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A Network Overview of Massive MIMO for 5G Wireless Cellular: System Model and Potentials

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Abstract— This research article presents an overview on massive MIMO systems and its signal processing applications in future trends unlocking the aspects fifth generation of cellular communication. The key technologies includes MIMO integration to emerging technologies like device to device support, heterogeneous networks, base centric architecture for millimeter wave range for developing future generation 5G standard for wireless cellular. The system modeling design is also illustrated thereby providing a direction for meeting high data and bandwidth needs in future by employing massive MIMO cellular networks with current wireless technologies have been identified**.**

Keywords— 5G, massive MIMO, base station, antenna arrays, D2D, millimeter wave, cell, heterogeneous network

INTRODUCTION

In communications, MIMO implies multiple-input and multiple-output and is used by combinations of multiple transmitters/receivers or antennas at both sides of digital communication systems. It can be termed as replica of smart antennas array group. In wireless communications MIMO techniques is evolving technology that offers considerable increase in data bandwidth without any extra transmission power. Due to these properties, MIMO technology is a vital aspect of modern cellular and wireless communication standards of today. These emerging fields includes WiMAX, HSPA+, 5G cellular, energy efficient satellites etc.

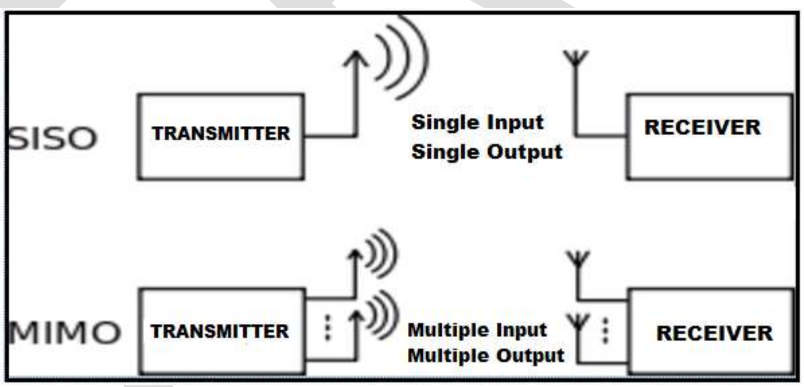

Figure 1: Block diagram of SISO and MIMO systems

Massive MIMO

It has been observed that massive MIMO networks can provide higher performance than partial multi-user MIMO since the multiple antennas used are much smarter. Massive-MIMO systems can be termed as the scenario of multi-user MIMO in which the number of transmitter terminals is very less than the number of BS (base station) antennas. For scattered environment, merits of massive MIMO technology could be further developed by using simple ZF(zero forcing) or MRT(maximum ratio transmission). Practically, for orthogonal channels the reception and transmission data lacks the channel coherence time. If more than one base stations (antenna) exist in this scenario, the devices renders these channels to various machines maintaining orthogonality optimal multiplexing. It can be argued that in the current text of disruption of emerging technologies massive - MIMO is the best choice for future generation wireless evolution for 5G.

MASSIVE-MIMO MODELLING FOR 5G

Let us consider a massive MIMO downlink system for single BS (base station) and ‘N’ users. ‘A_T’ antennas for transmission and use ‘k’ has ‘A_R’ antennas for reception.

