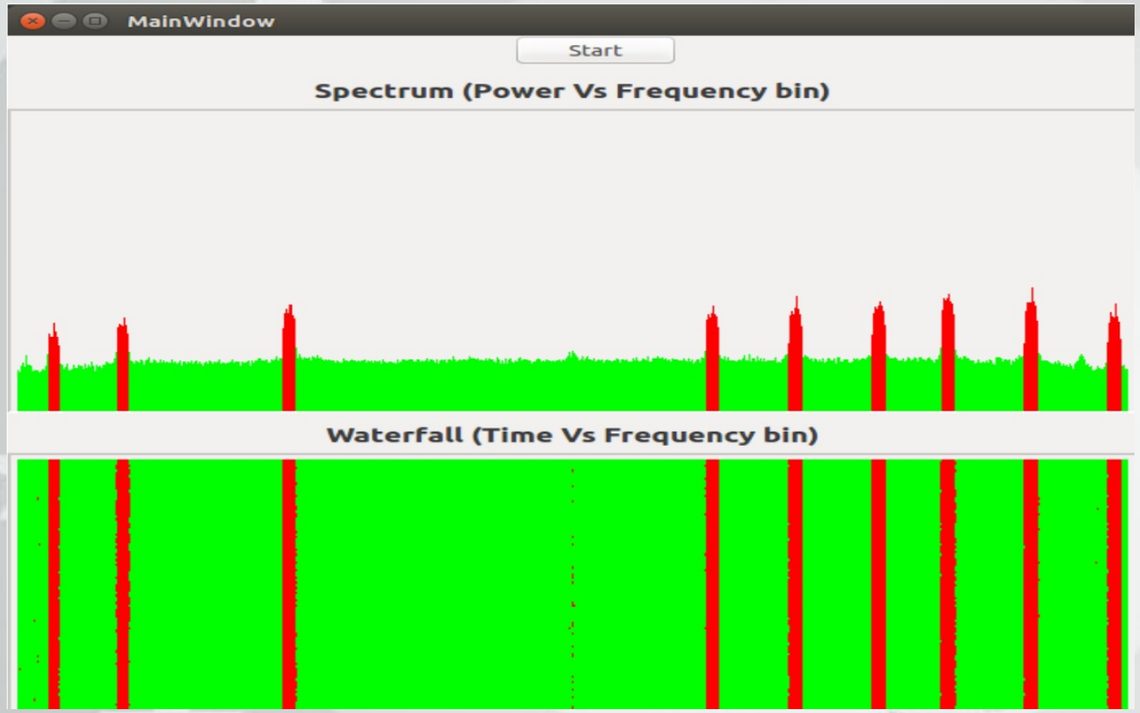
- Robust coverage over long range, inside rubble environment
- Control channel for unmanned devices
- Feedback channel for cognitive management of WiFi network



Spectrum Sensing Techniques

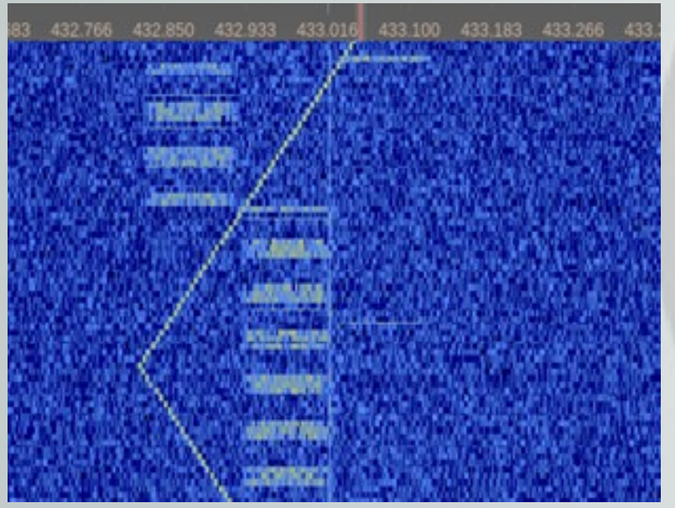
- Wideband Goodness-of-Fit (GoF) Sensing is a wideband spectrum sensing technique which calculates the area between the cumulative distribution function of each frequency bin and the noise cumulative distribution function. Contrary to energy detection, the threshold only depends on this area and not on the noise distribution. Moreover, it is possible to determine the presence of a signal with fewer samples than energy detection.
- Implementation of a real-time wideband GoF sensing application in the GPP with USRP

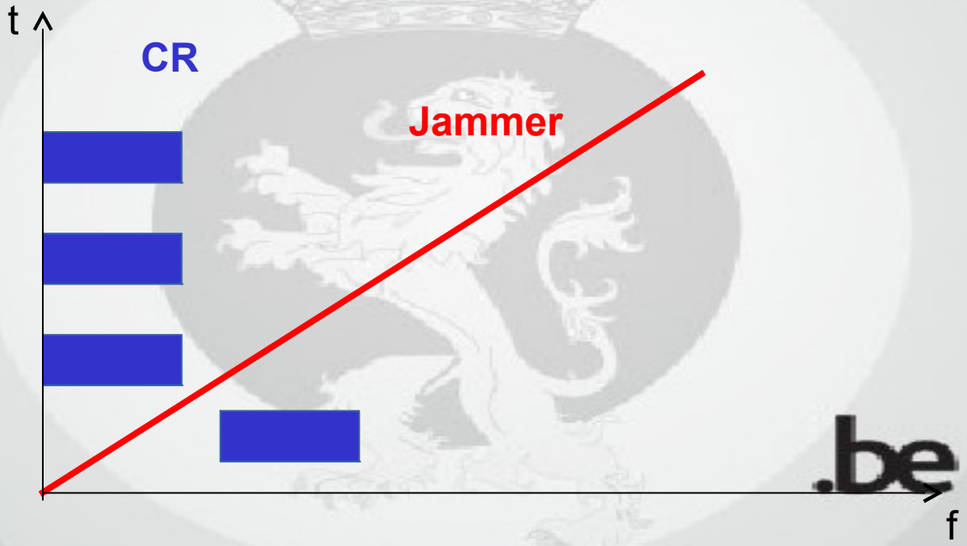




Learning Techniques

- CR should exploit learning and reasoning capacities for optimal resource management and resilience against malicious users.
- **Q-learning** is a model-free reinforcement learning adapted to the CR unknown hostile environment.
- It is applied to allow the CR learn the jammer strategy in order to pro-actively avoid jammed channels. Learning is done through Trial&Error: channel exploration until algorithm convergence.
- Implementation of an adapted variant based on wideband spectrum sensing to speed up the learning process and greedy exploration policy to minimize the number of collisions with the jammer during training.





CISS

Summary

- Implementation of several real-time applications in the GPP with USRP
  - The CogWave Framework
  - Standardised waveforms (AIS, dPMR, DMR)
  - Spectrum Sensing Techniques (GoF Sensing)
  - Learning Techniques (Q-Learning)
- Future work
  - Development of more standardised waveforms (NATO NBWF)
  - Development of small-sized hardware devices (mini-DMR)
  - Development of new learning techniques for cognitive radio