HAMMER - enabling hybrid beamforming and massive mimo through learning

GOALS

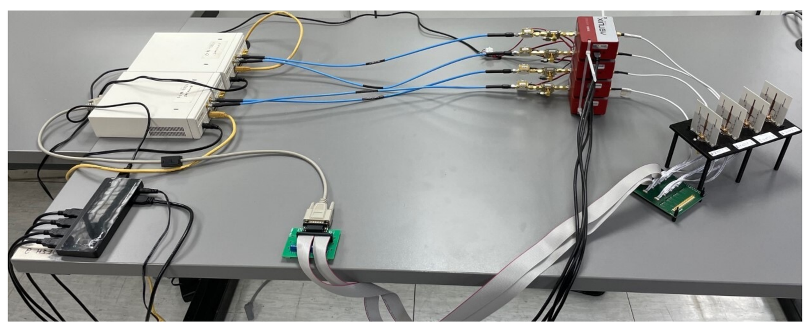
1. Development of a Multiport Parasitic Array Radiator with electronically steerable patterns and integration of the antenna to the w-iLab.t testbed.
2. Hybrid beamforming setup enabled by SDR (USRP X310)
3. Performance of extensive measurements in the testbed facilities using the provided mobility toolkit and 5G NR waveforms.
4. Development of deep learning (DL) schemes for beamforming and channel estimation through measurements.
5. Development of sandbox for link optimization test and a radio environment map (REM) service as virtual network function (VNF). Use of container swarm as the HAMMER cloud implemented on the Virtual Wall.
6. Development of a measurement collection service as VNF, a real-time monitoring app and a generative adversarial network (GAN) for the development of the proactive beamformer

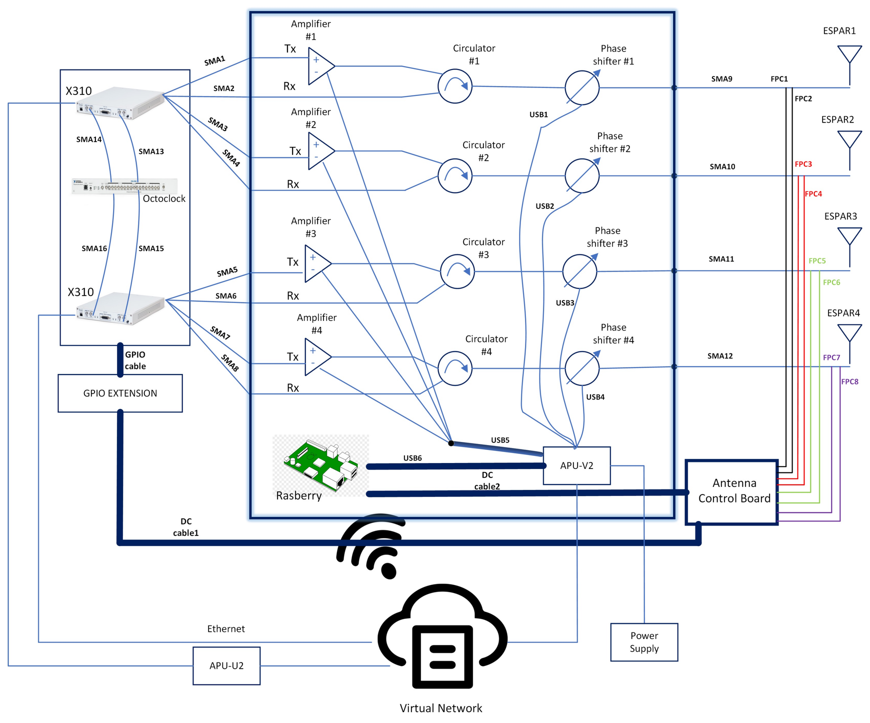
CHALLENGES

1. Design of an array that with only four RF chains provides 81 beam states.
2. The investigation of non-conventional massive MIMO and hybrid beamforming techniques to meet beyond 5G requirements.
3. Implementation of advanced beamformers with deep learning mechanisms hosted on mobile edge. *"Training the radio"*
4. Joint optimization of transmission over the available RF chains by the hybrid beamformer.
   a. Beamforming on the antenna
   b. Use of phase shifters
   c. And possible digital beamforming
5. Use of 5G NR waveforms over high-bandwidth SDRs and mobile measurements