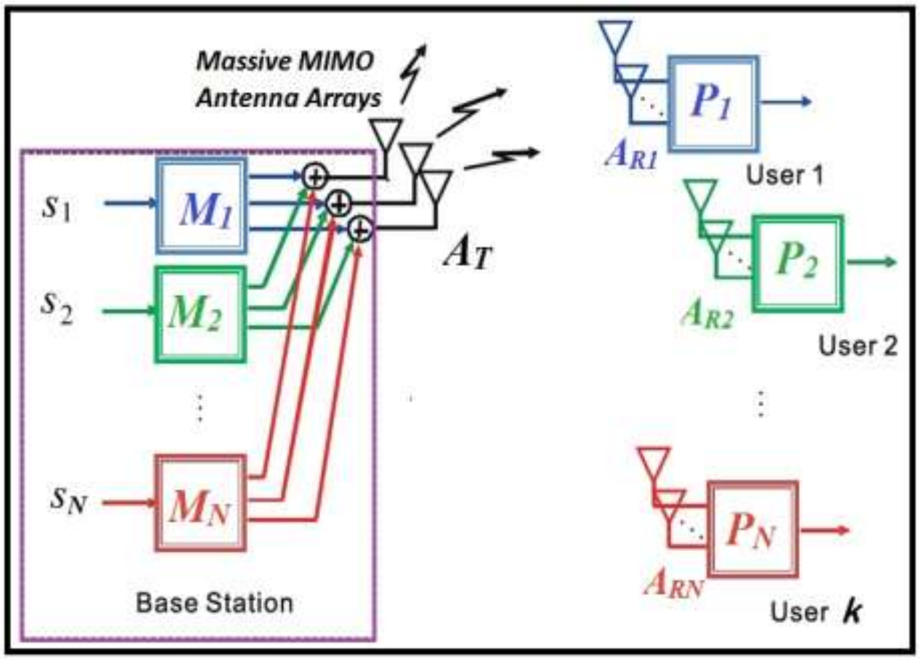

Figure 2: Massive-MIMO system model with ‘k’ users and ‘N’ base stations

If ‘d_k’ the data stream of kth user, the number of streaming data (sum rate) for all ‘k’ users can be written as

$$d = \sum_{k=1}^{N} d_k$$

Total number of receiver antennas is given by

$$A_R = \sum_{k=1}^{N} A_{R_k}$$

Clearly, we have chosen $A_R > A_T$. Using a fading channel for common BS and massive MIMO, the channel matrix for k^{th} user is given by $H_k \in A_{R_k} \times A_T$ **.**It is assumed that the channel H_k is quasi-static in nature and it is a constant. Let $s_k \in d_k$ be the transmitter signal for k_{th} user, the receiver matrix is thus given by $P_i \in A_{R_k} \times d_k$ .If ‘W_k’ is the white Gaussian noise of the channel, the total received signal Power ‘P_R’ is given by

$$P_R =_k^H H_k M_k s_k + P_k^H H_k \sum_{\substack{i=1 \\ i \neq k}}^{N} M_i s_i + P_k W_k$$

Where ‘P_k’is the kth user and M_i is the beamforming signal of kth user in the antenna array matrix. Clearly $M_i \in A_T \times d_k$

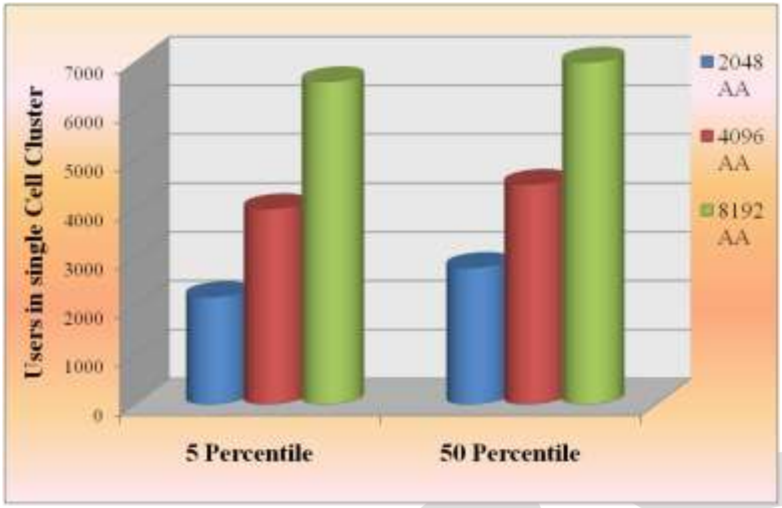

Figure 3: Massive-MIMO services provided to number of users by employing 2048, 4096 and 8192 Antenna Arrays (AA)

Massive MIMO proposals for this model by employing a very huge number of antennas to multiplex information signals in communication systems for several machines by utilizing devices-to-devices link (D2D) on each time-frequency access schemes (TDM/FDD), focus must be on optimizing energy radiated energy towards the directions intended while minimizing intra- and inter-cell interference. Figure 3 clearly highlights the comparison cellular services provided in terms of data rate gain for various antenna arrays for massive MIMO application in a 4X4 baseline for subscribers in a single cell cluster. The 8192 number of antennas is deployed by massive MIMO systems thereby increasing the user efficiency. Services to users with 2048 antennas in simple MIMO schemes were classically adopted where both ‘5’ and ‘50’ percentile of full efficiency is achieved. The MIMO systems with 5096 is the intermediate with optimal service provided .Thus increasing the number of array in antenna with advanced signal processing tools could a huge information could be transmitted which would be the requirement of 5G cellular.

