Wireless Networks In-the-Loop

gr-winelo – A GNU Radio Network Emulator

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Outline

Outline

SDR development thought through to the end

- SDR simplifies Radio development
  → ...well, most of the time ;)

- SDR introduces a new workflow for Radio development
  → Debugger, Profiler, Automated Tests, ...

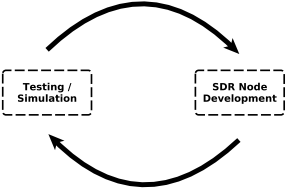
⇒ **Why just use them for a single block or a single node?**

Wireless Networks In-the-Loop

- Emulate the entire network
- Allow seamless switching

→ Same code base for measuremens **and** simulations

→ Iterative improvment in every single step



⇒ **Stay in the software domain as long as possible**

⇒ **Go back to the software domain as soon as possible**

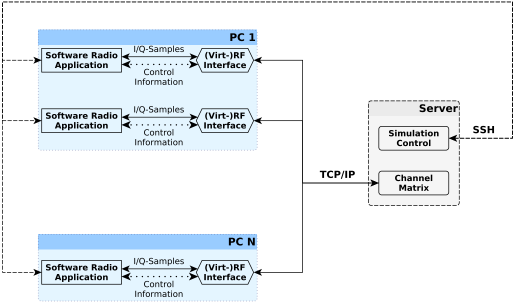
Benefits

- **Flexibility & Scalability**
  $\rightarrow$ Ever tested a network with 5+ nodes in different arrangements?
- **Only one codebase**
  $\rightarrow$ No need for Matlab, ns3, ...
- **Easy Debugging**
  $\rightarrow$ Set breakpoints on the air link!
- **"Controllable realism"**
  $\rightarrow$ Turn impairments on/off seperated from each other

$\Rightarrow$ **Reduced development time & increased feelgood factor!**

Inhalt

Basic structure



- Client/server architecture
- Two main components
  - → (Virt-)RF-Interface
  - → Channel matrix
- Developed at Communications Engineering Lab (KIT, Germany)

Timing

- Zero Padding – accurate and generic mode
- Realtime simulation mode
- Timed commands
- Absolute time (GPSDO)

Hardware- and channel emulation

- Modular channel models
- channel matrix
- Mixing and rate conversion

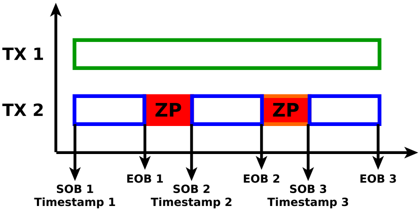
Simulation interface

- UHD compatible

Zero Padding

- *SOB*: Start of burst
- *Timestamp*: Tx time
- *EOB*: End of burst

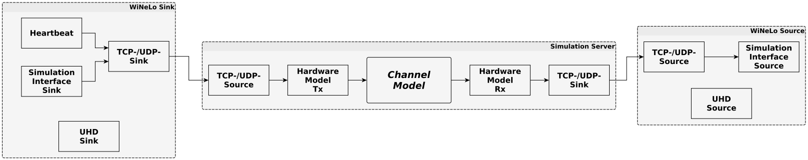
⇒ "Count" number of zeros!



Implementations

- Sample-accurate Zero Padding
- Generic (inacurate) Zero Padding
- Initial Zero Padding

Modular Design



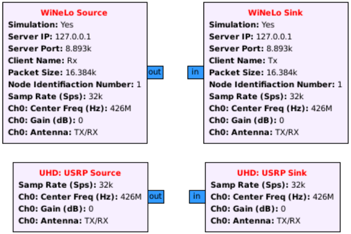
Modular design. . .

- on all layers.
- simplifies debugging.
- enables easy extensibility.
- provides an insight about the inner structure.
- enables easy replacement of individual blocks.

Simulation Interface

- Twisted for Signaling
- Sample exchange via TCP/UDP
- Seamless switching (simulation/measurement)

→ Support existing applications!

