INTRODUCTION TO MASSIVE MIMO IN CELLULAR TECHNOLOGY

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ABSTRACT

There has been massive development in the quantity of wireless equipment's in the last one decade requiring high device throughput and less energy consumption with the demand of increasing wireless equipment's. Massive multi-input multi-output system cites to the approachfacilitatingtelecommunicationbase stations with a very huge quantity of antennas. These systems use several hundred antennas toserve large number of mobile users at the same time. LTE and Wi-Fi standards are embraced in massive MIMO. Massive MIMO has utility of increased capacity, improved throughput, energy&spectral efficiency making it suitable to be designed with less expensive and low power components. Massive MIMO employed in 5G applications uses awful number of antennas compared to current LTE systems.

Keywords- Channel estimation, time-division duplexing, massive MIMO, pilot contamination.

I. INTRODUCTION

The need of data traffic has risen in last few years due to the unprecedented development of smart android phones and various wireless cellular devices, and therefore new systems need to be proposed to handle that much traffic.MIMO system serves as one of the solution to increasing data users.MIMO expands as Multiple-input multiple-output,where different source (transmitter) and the destination (receiver)antennas are usedas shown in figure 1. Basic MIMO networks use two or four antennas but Massive MIMO employs high number of antennas. Multiple antennas refer to the multiple streams being sent out to achieve multiplexing gain thus improving the communication capacity. It's alwaysadvantageous to add more antennas for improved efficiency, decreased radiated power, easier signal processing and reliably better cell-wide coverage (Marzetta, 2015). Certain advantages of massive MIMO encompass major use of low-power inexpensive materials, reduced latency, MAC layer description, and robustness in opposition to intentional jamming. The anticipated overall performance relies upon on the propagation environment that gives the terminals with asymptotically orthogonal channels; however experiments have not yet revealed any boundaries in this regard. With a huge quantity of antennas and associated transceiver lines, however, the drawbacks of massive MIMO encompass high device complexity an energy consumption of hardware.Massive MIMO depends on spatial multiplexing, which in impact relies at the uplink and downlink of the base station with adequate channel information. This can be easily accomplished on the uplink by having the terminals send pilots on the premise of which the base station estimates the channel responses to each terminal. The downlink is harder.

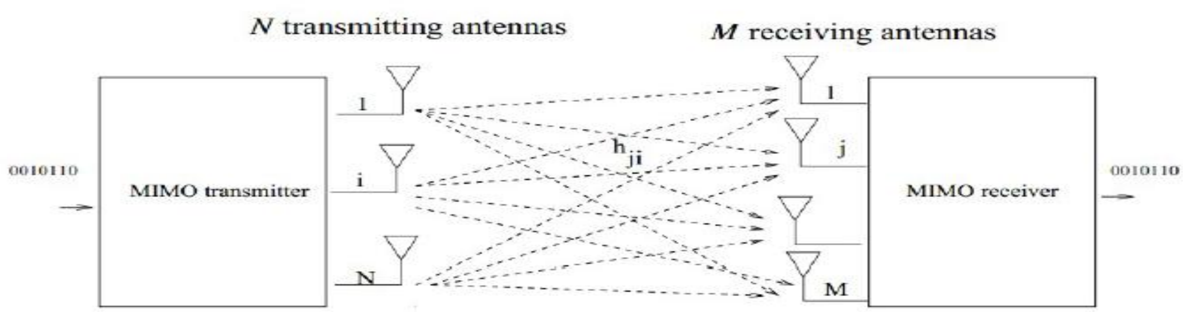

Fig.1 Structure of MIMO system

II. WHAT IS MASSIVE MIMO?

Here a base station is comprised of several antennas that servemany terminals at the same time, hence making it suitable for wireless system. Massive MIMO upgradesdeviceauthenticitywith a lot of antennas making multi-path possible for radio signal (Rithe, Khairnar, & Sharma, 2017). Being the salient concept, it draws the benefits of severalantennas at transmitting and/or receiving endwhich can considerablyenhance the network throughput, capacity (by separating independent wireless channels and utilizing them to send multiple stream of data all at the same time by applying diversity combining approach), and coverage without requisition of additional frequency range.MIMO antennas accompanied with Orthogonal OFDMA modulation format can enhance channel capacity and protect itfrom multi-path fading due to its scattering property(Adnan, Rafiqul, & Alam, 2016). Multi-input multi-output (MIMO) transmission is a well-known convergence strategy to boost communication efficiency. Massive MIMO networks will utilize beam forming technology, enabling the aimed use of spectrum. Till now, MIMO system is operationalin 4G wireless standards, such asWiMAX, Long Term Evolution (LTE), and wireless LAN (IEEE 802.11n).Downlink asBS to MSoperation, shown in the figure 2, necessitates transmission ofvarying data stream to every terminal.

