

# A SURVEY ON TECHNIQUES TO MITIGATE PILOT CONTAMINATION IN 5G MASSIVE MIMO

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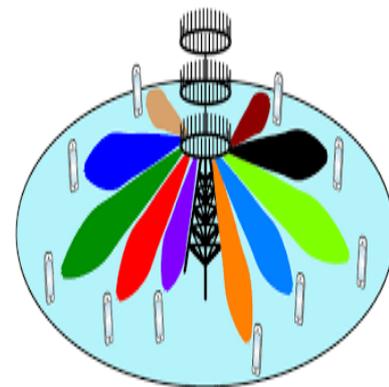
**Abstract:-** An antenna technology for wireless communications in which multiple antennas are used at both side the source (transmitter) and the destination (receiver), it's called "MIMO". A new idea in cellular MIMO is the use of large Number of BS antennas to receive several single-antenna terminals simultaneously. It's called "massive MIMO". Which provide better throughput and better spectrum efficiency with TDD operation. Massive MIMO is key technology to handle the rapid growth of data traffic. In the "5G" massive MIMO setting, The terminals are assumed fully loaded and a main impairment to the performance comes from the inter-cell pilot contamination, i.e., interference from terminals in neighbouring cells. By using the same pilots as in the home cell. This Type of pilot overhead can be reduced by reusing pilot sequences in nearby cells; however this method introduces interference in the channel estimation phase, the so-called "pilot contamination" effect. In this Paper, we study the effect of pilot contamination in 5G environments and investigate schemes to mitigate it.

**Key Words:-** MIMO, Massive MIMO, Pilot Contamination, 5G.

## 1. INTRODUCTION

The MIMO antenna technology has become an efficient Technology in modern cellular wireless communication systems. MIMO (multiple input, multiple output) is an antenna technology for wireless communications in which multiple antennas are used at both the source (transmitter) and the destination (receiver). There are several other antennas technology like MISO (multiple input multiple output) and SIMO (single input multiple output) apart from MIMO technique. A single antenna is fixed at the source and at the destination in wireless system but this technique cause problems with multipath effects [1]. Cellular communication networks are continuously evolving to keep up with the rapidly increasing demand for wireless data services. The number of wirelessly connected devices and their respective data traffic are growing rapidly as we transition into the fully networked society [2]. The growth is currently driven by video streaming, social networking, and new use cases, such as machine-to-machine communication and internet of things [3]. A fair

amount of the traffic is expected to the 5G Communication. Hence, future cellular networks need to handle urban deployment with massive numbers of connected UEs that request massive data volumes [4]. Since the cellular frequency bands are scarce, orders-of-magnitude capacity improvements are only possible by radically increasing the spectral efficiency (SE) [bit/s/Hz]. Use of massive MIMO is a promising technology that is expected to deliver high data rates as well as enhanced link reliability, coverage, and/or energy efficiency; and has therefore attracted lots of research interests. **Massive** multiple-input, multiple-output, is an extension of **MIMO**, which essentially groups together antennas at the transmitter and receiver to provide better throughput and better spectrum efficiency[5]. Massive MIMO, as illustrated in Fig. 1,



**Fig-1: STRUCTURE OF MASSIVE MIMO**

Theoretically, massive MIMO technology can offer some specific advantages towards the wireless communication system. Massive MIMO wireless system refers to a very large number of antennas with orders of magnitude, e.g., 100 or more [6] are equipped at the cellular BSs to enhance the system capacity, spectral and energy efficiency in both the downlink and uplink communications [7]. In essence, massive MIMO BSs exploit a very high degree of spatial multiplexing to improve the system capacity. As the BSs are deployed with a large number of antenna arrays, simple linear Beamforming/precoding is possible to increase the spectral and energy efficiency [9], [8], [7]. When the

number of BS antennas goes to infinity, the system capacity is largely limited by the inter-cell interference because of the pilot contamination. Therefore, pilot pollution has become one of the main reasons for the performance loss in massive MIMO systems. The paper is organized as follows. In Section 2, the Basic information about pilot contamination. The effect of pilot contamination and the different mitigation techniques to reduce the pilot contamination are presented in Section 3 and finally Section 4 concludes this paper.