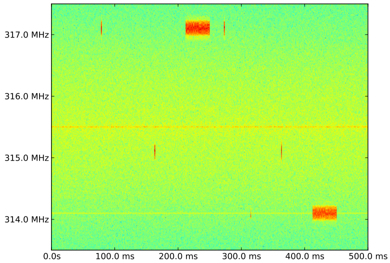


UHD Compatibility

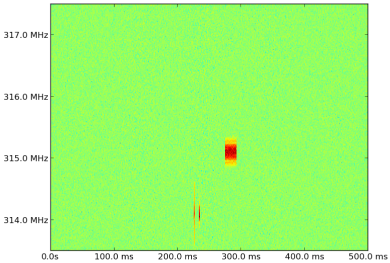
- Model hardware features (mixing, ...)
- Provide status information
- Identical methods & parameterization

P2P – Spectrograms

Measurement



Simulation



$\Longrightarrow$ DC-Offset

$\Longrightarrow$ Rx filter characteristic

$\Longrightarrow$ Length of data packet

$\Longrightarrow$ Interferer at 314,1 MHz

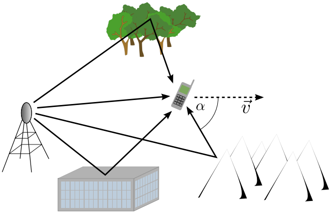
Live Demo 1


cd /home/mk/uni/code/grc-work/
./simple_trx_winelo.py --dev-addr=1 --port=12359 --net-id=1 --ampl-0=0.8mk@mk-ub:~/uni/measurements/test_apps/real$ cd /home/mk/uni/code/grc-work/
mk@mk-ub:~/uni/code/grc-work$ ./simple_trx_winelo.py --dev-addr=1 --port=12359 --net-id=1 --ampl-0=0.8
cd /home/mk/uni/code/grc-work/
./simple_trx_winelo.py --port=12360 --net-id=2 --ampl-0=0.8 --dev-addr=2mk@mk-ub:~/uni/measurements/test_apps/real$ cd /home/mk/uni/code/grc-work/
mk@mk-ub:~/uni/code/grc-work$ ./simple_trx_winelo.py --port=12360 --net-id=2 --ampl-0=0.8 --dev-addr=2
cd /home/mk/uni/code/py-scripts/telnet_traffic/
netcat 127.0.0.1 12359mk@mk-ub:~/uni/measurements/test_apps/real$ cd /home/mk/uni/code/py-scripts/telnet_traffic/
mk@mk-ub:~/uni/code/py-scripts/telnet_traffic$ netcat 127.0.0.1 12359
cd /home/mk/uni/code/py-scripts/telnet_traffic/
netcat 127.0.0.1 12360mk@mk-ub:~/uni/measurements/test_apps/real$ cd /home/mk/uni/code/py-scripts/telnet_traffic/
mk@mk-ub:~/uni/code/py-scripts/telnet_traffic$ netcat 127.0.0.1 12360
0:PER_FHAH- 1:Nettest* 2:
2013-07-01 08:41:28

Content

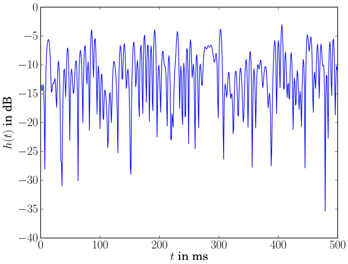
The Wireless Radio Channel

- How the wireless radio channel behaves depends largely on the environment of the system
  - Frequency band
  - Indoor vs. outdoor
  - Movement speed
  - Symbol period/data rate
  - Position of objects



- Multiple paths with different delays and phases
- Moving the receiver changes the phases resulting in interference
- Movement also affects the perceived carrier frequency (Doppler shift)

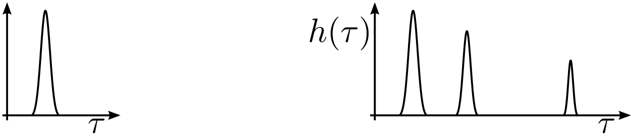
Channel Models



- The fluctuation of the received power is called fading
- Fading depends largely on
  - the frequency band
  - movement speed of transmitter, receiver and scatterers
  - position of transmitter, receiver and scatterers
- Channel models specifically tailored to a certain propagation environment can be used to test a system

The Channel Impulse Response

- A wireless radio channel can be described by the channel impulse response
- Imagine a short pulse is sent by the transmitter
- The signal at the receiver consists of all "echos" of the transmitted pulses: the channel impulse response.

