Understanding Channel State Information in Massive MIMO Wireless Communication

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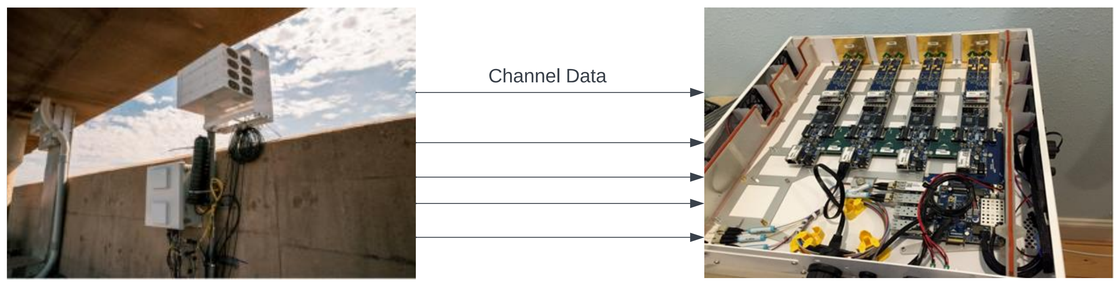
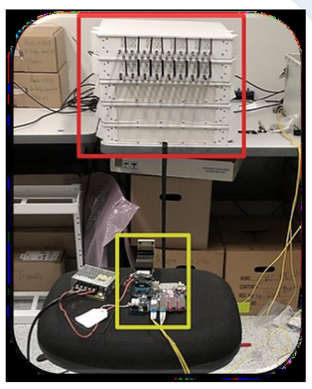
Introduction

- The Reconfigurable Ecosystem for Next-generation End-to-end Wireless project, also known as the RENEW project, provides an ***open-source massive MIMO platform*** for research in wireless networking.
- This MIMO technology allows researchers to use a method called Multi-User Beamforming, which lets base stations utilize numerous antennas to simultaneously send streams of data to multiple users. These base stations rely on ***Channel State Information*** to enable transmit and receiver beamforming.
- To understand CSI statistics in massive MIMO, we are developing a tool that will visually and statistically fit different probability distributions to the channel data collected from the Iris SDRs.



Hardware Setup

- The RENEW massive MIMO platform employs the ***Iris Software Defined Radio*** as its building block, with each SDR supporting two RF chains.
- Our hardware includes ***2 user equipment clients*** and a ***base station that holds 64 antennas***, with each antenna containing a radio.
- This Base station is connected to a Linux-based host machine through Fiber. We use this to access the Iris users in the vicinity of the base station.

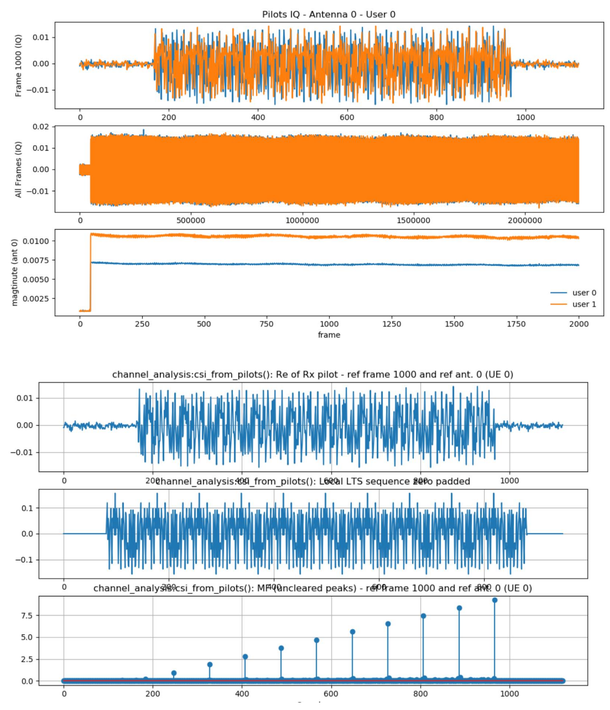


Software Setup

- The ***RENEWLab*** is one of the main software frameworks utilized in this project. This program provides researchers with methods for channel characterization, waveform evaluation, and the creation of datasets for machine learning.
- RENEWLab's C++-based framework ***Sounder*** is used to collect, record, and read the channel data obtained from these base station antennas.
- We are developing our tool in Python so that we can parse and analyze this channel data.

Method for Collecting Channel State Information

- To determine the CSI, we need to collect a lot of channel data. We do this by sending known sequences from the UE clients to the base station. Once the signals reach the receiver, it is used to estimate the channel.
- Sounder from the RENEWLab allows us to quickly transmit and collect data from one SDR to another. Running Sounder will pass a configuration file that contains parameters for the experiment
- This configuration file ***topology.json*** is then used to generate an HDF5 file, which contains raw IQ samples and metadata that can be used to determine the channel data.
- The data is then analyzed using ***plot_hdf5.py***, which then produces readable data points needed in the calculation of CSI along with numerous plots, including the plots shown to the right.



Channel State Information Statistical Analysis

- From the data in the HDF5 file, we can generate the CSI as an array with this structure: [Frames, Cells, Users, Pilot Repetitions, Base Station Antennas, Subcarriers]
- Using our Python tool, we can find the size and magnitude of this array and use it to create a ***histogram of the CSI***.
- Next, we can fit different probability distributions to the histogram, such as the ***Rayleigh Fading and Rician Fading distributions***, and check if they resemble the CSI or not. The Rayleigh and Rician PDFs are shown to the right.
- We accomplish this by matching the first two moments of the CSI, the expected value and variance, with the empirical moments to overlay a specific distribution on top of the data. From this, we can do a statistical test on which distribution is the best fit for the dataset

Conclusion

- Overall, The development of our Python tool will help increase the efficiency of the RENEWLab framework by providing a simplified method for interpreting channel state information.
- Future work on this experiment would include comparing the CSI histogram to other probability distributions to see which is the perfect fit for the data.

References

- Bejarano, O. (2021, April 21). Introduction. RENEW Wireless. Retrieved August 1, 2022, from https://wiki.renew-wireless.org/en/overview/introduction
- Tse, D., & Viswanath, P. (2005). Fundamentals of Wireless Communication (1st ed.). Cambridge University Press.