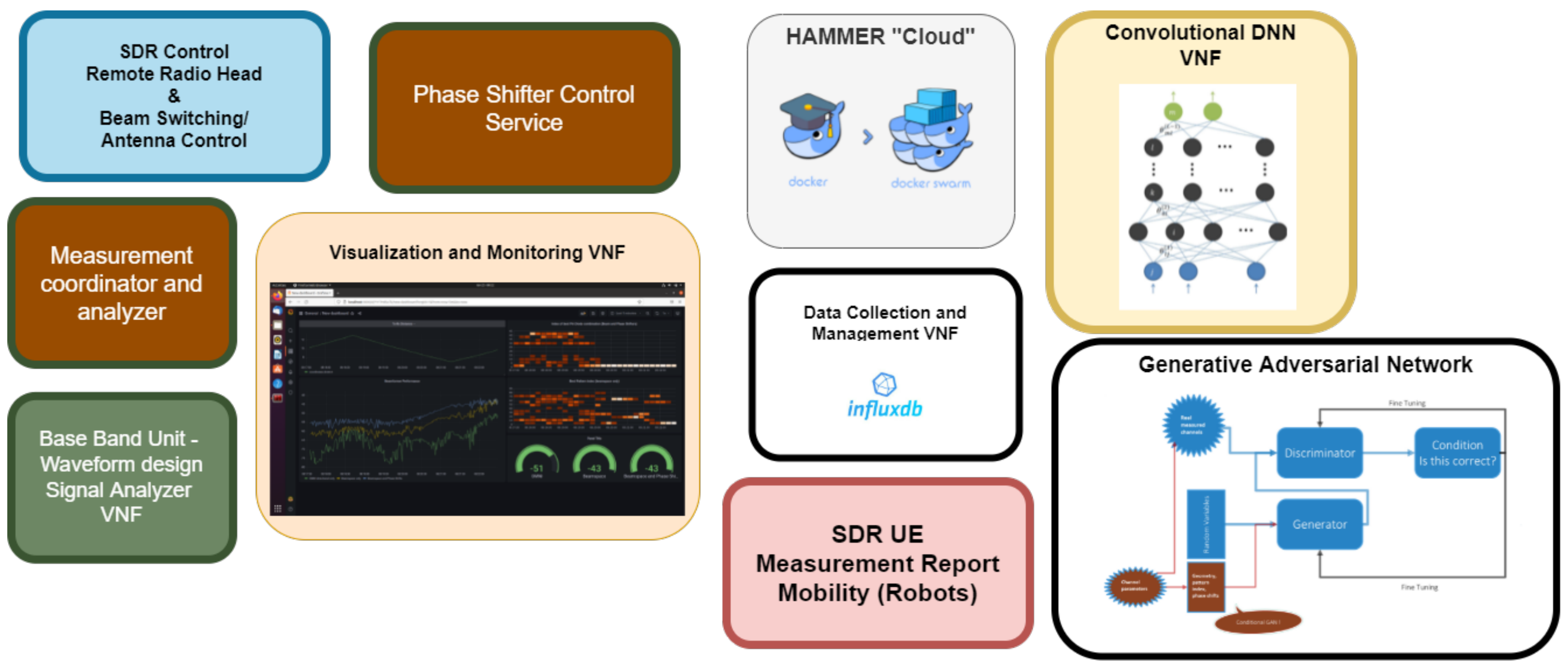
DEMO SETUP

1. Implementation and Integration of the HAMMER SDR Transceiver

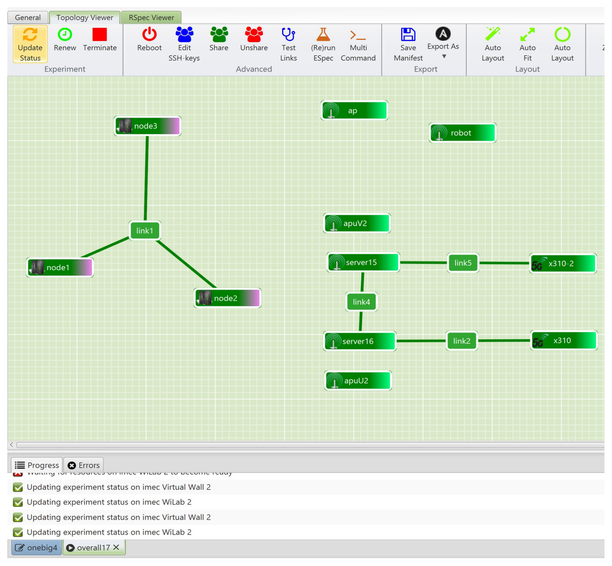


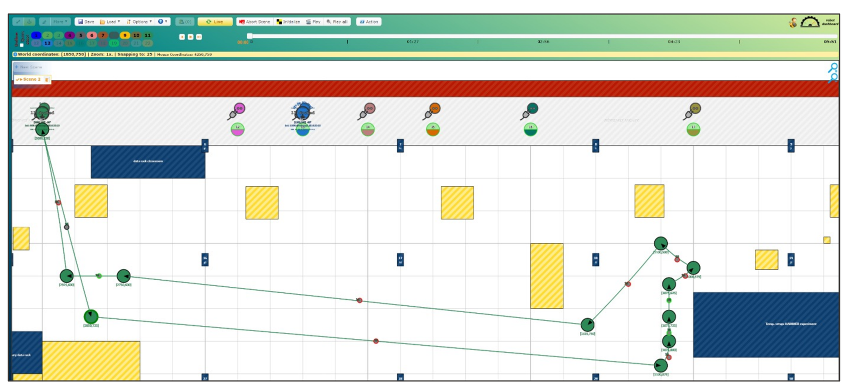


