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An Efficient Technique for Channel Estimation and Performance Optimization in 5G Large-Scale MIMO System

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***Abstract*—5G networks are digital cellular networks, for which the service area is divided into small geographical cells. The paper proposed support detection (SD)-based channel estimation scheme by utilizing the CS tools to estimate the beamspace channel with low pilot overhead. The key idea of these schemes is to efficiently utilize the sparsity of mm-wave channel in the angle domain. The basic idea is to decompose the total channel estimation problem into a series of sub-problems, each of which only considers one sparse channel component (a vector containing the information of a specific propagation direction). The simulation is done using MATLAB 9.4 software. The optimized SNR value is 40dB, while previously it is 0.9 to 10dB. The NMSE value is 10-1 dB while previously it is -1dB. Therefore, simulated result shows that the proposed approach gives significant better results than existing work.**

***Keywords*— Channel Estimation, Beam-space, 5G, MIMO, OFDM, Antenna, Array.**

I. Introduction

5G networks are digital cellular networks, for which the service area is divided into small geographical cells. The 5G wireless devices in a cell communicate by radio waves with a local antenna array and low power automated transceiver (transmitter and receiver) in the cell, over frequency channels assigned by the transceiver from a pool of frequencies that are reused in other cells. The local antennas are connected to transmission electronics connected to switching centers in the telephone network and routers for Internet access by high-bandwidth optical fiber or wireless backhaul connections. As in other cell networks, a mobile device moving from one cell to another is automatically handed off seamlessly to the current cell. 5G can support up to a million devices per square kilometer, while 4G supports only one tenth of that capacity. The new 5G wireless devices also have 4G LTE capabilities, as the new networks use 4G for initially establishing the connection with the cell, as well as in locations where 5G access is not available. [1]

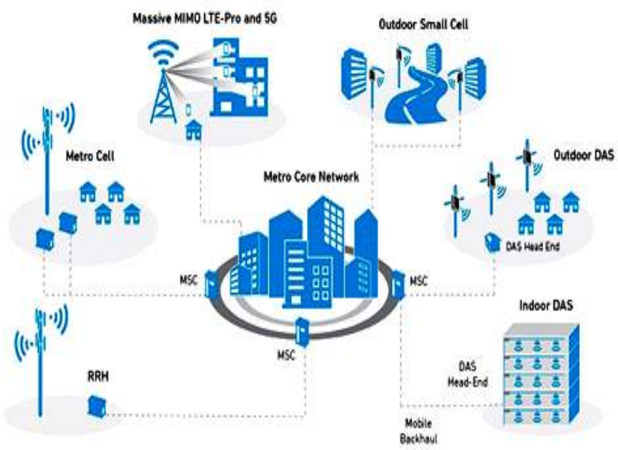

Figure 1: Wireless Infrastructure

Several network operators use millimeter waves for additional capacity, as well as higher throughput.[1] Millimeter waves have a shorter range than microwaves, therefore the cells are limited to a smaller size. Millimeter waves also have more trouble passing through building walls.[2] Millimeter wave antennas are smaller than the large antennas used in previous cellular networks. Some are only a few centimeters long.

Massive MIMO (multiple-input multiple-output) was deployed in 4G as early as 2016 and typically used 32 to 128 small antennas at each cell. In the right frequencies and configuration, it can increase performance from 4 to 10 times. [3] Multiple bitstreams of data are transmitted simultaneously. In a technique called beamforming, the base station computer will continuously calculate the best route for radio waves to reach each wireless device and will organize multiple antennas to work together as phased arrays to create beams of millimeter waves to reach the device.

II. Proposed Methodology

The contribution of proposed research work is as followings-

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- To make a 5G Large-Scale MIMO System model in MATLAB software.
- To assign more number of transmitter and receiver antenna as a MIMO system.
- To propose support detection (SD)-based channel estimation scheme with reliable performance and low pilot overhead.
- To measure performance parameters and optimize the better value with channel estimation.

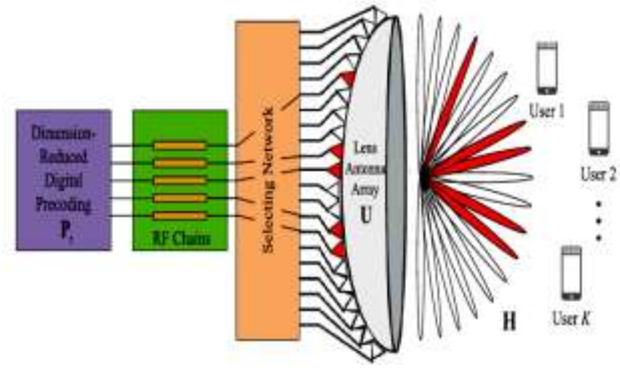

Figure 2: mm-wave massive MIMO with lens antenna array

Wireless mm-wave Massive MIMO with Lens Antenna Array the conventional channel in the spatial domain can be transformed to the beamspace channel by employing a carefully designed lens antenna array as shown in figure 2. Essentially, such lens antenna array plays the role of a spatial DFT matrix U of size N × N, which contains the array steering vectors of N orthogonal directions (beams) covering the entire space.