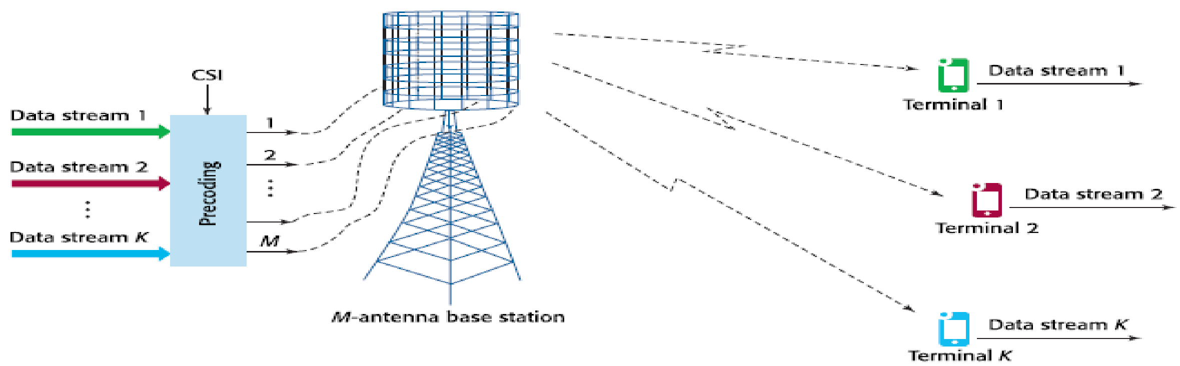

Fig.2A massive MIMO under downlink operation.

Massive MIMO employs spatial-division multiplexing in order to facilitate different datastreams to accompany similar times and frequencies. The reason behind the utilization of spatial multiplexing for wireless systems is due to the array of independently-controlled antennas. Figure 3 represents the working of multi-user MIMO system for uplink channel which is considerably opposite to that of downlink channel. Data streams are sent over the similar frequencies and at the common time. The same is received at the destination by antenna array in the form of collective data flows as up to date with the aid of the respective channels of propagation(Marzetta, 2015).

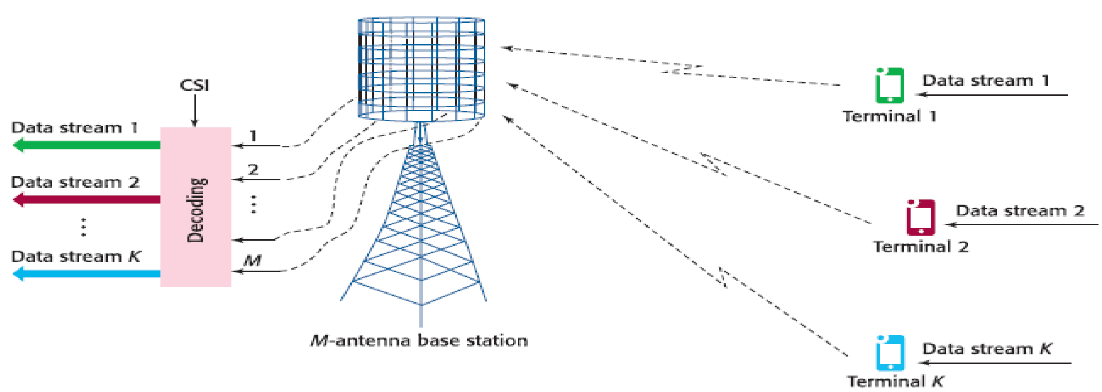

Fig.3 A massive MIMO under uplink operation.

III. SALIENT FEATURES OF MASSIVE MIMO

Few key benefits of multi-user MIMO systems are as follows:

1.Proliferates Capacity: MU-MIMO can expand the capacity by 10xor even more by opting invasive spatial multiplexing.

2. Upliftment of data rate: Data rate gets widen by Massive MIMO as several different multiple antennas can be used to transmit data streams which could serve multiple users concurrently with most bandwidth access.

3.Less Expensive: It can be designed with cheap and less power requiring components. It has replaced amplifiers in the Watt range with the milli-Watt rangeby utilizing 100s of them.

