Enhancing User Detection

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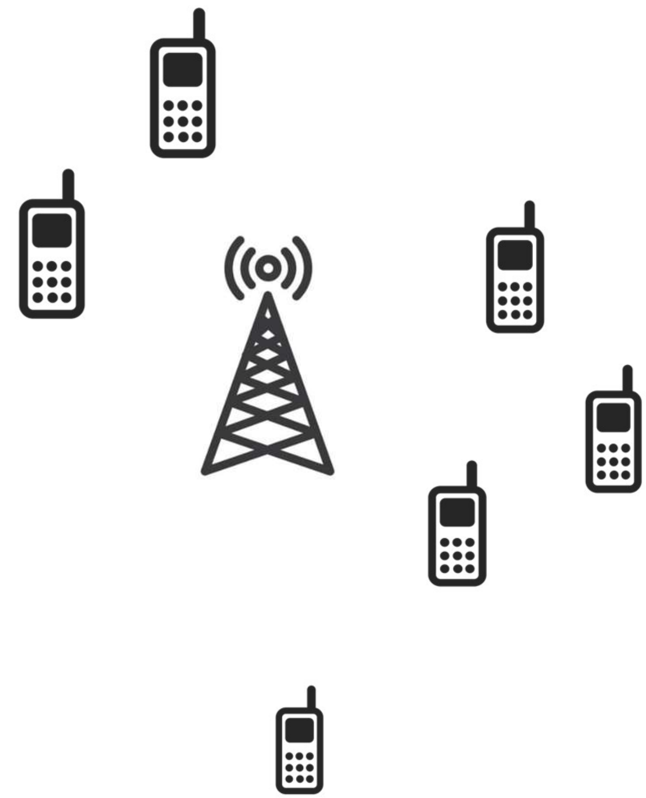
Problem Statement

My project focuses on enhancing wireless communication infrastructure.

Particularly, user detection.

If a given region has 1024 users and we know that at any given time 40 of those users are active, we want to determine the identity of the 40 who are active.

We have been unrolling IST.

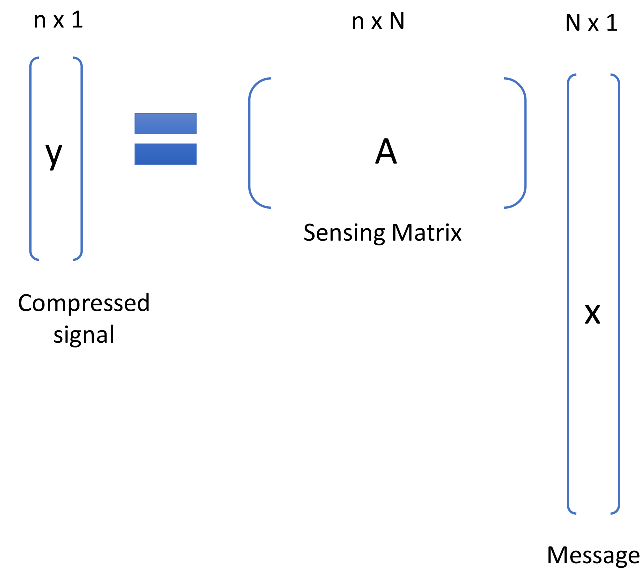


Problem Statement cont.