## 2. PILOT CONTAMINATION

In multi-cell systems, we cannot assign orthogonal pilot sequences for all users in all cells, Due to the limitation of the channel coherence interval. Orthogonal pilot sequences have to be reused from cell to cell. There for, the channel estimate obtained in given cell will be contaminated by pilots transmitted by users in other cells. This effect, called "Pilot Contamination"[10].

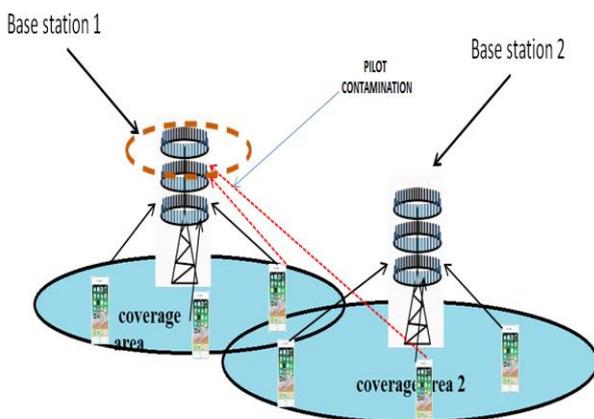


Fig-2: PILOT CONTAMINATIONS

The base station wants to know the channel responses of its user terminals and these are estimated in the uplink by sending pilot signals. Each pilot signal is corrupted by inter-cell interference and noise when received at the base station. For example, consider the scenario illustrated above where two terminals are transmitting simultaneously, so that the base station receives a superposition of their signals that is, the desired pilot signal is contaminated

### 2.1 EFFECT OF PILOT CONTAMINATION

- When estimating the channel from the desired terminal, the base station cannot easily separate the signals from the two terminals. This has two key implications:

1, The interfering signal acts as noise that reduces the channel estimation accuracy.

2, The base station unintentionally estimates a superposition of the channel from the desired terminal and from the interferer.

- Which is reduced the system performance
- Increase the Interference between Users.

## 3. METHOD TO REDUCE THE PILOT CONTAMINATION

In this chapter, we study techniques to mitigate pilot contamination in massive MIMO systems and analyse the scenarios under which they are effective in improving the channel estimation.

### 3.1 PILOT OPEN-LOOP POWER CONTROL

We study a pilot open loop power control (pilot OLPC) scheme that allows the terminal to adjust the transmit power of its pilot signal based on its estimate of the path loss to its serving BS. Pilot OLPC attempts to maximize SNR fairness of pilot signals for cell-edge terminals by compensating for their additional path loss. This path loss compensation has the intended effect of reducing overall pilot interference in the network at the cost of SNR degradation for terminals located close to the BS. OLPC provides a coarse operating point for the terminal power in terms of transmit power per RB. With closed-loop power control, the BS sends periodic power increment/decrement messages based on the SINR estimates, that defines a tighter short-term operating point. The open-loop operating point for transmit power per RB depends on two factors: (i) a semi-static base level,  $P_0$ , assumed to be same across the network, and (ii) an open-loop path loss compensation component. In presence of OLPC, the terminals with strong channel conditions at the BS back-off their transmit power reduce their SNR to the desired level. The gains in rate in a multi-cell setup with OLPC depend on the operating point  $P_0$ , the number of terminals in each cell and their distribution within the cells. We assume the criteria for goodness of channel estimates for spatial multiplexing as  $NMSE \leq 0dB$ . At  $NMSE = 0dB$ , the mean square error of channel estimation is equal to the average channel gain, which implies that half of the transmitted signal power with maximum ratio transmission is expected to be directed away from the desired terminal[11].