4. Enhanced energy efficiency: It is achieved with the ability of the base station to concentrate its radiated energy in the known direction of location of terminals as shown in figure 4.

5.Minimizes interference (Larsson, Edfors, Tufvesson, & Marzetta, 2014): It is achieved with the ability of the base station todeliberatelycircumvent transmission in directions in which spreading interference would be dangerous.

6. Reduces Latency: Multi-MIMO depends on the concept of large quantity of antennas and beam formingthereby to avoid fading dips, thus minimizing latency on the air interface.

7. Increases robustness to jamming: Massive MIMO uses joint channel estimation and decoding to cancel signals from intentional jammers as compared to the systems designed for channel estimation using uplink pilots where smart jammers may additionally cause dangerous interference with modest transmission power.

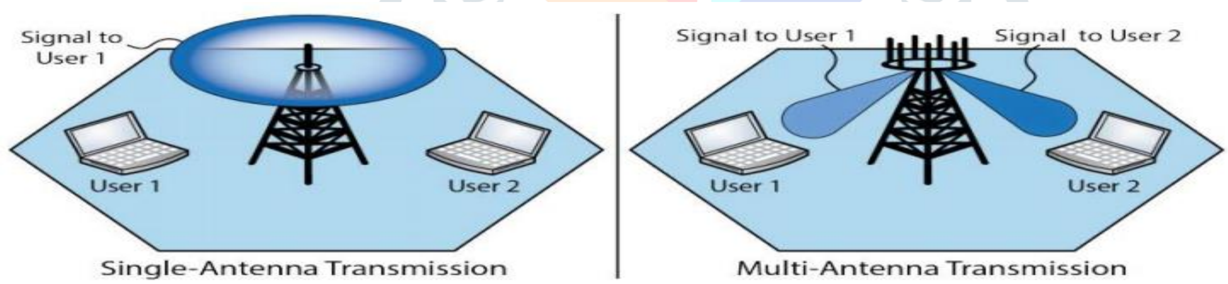

Fig.4 Ability of the base station to concentrate its radiated energy in the known direction of location of terminals for energy enhancement.

IV. TDD and FDD

By ascending (TDD), MU-MIMO is adaptable to any expected levelw.r.t the total count of service antennas (Marzetta, 2015). Pilot signal is needed for estimating the channel state information (CSI), however there are two disadvantages:

1. Most favorable downlink pilots would be placed at right angled betweenthe antennas. It states that the time required for downlink pilots by the frequency assets is commensurate with the range of antennas, (Jose, Ashikhmin, Marzetta, & Vishwanath, 2010)A massive MIMO solution might therefore require upto hundred times more power than a traditional model.

2. The range of channel responses to be measured at each terminal is proportional to the wide variety of antennas at the base station. Consequently, the uplink assets required to alert the BS of the channel feedback could be as high as a 100x as in traditional systems.Figure 5 shows the time division duplexing

(TDD) slot structure for M amount of service antennas and K amount of end users ensuring in time channel state information.

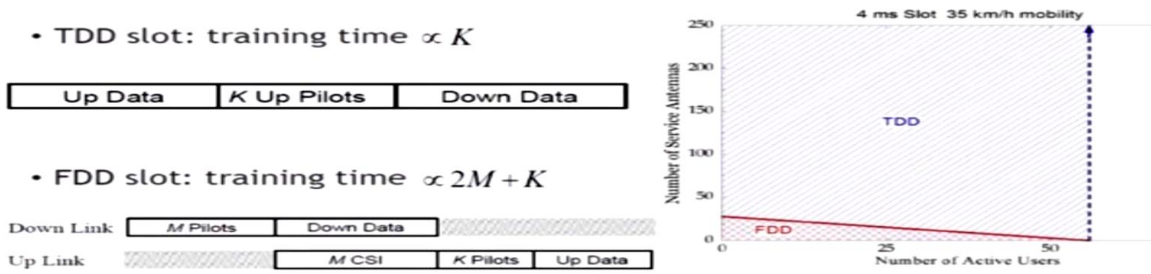

Fig.5 TDD slot structure ensures timely channel state information: M service antennas, K users

V. CHANNEL ESTIMATION

This section discusses about estimating a channel at the base station.

1. Channel Estimation

Conventional MIMO systems require CSIat BS to perform multi-user precodingfrom BS to MS and detection from MS to BS.Either of the time frequency resource, required for channel estimation(Lu, Li, Swindlehurst, Ashikhmin, & Zhang, 2014)varies with the amount of transmittingantennas and is not affected by total unit of receiving antennas. Channel estimation scheme varies with the type of the duplexing style(TDD or FDD).