The message, x, corresponds to the IDs of the active users on the channel

A is the sensing matrix filled with Gaussian random variables

y is the compressed signal that will be demodulated



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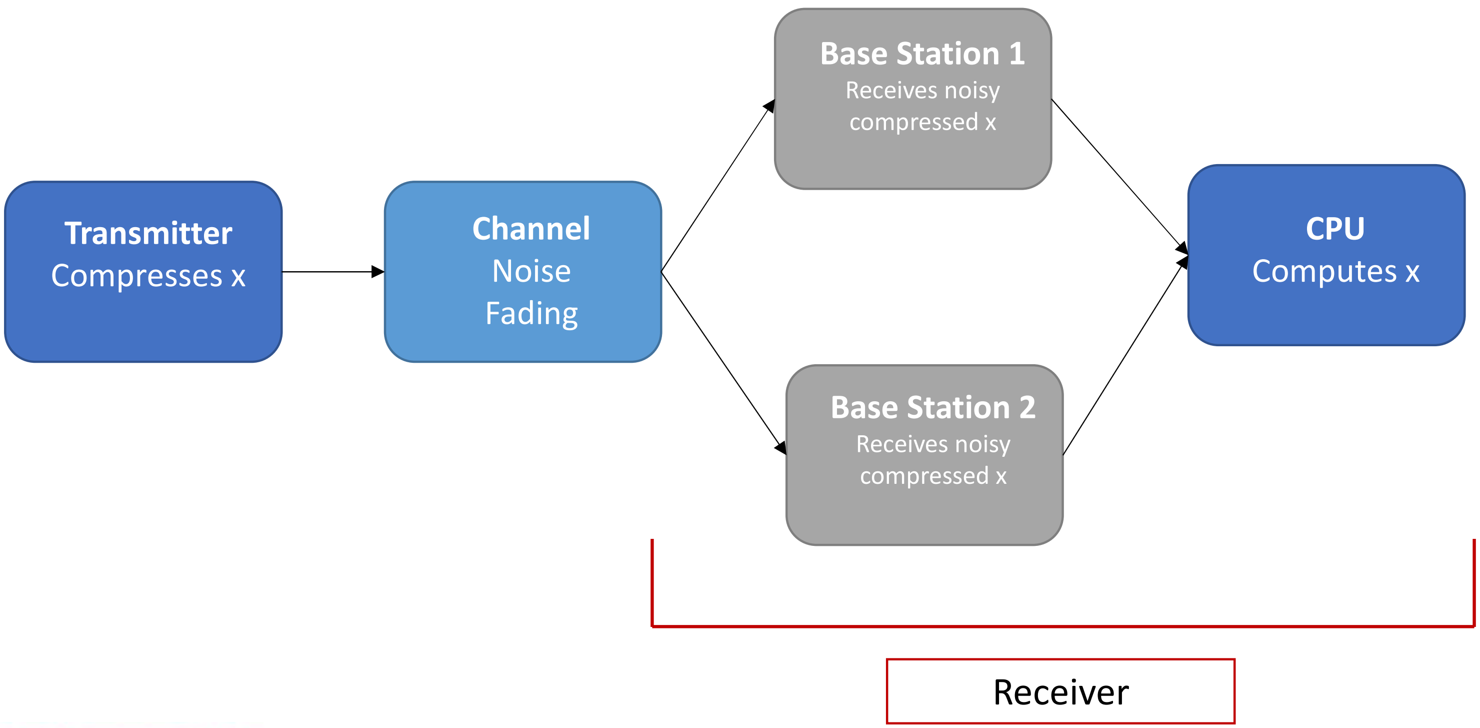
System Overview



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Transmitter

Each user generates a signal ‘x’ with one non-zero entry
The index of the entry corresponds to their unique identifier

A compressed signal ‘y’ is sent through the channel
‘y’ corresponds to one column of the sensing matrix

```
x:
[[0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]]
```

```
y:
[[ 0.18609062 -0.02841877  0.60752074 -0.20797172 -0.29655924 -0.2904473
  -0.11436338]]
```

Small scale shown

Transmitter

The Sensing Matrix, ‘A’, is used to compress the message to be sent

It is composed of Gaussian random variables with variance equal to the inverse of the number of measurements

This ensures that the energy of each column of the matrix is one

```
A:
[[ 0.61907209  0.43591044  0.04566556 -0.4116875   0.1364696   0.3262833
  -0.30159148]
 [ 0.46570521 -0.04371449 -0.22909904 -0.34738089 -0.13852926 -0.2542261
  -0.44702077]
 [ 0.1752229   0.43110585  0.70911771 -0.25505137  0.09627508 -0.23343727
   0.67543818]
 [ 0.18609062 -0.02841877  0.60752074 -0.20797172 -0.29655924 -0.2904473
  -0.11436338]
 [-0.1175651   0.36792376 -0.28266314  0.17120891  1.10455262  0.0615296
  -0.2994388 ]
 [-0.3547516  -0.07364754  0.06998407  0.75790943  0.12938228 -0.11989203
  -0.29684396]
```

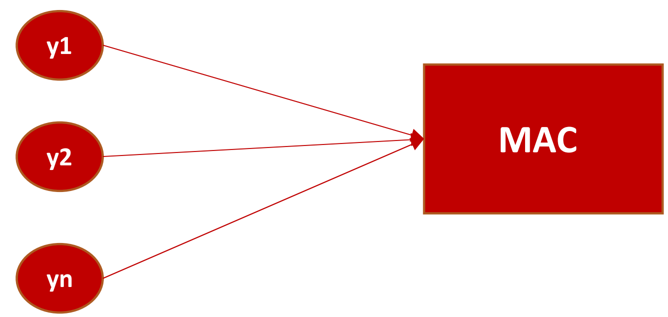
Only small part of ‘A’ shown

Channel

We utilize a Gaussian Multiple Access Channel (MAC) that linearly combines all the messages that the users transmit.