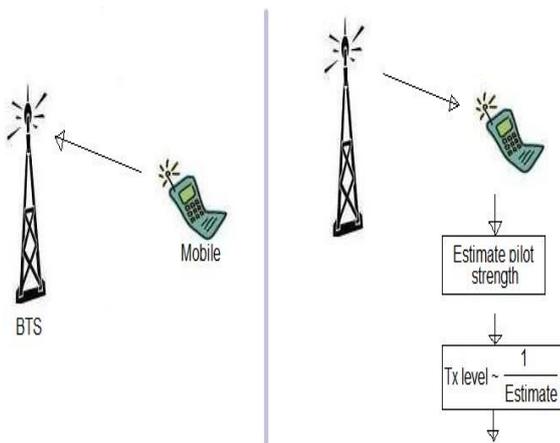


Fig-3: POLPC

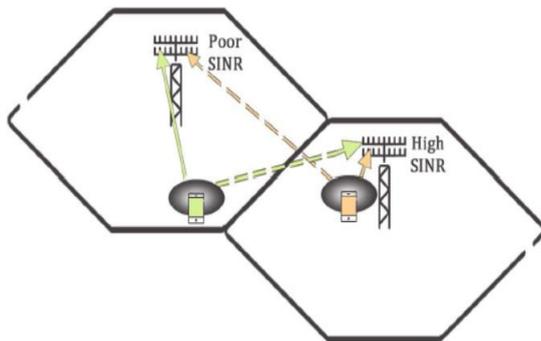


Fig-4: PILOT REUSE AT CELL-EDGE AND CLOSE TO BS

### 3.2 LESS AGGRESSIVE PILOT REUSE

Full pilot reuse leads to maximum inter-cell interference during channel estimation, which can be mitigated using a less aggressive pilot reuse factor. Pilot reuse is analogous to the traditional frequency reuse in the sense that terminals within the pilot reuse area can utilize only a fraction of the time-frequency resources, during the channel estimation phase. However with pilot reuse, each terminal is free to use all the available resources for communication for the rest of the coherence interval. The pilot reuse factor  $1/U$  is the rate at which pilot resources may be reused in the network, where  $U$  is the number of cells that are assigned orthogonal pilots. A factor  $U > 1$  always reduces the pilot contamination effect by assigning orthogonal pilots to neighbouring cells, the next-neighbour cells and so on. The total Number of unique time-frequency elements reserved for pilot transmission are  $KU$ , where  $K$  is the number of terminals per cell.

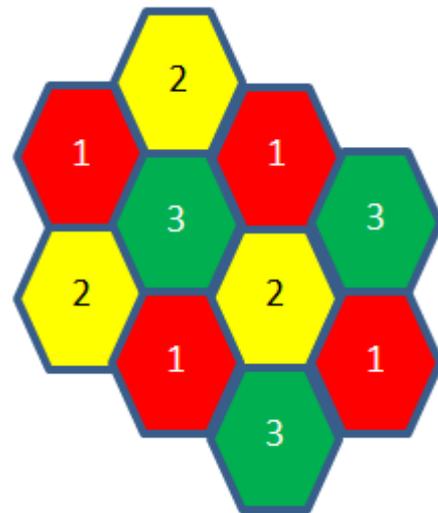


Fig-5: PILOT REUSE 1/3 PATTERN

Here we consider a less aggressive reuse factor in detail, where orthogonal pilot sequences are assigned to interfering terminals in the adjacent cells. In case of hexagonal network layout, the smallest reuse factor that ensures orthogonal pilots in adjacent cells is  $1/3$  using a reuse pattern as described in Fig.(6) To implement this reuse factor, we require  $3K$  time-frequency resources to generate 3 groups of  $K$  mutually orthogonal pilot sequences each. We allocate a pilot group to each cell according to the reuse pattern, and the pilots within that group are distributed to the terminals as in the case of full pilot reuse. Similarly, we can define pilot reuse schemes for  $U = 4, 7, 9$  etc. that successively reduce the pilot contamination. A larger  $U$  implies a larger distance  $r$  between cells using the same set of pilot sequences[12].

### 3.3 SOFT PILOT REUSE

In soft pilot reuse scheme, The users inside the cell can be divided into two groups. The center users and the edge users, in terms of large-scale fading coefficients. Based on this characteristic, the soft pilot reuse (SPR) scheme was presented. [13] The received power in the reverse link depends on the transmit power of the terminal and also its location with respect to the BS. A cell-edge terminal usually has poor SNR at its serving BS and causes higher interference at nearby cells, than a terminal located far from the cell edge. If two cell-edge terminals from different cells are located close to each other and share the same pilot sequence, they suffer from significant pilot contamination. On the contrary, terminals located close to the BS are robust against interference from other cells. The pilot reuse scheme described above, though attractive on account of simple implementation, gives equal priority to all terminals while assigning pilot sequences.