(i). Channel Estimation of TDD Applications

Signals from MS to BS and BS to MS are transmitted in the different time interval but both share the same frequency range in case of TDD devices and hence, the services uplink and downlink arecorrelative in nature. Refer figure 6 to obtain CSI.

For transmission from MS to BS (uplink): the base station needs channel state information (CSI) (which is estimated at BS) to identify the signals disseminatedfrom the K devices. On the basis of which the BS estimates the streams, the K devices deliver K orthogonal pilot sequences to the BS. This technique calls for much less use of the K channel.

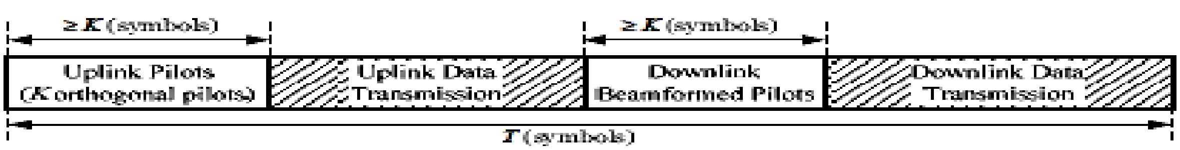

Fig.6 Slot design and estimation of channelsfor TDD applications

For transmission from BS to MS(downlink):The transmitted signals should be precoded by CSI. The channel measured at the BS during the uplink can be used to precode the transmit symbols supported by the channel reciprocity.Information about the effectivechannel gain is achieved by beamformed pilots, where the active channel gains are often approximated by every user based on the signal received from the pilot signal. This technique needs at least K channel.

(ii). Channel Estimation of FDD Devices

In a FDD system, signals from MS to BS and BS to MS are transmitted in the different frequency band but share the same time slot and hence, the downlink anduplink channels are not mutual. CSI corresponding to the uplink and downlink is different in case of Frequency division duplexing. The information about thechannel and users at BS can be acquired by the scheme showin figure 7.

For the downlink transmission: To acquire CSI, a two-step process isrequired. Firstly, the BS sendsM orthogonalsequences to all K users, andthen all users' acknowledge estimated CSI (partial or complete)to the base station. The time taken to sendthe pilot symbols from varies with the number ofantennas at the BS. More the BS antennas less will be the channel estimation possible.Consider, for example, a coherence interval of 1 ms 100 kHz sign, that can help transmit a 100 complex symbols. The entire coherence interval could be used for downlink while there are a hundred antennas at the BS if orthogonal pilot waveforms are used for channels to every antenna, whereas there may be no numerical transmission symbol left.

For the uplink transmission: Users send various pilot sequences in channel estimation K. BS antennas do not have an impact on the time required to send a signal to BS. In this process minimum K channeluses are required for the uplink.

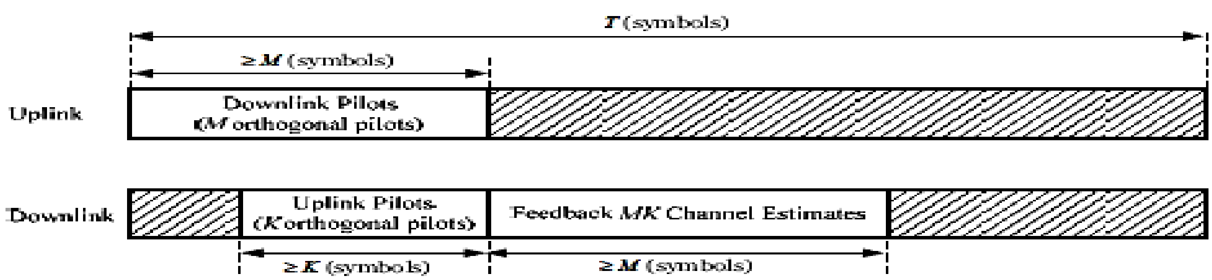

Fig. 7 Slot design and estimation of channel for FDD applications

VI. MASSIVE MIMO CODING:

1. Precoding

It is feasible to apply non-linear and linear precoding methods for standard MIMO structures. Nonlinear strategies(Lu et al., 2014), along with dirty-paper-coding (DPC), vector perturbation (VP) and lattice-aided techniques, have better overall performance in comparison to linear precoding methods, but with extra complexity of implementation.Through growing the number of base station (BS) antennas in massive multi-input multi-output (MIMO) systems, linear precoding schemessuch as MFand ZF can acquire near-optimal performance, making them extra perfect than non-linear precoding strategies(Xie, Dai, Gao, Dai, & Zhao, 2016).Use of low-complexity linear precoding strategies in massive MIMO structures is therefore more practical(Lu et al., 2014).