MASSIVE-MIMO AND 5G CELLULAR

In massive MIMO present research challenges include estimation of criticality of coherent channels. Propagation impairments for massive MIMO in present context could also be hypothetically calculated on experimental basis for channel orthogonality. This could be further implemented on the basis of lower costs in the context of hardware power consumption in each of the antennas.
Considering present scenario 5G has many merits over 4G

i) Non- bulky in space
ii) Directive antennas
iii) Coherent angle spread of the propagation

There are limited number of antennas in MIMO employing single-user that is fit for current standard of cellular communication. But massive MIMO is not limited if TDD (Time Division Duplex) is incorporated for enabling channel characterization.
This relative scenario has massive MIMO’s application which governs the multiple antennas distributed in which a small town or university campus or city could be utilized.

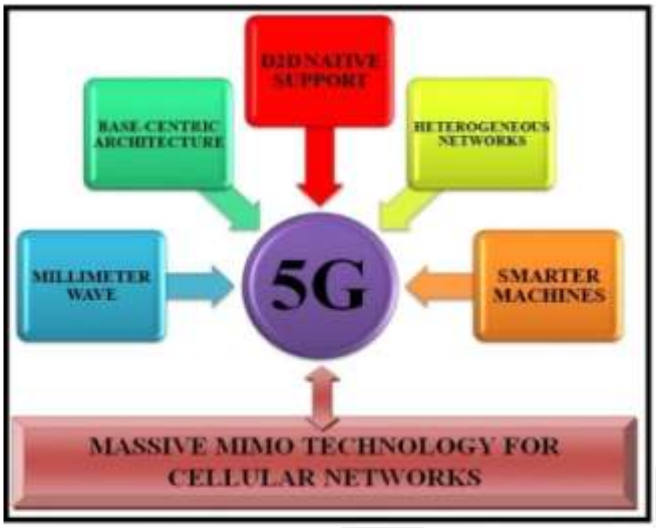

Figure 4: Integration of various emerging technologies towards 5G wireless system.

A. Millimeter Wave (mm-Wave)

The frequencies in the range of 600 MHz to 1600 MHz are currently in use for cellular . This little range can hardly be exploited for future generation wireless access systems by reframing the system. Higher spectrums in the ranges of GHz and THz could be deployed by utilizing techniques in cognitive radio. The highly potential field is exploited by wavelength in millimeter range and hence the term millimeter wave is in practice. Today different cellular and wireless firms want a radical increase in capacity emerging trends which has to be carried in coming years beyond fourth generation of wireless standards in Long Term Evolution (4GLTE). Around 2020, the cellular networks would face a very high speech and data traffic and thereby higher capacity demands for data rate and bandwidth. For wireless future wireless generation of 5G mobile data rates must increase up to several gigabit per second (Gbps) range, which can only be processed by using the millimeter wave spectrum steerable antennas. This would support 5G cellular backhaul communications in addition to integration of world-wide fidelity in wireless services. Since Massive MIMO is a spatial processing technique which would have orthogonal polarization and beam-forming adaptation, this smaller millimeter wavelength is suitable frequencies. The highly populated geographical regions could be covered by 4G+ to 5G technologies by setting backhaul link using massive MIMO in case of greater bandwidth challenges. Cost per base station will significantly reduce due to innovative architectures of co-operative MIMO, thereby minimizing interference relays and servicing base stations.