2. Development and deployment of HAMMER software & VNFs

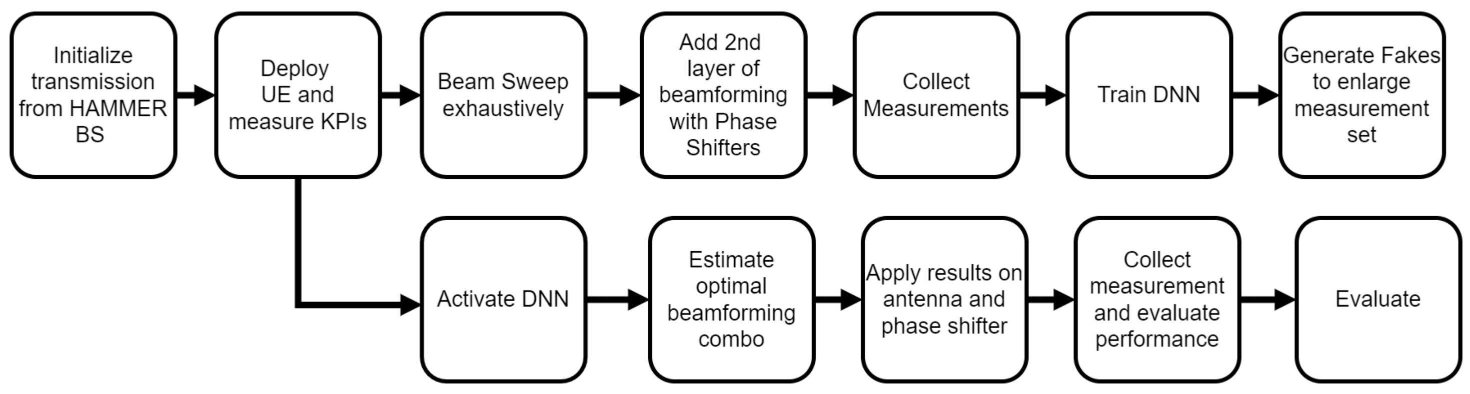


3. Deployment of experiments in Fed4Fire+



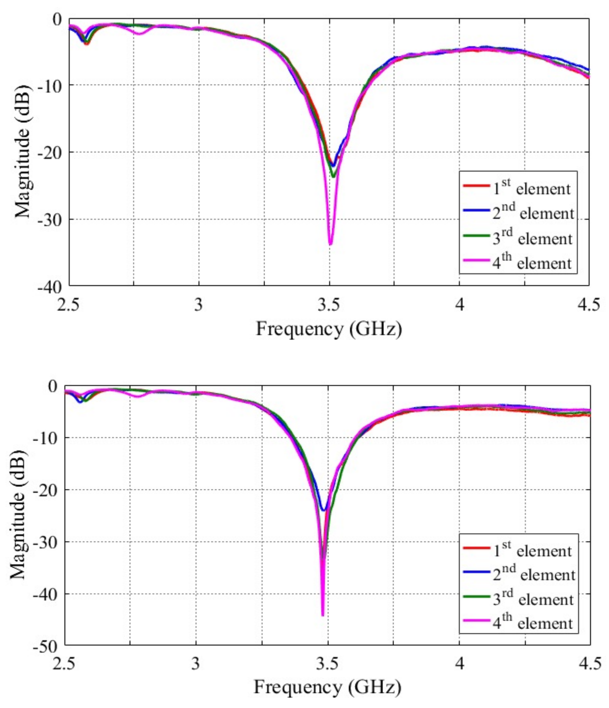