Conventional linear precoding schemes inclusive of zero-forcing (ZF) precoding, but, contain huge-size matrix inversion with high computational complexity, especially in massive MIMO systems. A linear precoding scheme primarily based on the symmetric successive over relaxation (SSOR) approach was suggested to lessen the complexity. The frequency of the classical ZF precoding can be reduced by using about one order of significance without loss of overall performance (Xie et al., 2016). The constantprecoding envelope method: minimizes multiuser interference (MUI) in a massive multi-input multi-output (MIMO) antenna device(Chen, Wen, & Wong, 2014).

As the name suggests, maximum filtering ratio aims at maximizing the signal-to-noise ratio (SNR). It is the simplest approach from a point of view of signal processing, as the detection / precoding matrix is simply the CSI matrix's conjugate transpose or conjugate, H. This method's big downside is that inter-user conflict is overlooked.

Zero forcing precoding attempts by designing the optimization criteria to reduce it to resolve the inter-user interference problem. The matrix for detection / precoding is the CSI matrix's pseudo-inverse. It is more computationally expensive to calculate the pseudo-inverse than the complex conjugate, as in the case of the peak ratio. Nevertheless, the energy obtained at the consumer suffers from concentrating too carefully on reducing the interference.

Minimum mean-square error attempts to strike a balance between most signal amplification and interference reduction. This holistic view comes with the complexity of signal processing as a price tag.The minimal mean-square approach to error incorporates an optimization concept for regularization known as β. It is sometimes referred to as regularized zero forcing (RZF) in literature as well.

This is not an exhaustive list of methods for precoding / detection, but offers a summary of the key linear approaches. It is also possible to apply nonlinear signal processing methods such as dirty paper coding and the cancelation of successive interference. While these techniques offer optimum capacity, they are very complex and hard to implement.

For massive MIMO, where the quantity of antennas is high, the linear approaches mentioned are generally sufficient. The selection of a precoding / detection technique depends on the computing resources, the number of antennas, the number of users, and the complexity of the system's specific environment.The maximum ratio solution may well be adequate for large antenna arrays where the quantity of antennas is substantially higher than the count of users.

2. Spatial Multiplexing

Spatial multiplexing requires configuration of the MIMO antenna. A high-rate signal is split into multiple lower-rate streams in spatial multiplexing and each stream is transmitted in the same frequency channel from a different transmitting antenna.If these signals arrive with sufficiently different spatial signatures at the receiver antenna array and the receiver has correct CSI, these streams can be divided into comparable channels. It is a powerful approach for higher signal-to-noise (SNR) channel capacity.The paramount quantity of spatial streams at the transmitter or receiver is limited by the smaller number of antennas. Spatial multiplexing at the transmitter can be used without CSI, but when CSI is available, it can be combined with precoding. This multiplexing can be even considered for transmitting concurrentlyto various receivers, known as multiple access space-division or MIMO multi-user, where the transmitter requires CSI. Receiver scheduling with various spatial signatures allows for good separability.

PILOT CONTAMINATION

Most importantly, the reuse of different co-channel cells pilot sequences will generate pilot pollution within a multi-cell setup. The quality of massive MIMO degrades very significantly when there is pilot contamination.In multi-cellular approach, due to the channel interval limitation, we can't assign orthogonal pilot sequences to all users in all cells. Orthogonal pilot sequences from cell to cell ought to be reused.Therefore, pilots transmitted by users in other cells may also contaminate the channel estimate received in a given cellular. This impact, referred to as "pilot contamination," decreases the quality of the device, along with user interference. The asset pilot signals are used to synchronize and equalize as shown in figure 8. Estimate the state of the channel data as well.

