Wireless Networks In-the-Loop

gr-winelo – A GNU Radio Network Emulator

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Outline

1. The Idea
2. Basic Principles and Implementation
3. Channel Models
4. Outlook
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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 measurements and simulations
→ Iterative improvement 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**
  - Ever tested a network with 5+ nodes in different arrangements?

- **Only one codebase**
  - No need for Matlab, ns3, ...

- **Easy Debugging**
  - Set breakpoints on the air link!

- **"Controllable realism"**
  - Turn impairments on/off seperated from each other

⇒ Reduced development time & increased feelgood factor!
Inhalt

1 The Idea

2 Basic Principles and Implementation

3 Channel Models

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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 (inaccurate) Zero Padding
- Initial Zero Padding
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

⇒ DC-Offset
⇒ Rx filter characteristic
⇒ Length of data packet
⇒ Interferer at 314,1 MHz
Live Demo 1
Content

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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)
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)

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 correlates 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
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## Outlook

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

<table>
<thead>
<tr>
<th>Channel Model</th>
<th>Name</th>
<th>Passed Samples</th>
<th>Virtual Time</th>
<th>Frequency</th>
<th>Samplerate</th>
<th>Packet Size</th>
<th>Data Port</th>
<th>Hardware Model</th>
<th>Host IP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Node 1</td>
<td>FHAH Tx 1</td>
<td>13828264</td>
<td>13.828264</td>
<td>426100000</td>
<td>1000000</td>
<td>4096</td>
<td>8894</td>
<td>basic</td>
<td>127.0.0.1</td>
</tr>
<tr>
<td>Node 2</td>
<td>FHAH Rx 1</td>
<td>13828264</td>
<td>13.828264</td>
<td>426100000</td>
<td>1000000</td>
<td>4096</td>
<td>8895</td>
<td>basic</td>
<td>127.0.0.1</td>
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<tr>
<td>Node 3</td>
<td>FHAH Tx 2</td>
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<td>49.273293</td>
<td>427100000</td>
<td>1000000</td>
<td>4096</td>
<td>8896</td>
<td>basic</td>
<td>127.0.0.1</td>
</tr>
<tr>
<td>Node 4</td>
<td>FHAH Rx 2</td>
<td>49273293</td>
<td>49.273293</td>
<td>427100000</td>
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<td>8897</td>
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<td>127.0.0.1</td>
</tr>
</tbody>
</table>
Questions?

Thanks for your attention!

⇒ github.com/no-net
⇒ github.com/gbaier