4. Experimentation in TWO STAGES: TRAINING VS TESTING

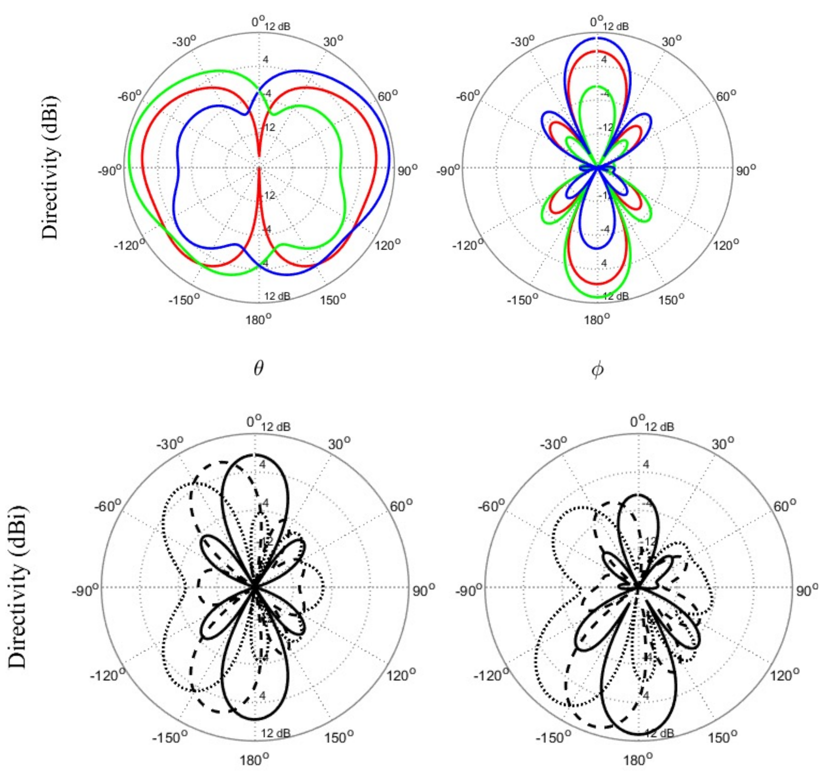


RESULTS

Successful design, development, integration and validation of the multi-pattern steerable antenna