We assume the infrastructure is in place that enables all the messages to be sent at the same time.

Note: In reality the channel combines the compressed signals, in our code we combine the original x's and then compress it because it yields the same results.



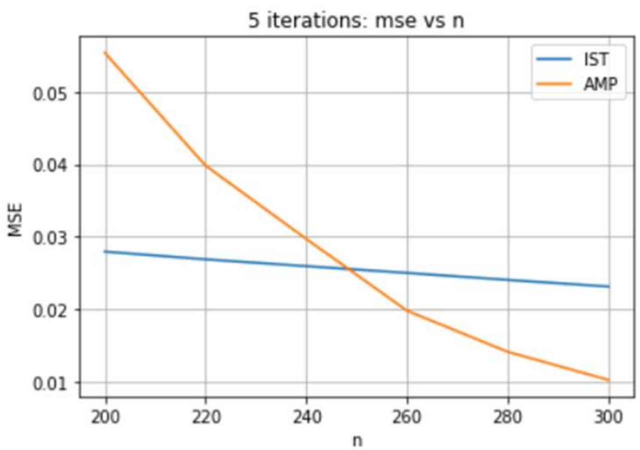

```
x:
[[0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 1. 1. 0. 1. 0. 0. 0. 0.]]

y:
[[ 9.92744371e-01  5.56025513e-01  2.57170829e-04  1.51137074e+00
   3.82626948e-01 -5.99394961e-01 -1.22892737e+00]]
```

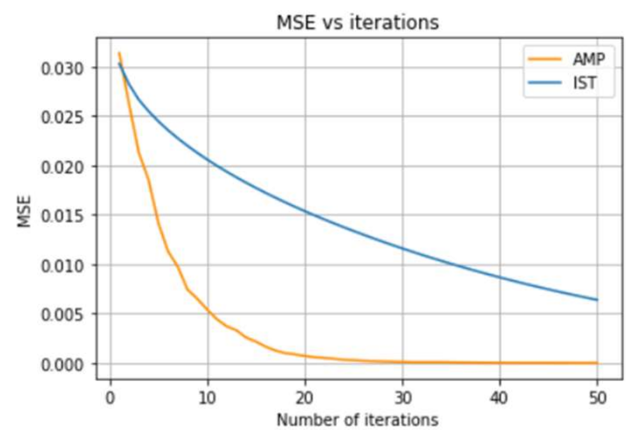
Receiver

Created and ran simulations on IST and AMP to get a baseline
AMP requires more measurements to behave efficiently. The graph on the left helped me determine how many measurements I want to take.

Then I mapped how each one operates as the number of iterations increases.



N = 1024 | k = 40



n = 270 | N = 1024 | k = 40
no noise

n: Number of measurements
N: Number of total users
k: Number of active users

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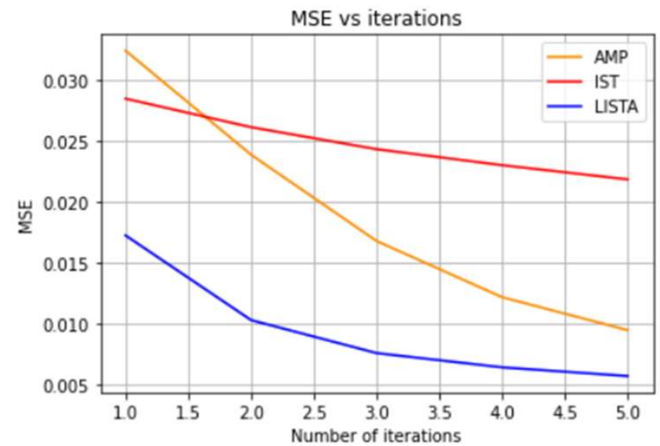
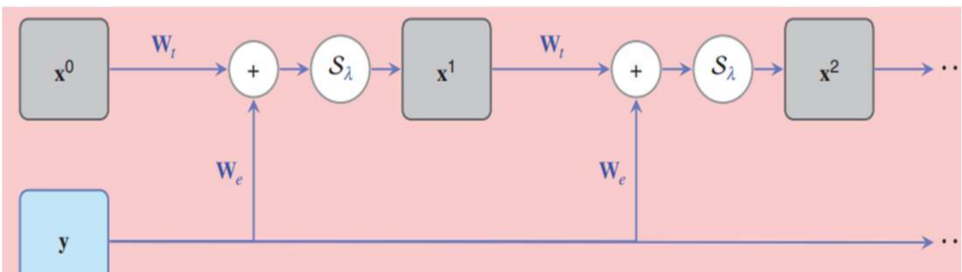
Receiver - LISTA