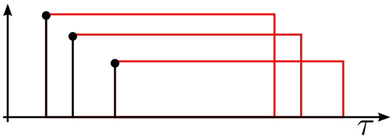


(a) transmitted impulse

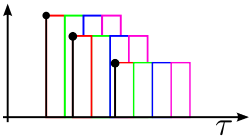
(b) channel impulse response $h(\tau)$

Intersymbol Interference

- How does the length of the CIR (delay spread) affect the transmission of data?
- If the delay spread is short compared to the symbol period only the echos of the same symbol interfere (frequency flat)
- A relatively long delay spread results in Intersymbol Interference (frequency selective)



(a) frequency flat

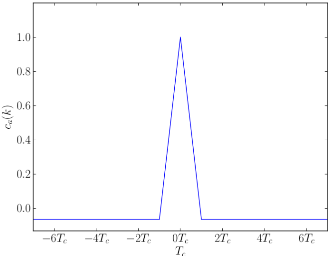


(b) intersymbol interference

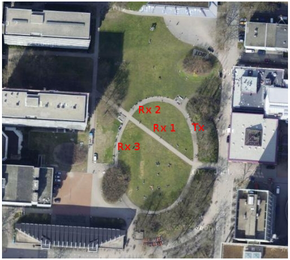
- When designing a system the expected radio channel has to be considered

Channel Sounding

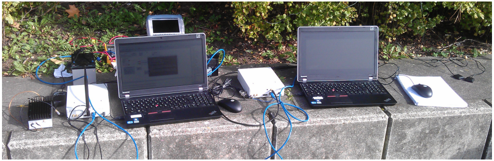
- Measuring the CIR is called Channel Sounding
- The easiest way is to just transmit a short pulse. But the Signal-to-Noise Ratio is bad
- A correlation channel sounder exploits the autocorrelation properties of maximum length sequences (MLS)
  - The transmitter sends an MLS
  - The receiver correlatates the received signal with the same MLS



Channel Sounding: Measurement Setup



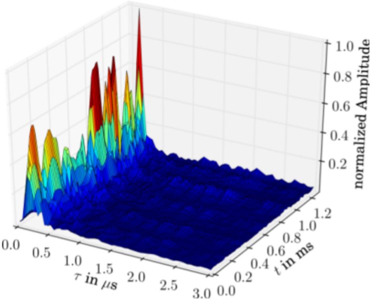
(a) Forum @KIT (Google maps)



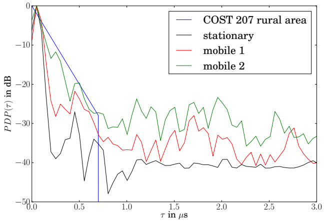
(b) Measurement Setup

- Two USRP N210 both equipped with a GPS Disciplined Oscillator (GPSDO)
- Oscillators of the transmitter and receiver have to be synchronized for measuring the Doppler spectrum
- Sample rate is too low for indoor measurements

Channel Sounding: Measurement Results



(a) CIR with a moving receive antenna



(b) Comparison with COST207 rural area model

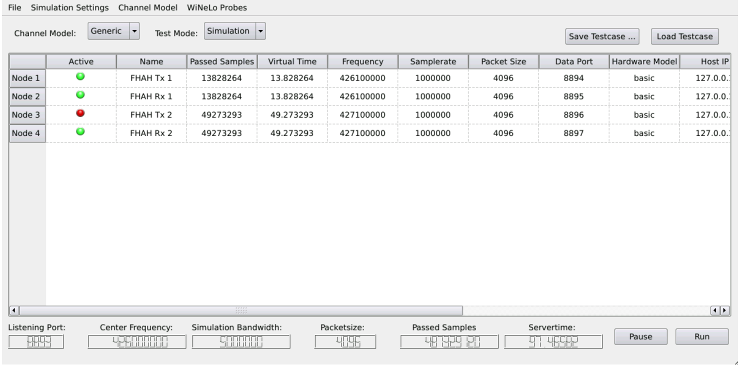
Channel Models in WiNeLo

- WiNeLo comes with some channel models: AWGN, Rayleigh, COST207
- Every GNU Radio block can be used: gr-channels
- Channel models can be created from channel sounder measurements: very basic and still experimental

Outline

Outlook

- Clean up code base
- Alpha release in 2014
- Add more HW & channel models
- Centralized test management with WiNeLo integration



Questions?

Thanks for your attention!

⇒ **github.com/no-net**

⇒ **github.com/gbaier**