The basic steps of methodology is as followings-

- First design an adaptive selecting network for mm-wave massive MIMO systems with lens antenna array to formulate the beamspace channel estimation problem as a sparse signal recovery problem.
- Now apply support detection (SD)-based channel estimation scheme with reliable performance and low pilot overhead.
- This allows a system to have better performance in a fading environment.
- Then, by utilizing the special structural characteristics of mm-wave beamspace channel, we propose a SD-based channel estimation scheme with low pilot overhead.
- Millimeter-wave (mm-wave) massive MIMO with lens antenna array can considerably reduce the number of required radio-frequency (RF) chains by beam selection.
- However, beam selection requires the base station to acquire the accurate information of beamspace channel.

The contributions of this research can be summarized as follows:

(1) Design an adaptive selecting network, which consists of a small number of 1-bit phase shifters, to replace the recently proposed selecting network in mm-wave massive MIMO with lens antenna array. For data transmission, the proposed adaptive selecting network can select beams like the traditional one, while for channel estimation; it can perform as a combiner to obtain the efficient measurements of beamspace channel. Then, based on the proposed adaptive selecting network, we formulate the beamspace channel estimation problem as a sparse signal recovery problem.

(2) Propose a SD-based channel estimation scheme. The basic idea is to decompose the total channel estimation problem into a series of sub-problems, each of which only considers one sparse channel component (a vector containing the information of a specific propagation direction). For each channel component, we first detect its support (i.e., the index set of nonzero elements in a sparse vector) by exploiting the structural characteristics of mm-wave beamspace channel. Then, the influence of this channel component is removed, and the support of the next channel component is detected in a similar method.

III. Simulation And Results

The implementation of the proposed algorithm is done over MATLAB 9.4.0.813654 (R2018a). The signal processing toolbox helps us to use the functions available in MATLAB Library for various methods like Windows, shifting, scaling etc.

The following simulation parameters are taken for script writing and simulation of the proposed concepts-

Table 1:
Simulation Parameters

Sr. No.	Parameter	Value
1	Total Number of Instants Q	240
2	Normalized MSE (NMSE)	10^{-1}
3	SNR (SNR)	40
4	No of transmit receiving wires	550
5	Normalized MSE	0.005-0.015
6	Capacity	15 bps/Hz

In table 1, simulation parameters are showing which is taken during the execution of MATLAB script. In this number of transmitter and number of receiver antenna keep change.

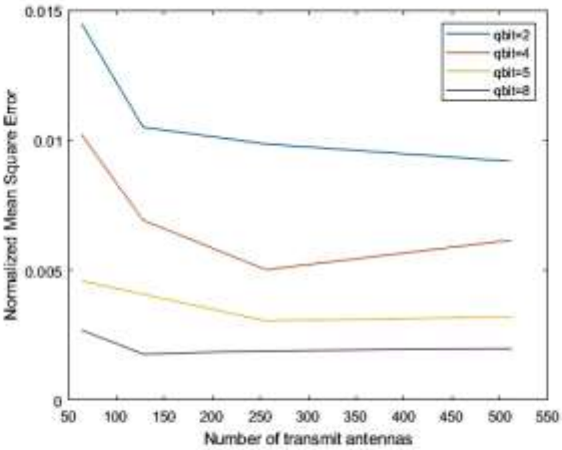

Figure 3: NMSE vs No of transmitter antenna

Figure 3 shows the Channel was constructed according to multi transmitter (M) and it is directly related NMSE so, we can see the above graph the relation of NMSE and Mt. While increasing the Mt, NMSE is decreasing as it is expected. Also, after 256 transmitter antennas number NMSE is keeping the same NMSE value so 128 is optimum number of antennas.

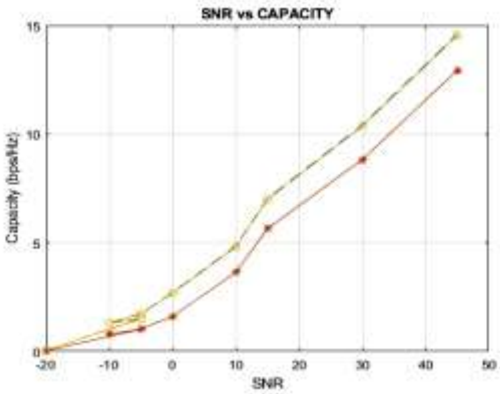

Figure 4: Capacity vs SNR

Figure 4 shows the graph which is provided that the increased SNR values capacity is increasing as an expected. The estimated channel capacity is shown with red line and its capacity less than perfect and error channel's. Also, perfect channel capacity is higher than the error channel's because error decreases the capacity of the channel.

Table 2:
Result comparison

Sr No	Parameters	Previous Work	Proposed Work
1	Method	Time and Spatial Correlation	Support Detection
2	Modulation	Q-QAM	M-QAM
3	SNR	0.9 – 10 dB	40 dB
4	NMSE	-1 dB	10^{-1} dB

Table 2 is showing comparison table of proposed and previous work in terms of modulation scheme, SNR and NMSE. The optimized SNR value is 40dB, while previously it is 0.9 to 10dB. The NMSE value is 10^{-1} dB while previously it is -1dB.Therefore, simulated result shows that the proposed approach gives significant better results than existing work.

IV. CONCLUSION

Therefore the performance analysis of this research work proves that the proposed SD-based channel estimation scheme can detect the support of sparse beamspace channel with higher accuracy than the classical CS algorithms. The complexity analysis further shows that SD-based channel estimation enjoys low complexity, which is comparable with that of LS algorithm. Simulation results verify that the proposed SD-based channel estimation scheme can achieve much better NMSE performance than conventional schemes, even in the low SNR region. This makes it more attractive for mm-wave massive MIMO systems with lens antenna array.

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