We develop a soft pilot reuse (SPR) scheme that mitigates pilot contamination by assigning additional orthogonal pilot resources to cell-edge terminals.

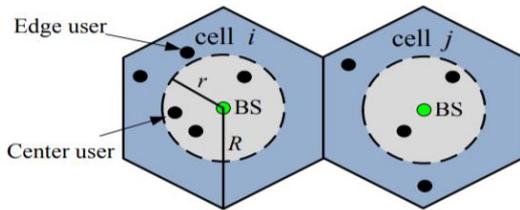


Fig-6: ILLUSTRATIVE EXAMPLE OF USER GROUP DIVISION IN THE CELL

Based on SPR, the authors in divided all cells into three groups and adopt the time-shifted scheme in the uplink training stage for all groups so that the PCs can be effectively reduced

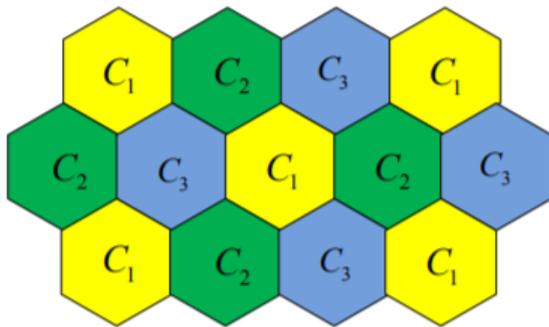


Fig-7: THE THREE GROUPS INCLUDING ALL CELLS.

### 3.4 RANDOM ACCESS PROTOCOL

To put This Protocol into context, we first review the protocol used on the Physical Random Access Channel (PRACH) in 5G, summarized in Fig (8).

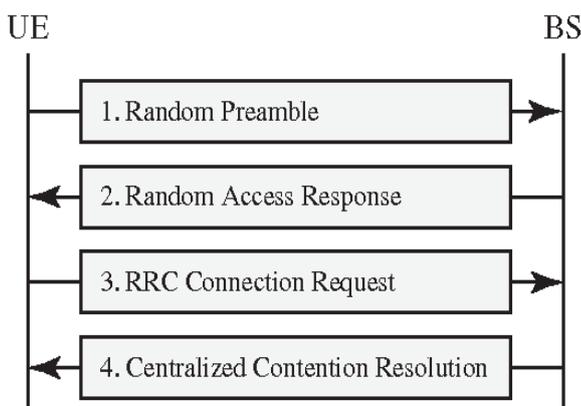


Fig-8: THE PRACH PROTOCOL OF THE 5G SYSTEM.

### Random access protocols can initialize in 4 steps

#### Step1.

The accessing UE picks randomly a preamble from a predefined set. The preamble is a robust entity that enables the BS to gain synchronization. It does not carry a specific reservation information or data and thus has a role as a pilot sequence. Since multiple UEs pick preambles in an uncoordinated way, a collision occurs if two or more UEs select the same preamble. However, at this stage the BS only detects if a specific preamble is active or not.

#### Step2.

The BS sends a random access response corresponding to each activated preamble, to convey physical parameters (e.g., timing advance) and allocate a resource to the UE that activated the preamble.

#### Step3.

Each UE that has received a response to its transmitted preamble sends a RRC (Radio Resource Control) Connection Request in order to obtain resources for the subsequent data transmission. If more than one UE activated that preamble, then all UEs use the same resource to send their RRC connection request in Step 3 and this collision is detected by the BS.

#### Step4.

It is called contention resolution and contains one or multiple steps that are intended to resolve the collision. This is a complicated procedure that can cause considerable delays [14].

### 3.5 STRONGEST-USER COLLISION RESOLUTION (SUCR)

In a Random access mechanism The Intra-cell Pilot collision becomes unavoidable. To Address This Issue we need to one Protocol which called "SUCR".