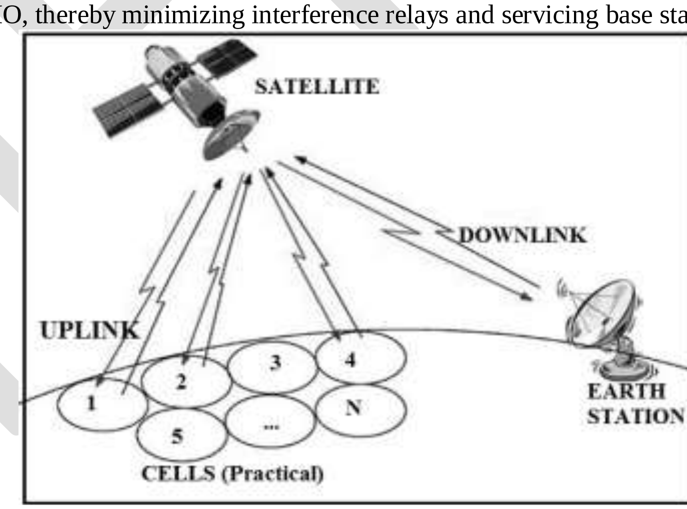

Figure 5: A satellite-cellular communication system showing uplink and downlink

The wireless operators would reduce cellular coverage area to pico and femto cells for generating spatial reuse. Since cellular networks would face gigantic traffic (data and speech) over next ten to twenty years, a huge challenge would be to harmonize frequency bands by ITU to GHz and THz. This will enhance low cost of service and roaming. The mobile network operators are planning to fulfill future needs, by combing of to share spectrum for this solutions which would be beneficial beyond 2020.

B. Base-centric architectures.

For 5G evolution the base centric architectures would have major role to play in wireless communication. The up-linking and down-linking concepts must be integrated to data wireless channels for better servicing of data flows with different priorities towards nodes set within wireless network.

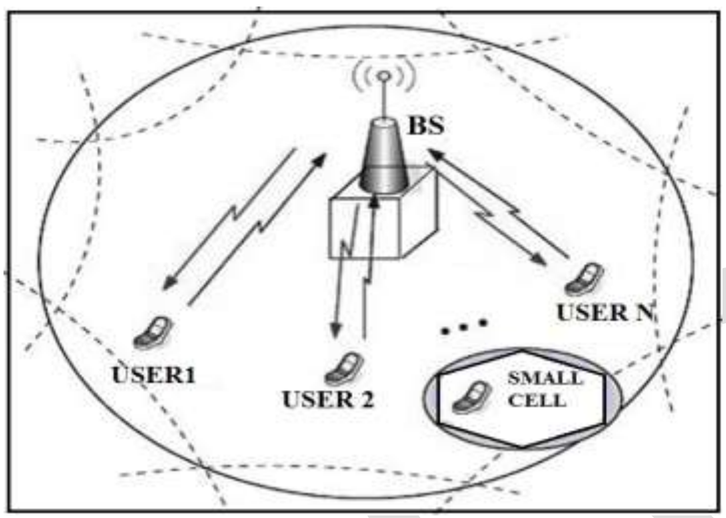

Figure 6: Base-centric architecture employing small cell for 'N' users.

Wireless designs in this concept are based on the axiomatic cells roles as which are basic building block units within the the radio network access. By use of base centric design both control and traffic signals are transmitted under same downlink and its corresponding uplink connection for more denser networks in future some vital changes must be done to 5G. The increase in transmit power in base stations is a major issue for denser coverage areas. This base centered architecture would employ massive MIMO for a decoupling uplink as well as downlink and thus would allow the link data to flow through various of nodes set. Virtual radio access networks (RAN) will have node and the hardware allocation for handling the processing associated with this node. Dynamic hardware resources allocation in a base centered mode must depending on network operator's defined matrix operator. Architectural network design in this context should compensate multi-hop by imposing partial centralization via aggregation of resources

C. Device-to-Device (D2D) Native Support

Cell-phones, local small cell wireless networks are a deciding factors of smart proxy call caching for redefining new aspects of device supports by use of massive MIMO. The 5G wireless cellular must employ base-centric architectural structures and invent new a device-support so that human devices could easily communicate with virtual emotions.

Table 1: Features of Device-to-Device support

D2D Support	Features and examples
Real-time operation with low latency	• Demands reliable data transfer a given time . • Vehicle to D connectivity improving traffic by alert and control messages.
Massive Device inter-connection	• Some D2D services might require over 10 devices connection • Devices operating typically at hundred per base station for smart grids and meter sensors.
Higher Reliability Linkage	• More safe and reliable than wired standards • Virtual and operational wireless link everytime and everywhere.