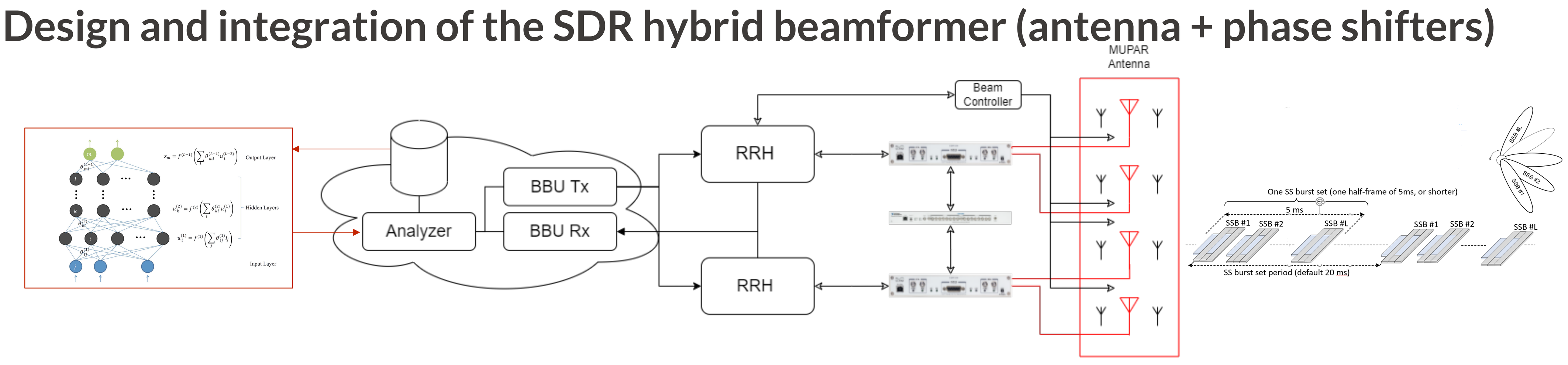


S-parameters for the 4 actives at 3.5GHz

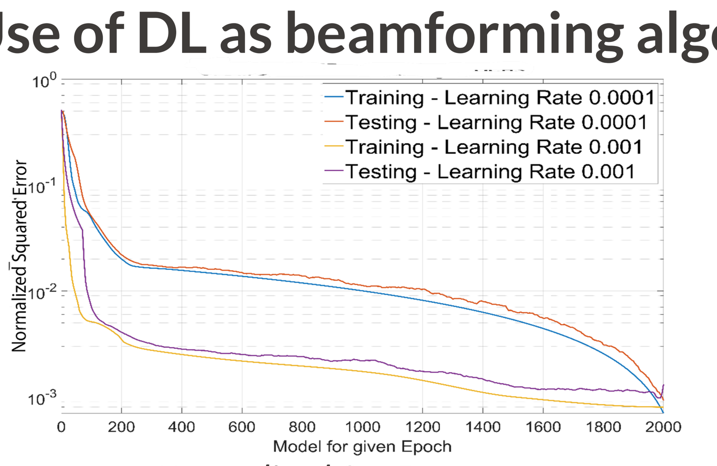


Pattern reconfiguration examples

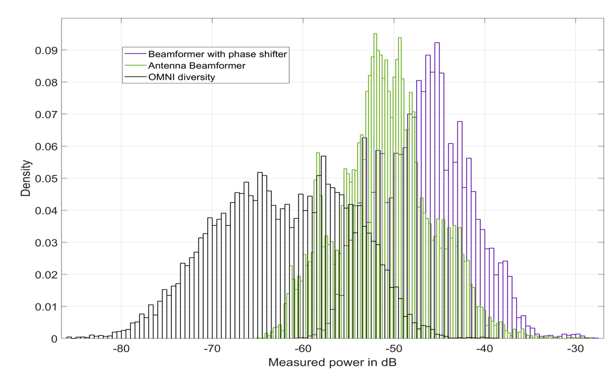
Design and integration of the SDR hybrid beamformer (antenna + phase shifters)



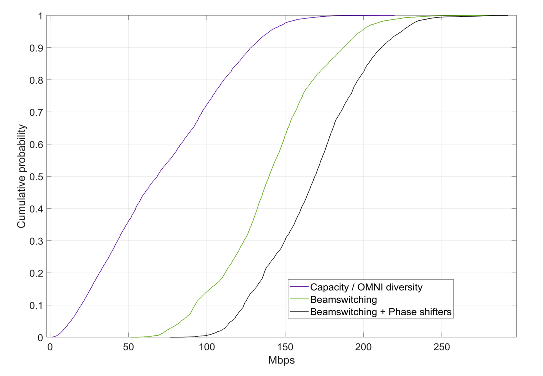
Use of DL as beamforming algorithm – Training, testing, validation



Normalized Sq. Error
Successful Model Training - Small deviation during testing



Beamforming gain histograms
>15 dB for 50% (antenna + phase shifters)



Capacity CDFs
Tripling(!) vs. 4-element diversity

CONCLUSIONS

1. Deep neural networks (DNNs) can be used for non-conventional beamforming and performance asymptotically approaches optimum.
2. The use of phase shifters together with the antenna significantly improves performance.
3. MUPAR antenna features can give a new point of view for the new generation base stations (BSs) (especially the indoor BSs employed in micro/pico-cells) offering a strong economic impact.
4. A scalable cloud/virtualized environment can support radio functions. C-RAN brings significant reconfiguration benefits.
5. Hybrid beamforming can be used to decrease the transmission power levels of the BSs, prevent unnecessary broadcasting with omnidirectional fixed patterns and achieve a minimization of the exposure to EM radiation.

The Fed4FIRE+ experience

- Gained access to hardware and software resources, that otherwise could not be exploited due to increased costs.
- Gained knowledge and applied research experience in a plethora of scientific fields in wireless communications.
- Diversity of available resources, High availability, Short learning curve.
- Easy, remote access through generally stable tools (very important in the Covid-era)
- Opportunity to work with the w.iLab.t team consisting of highly-trained, scientifically-acclaimed researchers & engineers. Very easy communication, extremely efficient support.