Developed a neural network following the flow shown in the diagram below. Designed custom network layers and weights.

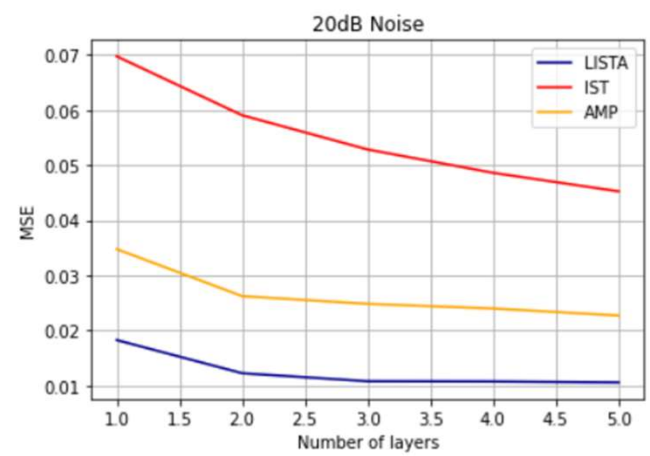
LISTA converges faster than IST and AMP with and without noise.



n = 270 | N = 1024 | k = 40



(c)



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Execution Plan

9/20	10/5	10/24	11/15	11/25
Simulate and evaluate multi-bit transmission through noisy channel	Establish a baseline by comparing BER/MSE of different models	Create data set	Run training loop and test	Add noise and fading **fading not completed yet*
Monte Carlo performance tests	Read about algorithm unrolling and deep learning	Determine what parameters to compare with	Architecture developed	Compare MSE of learned vs. unlearned
Read through papers regarding URA and channel modeling			Write background for thesis based on IST unrolling	Begin alterations based on performance evaluation results

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Validation Plan

Goal: Have learned algorithm perform better than unlearned algorithm in terms of MSE vs. iterations/layers.

Improve probability of Misdetection/False Alarm

Currently: Beating other algorithms when going through less than 12 layers.

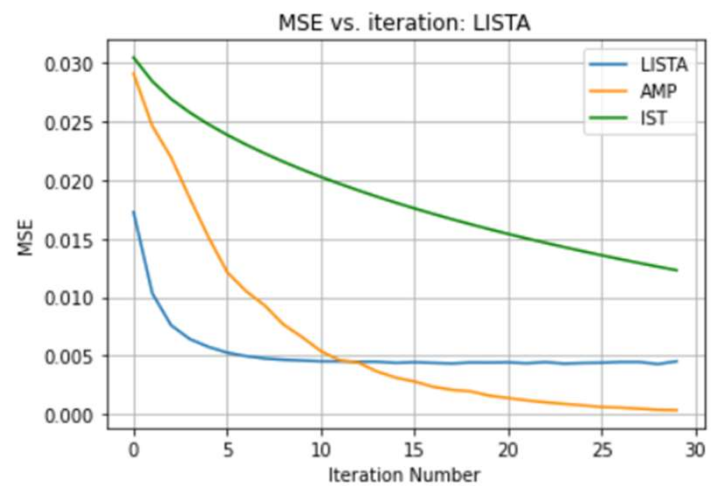
What to explore next

Work on :

- Get LISTA to continue to improve beyond 7/8 layers
- Fix the weights of first layers and keep training others

Going forward (2023):

- Add Rayleigh fading
- Expand to operate on two base stations



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