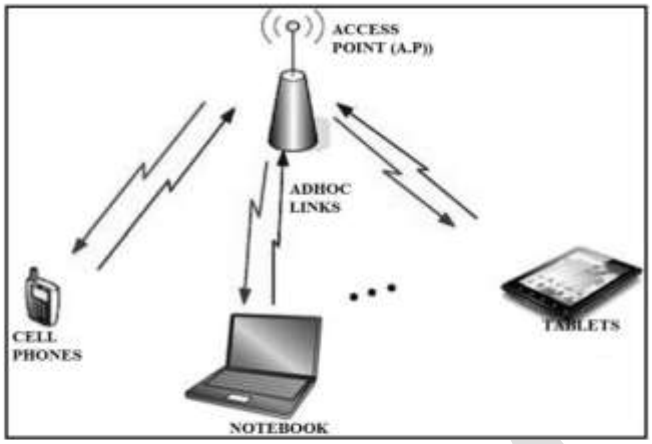

Figure 7: Device-to-device Ad-hoc connections in present scenario

Data transmitted by several possible contexts of heterogeneous networks greatly rely on the sets of device to device support which is also discussed in next section. These network sets must provide full connectivity aspects of a given machine in session cellular approach. Wireless systems have become necessities like water and electricity. Thus it must be dealt with utmost commoditization, thereby enhancing new types of requirements. These would be brought upon by employing massive-MIMO modeling. In systems that employ voice centric operations, a call is established when two parties in close proximity have situations co-locations of several devices share multimedia content. A single hop is usually established to utilize multi-operational tendencies of a single hop. This is responsible for waste of signaling resources. The transmission powers of a several watts in both downlink and uplink are consumed to achieve a few milli watts per device. Thus battery drains and also there is increase in interference occupying the same resources for signaling everywhere. This can be minimized if we focus on accompanying overheads by controlling estimation of used wireless channel by employing massive MIMO which can focus on enhancing the capacity for 5G based D2D. The current wireless network researchers must study this 4G+ systems and must ensure that a green network focusing on current studies is detected for safety of the public safety

D. Heterogeneous Networks

The base-station is becoming denser rapidly, driven by the rise of heterogeneous networks. While heterogeneous networks were already standardized in 4G, the architecture for next generation massive MIMO employments would be designed to support those 5G networks. Heterogeneous network which represent a novel networking paradigm based on the idea of deploying short-range, low-power, and low-cost base stations operate in conjunction with the main macro-cellular network infrastructure. 5G networks would provide high data rates, allow offloading traffic from the macro cell and providing dedicated capacity to homes, enterprises, or urban hotspots. As Evolution of wireless cellular devices continues to explode, the traffic demand in wireless communication systems is also increasing. It is expected that the traffic demand will increase up to twenty times by 2020 as that of 2014.One of the main challenges of Heterogeneous Network is planning and managing multilayer, dense networks with high traffic loads. The tools used today for network planning, interference management and network optimization require too much manual intervention and are not scalable enough for advanced Heterogeneous Networks. Self-organizing networks (SON) enables operators to automatically manage operational aspects and optimize performance in their networks, and to avoid squandering staff resources to micromanage their radio access networks. In denser networks, automization reduces the potential for errors, and frees up precious resources to focus on more important activities of network design, management and operation. . Mobile networks continue to become faster and capable of transporting more traffic, thanks to the increased efficiency and wider deployment of 3G, 4G technologies now and 5G in future.
It also introduces network-performance optimization processes that are too granular or too fast for manual intervention – and these bring benefits not only to multi-layer networks, but also to the macro-dominated networks of today. SON can be thought of as a toolbox of solutions. Yet performance improvements are not sufficient to meet the increase in traffic load driven by more subscribers, more applications, and more devices. To meet subscribers' demand for ubiquitous and reliable broadband connections, operators have to do more than expand their networks. They have to embrace a deep, qualitative change in the way they plan, deploy and operate their networks. Heterogeneous Networks are central to this change: they capture multiple, convergent dimensions along which networks have started to evolve gradually. The move toward Heterogeneous Networks is driven by a combination of market forces, capacity limitations in the existing infrastructure, and new technologies that enable operators to deploy and manage dense, multi-layer networks that increasingly include small cells. Operators can choose which ones to adopt and when, depending on their needs, their strategies, and the maturity of the solutions. SON standardization efforts started with 3GPP Release 8 but are still ongoing, so there is a varying level of maturity among tools, in terms of both specifications and the commercial availability of products. The focus of SON

standardization has gradually moved from the macro-cell layer to the small-cell layer, as the small-cell market expands and ecosystem players encounter the challenges that small cells introduce in mobile network.