SUCR Protocol, which is an efficient way to operate the RA blocks in LTE Massive MIMO system. The four main steps of the SUCR protocol are illustrated in fig (9).



**Fig-9: THE SUCRE RANDOM ACCESS PROTOCOL FOR MASSIVE MIMO.**

There is also a preliminary Step 0 in which the BS broadcasts a control signal. Each UE uses this signal to estimate its average channel gain and to synchronize itself towards the BS[14].

**Step1.**

A subset of the inactive UEs in cell *i* want to become active. Each such UE selects a pilot sequence at random from a predefined pool of RA pilots. BS *i* estimate the channel that each pilot has propagated over. If multiple UEs selected the same RA pilot, a collision has occurred and the BS obtains an estimate of the superposition of the UE channels. The BS cannot detect if collisions occurred at this point, which resembles the situation in 5G.

**Step2.**

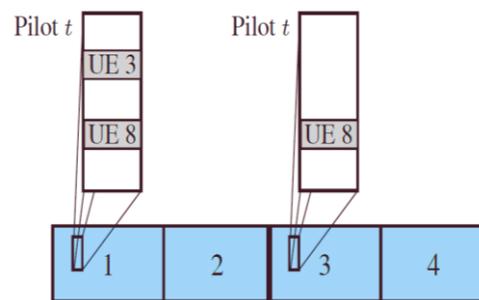
The BS responds by sending DL pilots that are pre coded using the channel estimates, which results in spatially directed signals toward the UEs that sent the particular RA pilot. The DL signal features an array gain of *M* that is divided between the UEs that sent the RA pilot. Due to channel reciprocity, the share of the array gain is proportional to their respective UL signal gains, particularly when *M* is large, which enables each UE to estimate the sum of the signal gains and compare it with its own signal gain (using information obtained in Step 0). Each UE can thereby detect RA collisions in a distributed way. This departs from the conventional approach in which collisions are detected in a centralized way at the BS and broadcasted to the UEs.

**Step3.**

This mechanism is illustrated in Fig. (10). The probability of non-colliding pilot transmission in Step 3 is vastly increased in the SUCR protocol, which enables the network to admit UEs also in crowded scenarios. The transmission in Step 3 also contains the identity of the UE and a request for payload transmission, resembling the RRC Connection Request in 5G.

**Step4.**

It grants these resources by assigning a pilot sequence that can be used in the payload blocks or starts further contention resolution (e.g., in an 5G fashion or by repeating the SUCR protocol) in the few cases when RA collisions remain. Hence, the SUCR protocol both stands on its own and can complement conventional contention resolution methods.



**Fig-10: ILLUSTRATION OF A UE COLLISION AT RA PILOT T RESOLVED BY THE SUCRE PROTOCOL, WHERE ONLY THE UE WITH STRONGEST SIGNAL GAIN REPEATS THE PILOT IN STEP 3**

**4. CONCLUSIONS**

Channel estimation is one of the challenging problem in 5G massive MIMO systems as the conventional techniques applicable to MIMO systems cannot be employed Because of an exceptionally large number of unknown channel coefficients. Different methods for mitigating pilot contamination due to limited coherence time proposed by various authors are reviewed. Sources of pilot contamination & the impact of pilot contamination have also been studied. Some mitigation techniques have been reviewed like OLPC, SPR, PILOT REUSE FACTOR, & RANDOM ACEES PROTOCOL. The key findings of this paper are summarized below:

- With pilot open loop power control (pilot OLPC) the NMSE-fairness is improved, and the channel estimates for most terminals are good enough for precoding – (NMSE<0 dB).

- By using less Aggressive pilot Reuse method we showed that the net throughput could be improved in general by allowing neighbouring cells to use different sets of pilot sequences.
- The SPR scheme is a reliable and well-performing technique to reduce the PC. In which we can divide all cells into three groups and adopt the time-shifted scheme in the uplink training stage for all groups.
- We introduced the SUCR random access protocol for 5G Massive MIMO systems. It resolves the pilot collisions that occurs when UEs select pilot sequences at random in an attempt to access the network, before being allocated dedicated pilots.

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