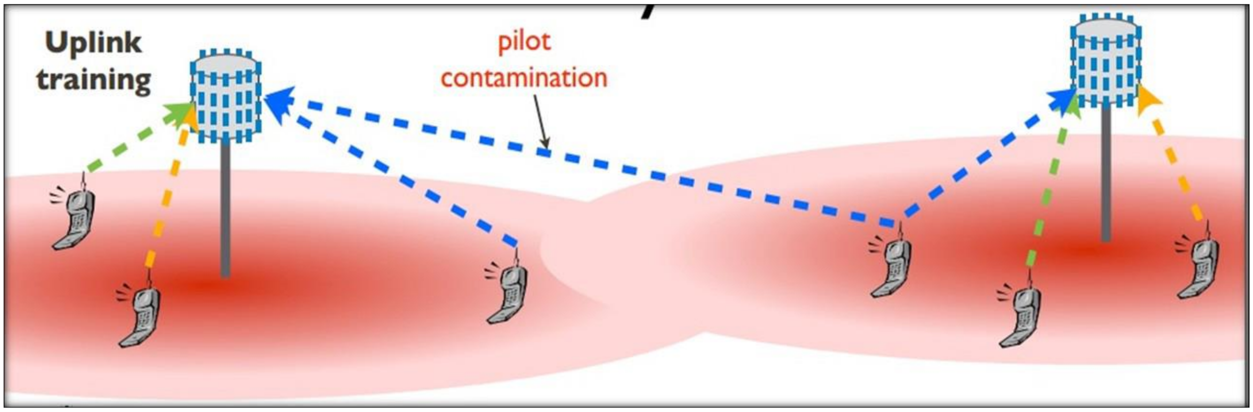

Fig.8 Allocation in massive MIMO system

Distance between users and base station (Gao, Edfors, Tufvesson, & Larsson, 2015):

(a) Closely situated with line of-sight (LOS) conditions: It is assumed that the spatial separation of the users is in particular difficult, and the LOS circumstance may additionally result in a high correlation among the channels of various customers.

(b) C*o-located with NLOS*: We nonetheless have applications near the base station antenna arrays, however with NLOS. The richly dispersed NLOS state will improve the scenario by providing more "favorable" propagation and as a consequence permitting higher spatial separation of users.

(c)*Well separated with LOS*: Increased user separation must assist improved overall performance; the spatial fingerprints of the four customers are extensively distinctive, indicating a favorable user decorrelation situation for extensive ranges.

ALLEVIATION OF PILOT CONTAMINATION

1. Pilot Open-Loop Power Control: This system (pilot OLPC) permits the device to change itspilot signaltransmission capacity based on its path loss estimate for its BS operation.

2. Less Aggressive Pilot Reuse

(i) Pilot reuse is just like conventional frequency reuse within the sense that, in the course of the channel estimation technique, terminals inside the pilot reuse location will use most effective a fraction of the time-frequency sources as shown in figure 9.

(ii) The 1/U pilot reuse factor is the level at which pilot assets within the network can be recycled, in which U is the quantity of cells allotted to orthogonal pilots.

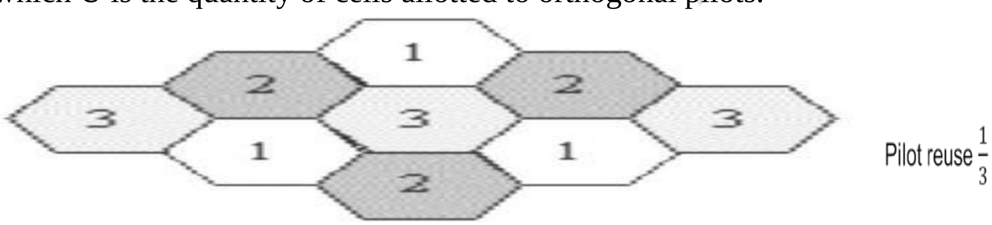

Fig. 9Demonstration for Less Aggressive Pilot Reuse

MASSIVE MIMO LIMITATIONS

1) Channel Reciprocity:There may be no mutual hardware chains within the base station and terminal transceivers between the uplink and downlink.

2) Pilot Contamination:Only when analyzing a multi-cellular MIMO system with training is pilot contamination encountered, and is lost when focus is reduced to a single-cell setting. Pilot contamination occurs when one cell is used to estimate the channel at the base station. This pollution is caused by using non-orthogonal training sequences (Jose et al., 2010).

CONCLUSION

Massive MIMO spatial multiplexing has the capability to become a game-changing technology in the discipline of cellular connectivity, permitting improved network capacity and performance in urban high-traffic areas. The heterogeneity provided by multipath propagation is exploited to enable simultaneous and frequency resource data transfer between a base station and multiple users. Because of the channel reciprocity between the base station antennas and the users, the whole sophistication of the signal processing can be preserved at the base station, and the classification of the channel can be performed in the uplink.

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