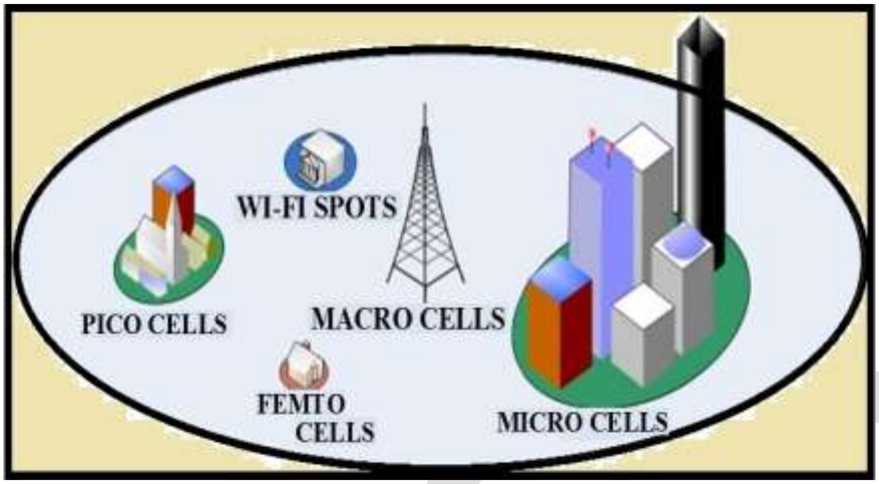

Figure 8: A typical heterogeneous network

Operators expect Heterogeneous Networks to deliver a higher capacity density, increase spectrum efficiency, and improve the subscriber experience, while lowering the per-bit cost of transporting traffic. Achieving these goals is necessary, but it will not be easy. Operators and vendors are jointly working to ensure a smooth transition to Heterogeneous Networks, but the process will require time, effort and the establishment of a robust ecosystem. In the process, mobile networks will become more complex.

E. Multiple Cell-Cluster and applications to Smarter Machines (Wireless devices)

For the multi-user MIMO downlink in a single and in clustered multiple cells, we consider the situation in which the total number of receive antennas of the served users is larger than the number of transmit antennas of the serving base station (BS).

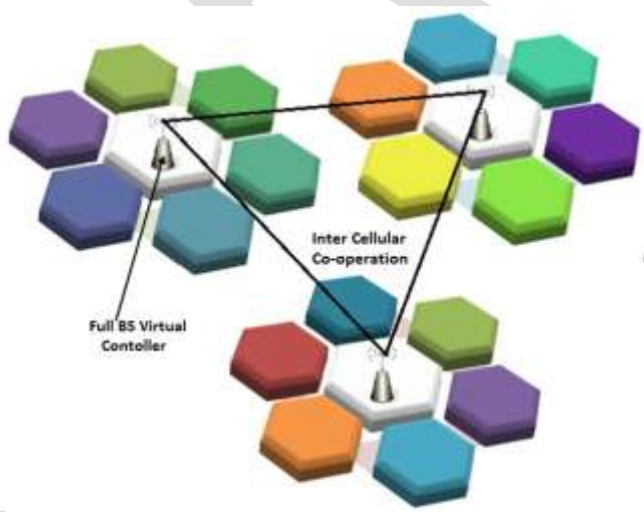

Figure 9:. Clustered cellular scenario with a virtual controller for full Base Station coordination within each cluster.

This situation is relevant for many scenarios. For instance, in multi-user MIMO broadcast channels, the BS simultaneously serves as many users as possible and hence a large total number of receive antennas..As Clustered cellular scenario, in each cluster there is a virtual controller due to the full BSs coordination within each cluster which is shown in figure 9. .Newer technologies which could be included to current scenarios are LiFi (Light Fidility), WiZig+ , etc.It must be noted that, the power consumptions of assembled A/D (Analog to Digital) converters at frequencies from 300 MHz to 30 GHz has been considered in this section. It has been found that these costs and energy related parts must adopt massive-MIMO technology for achieving higher efficiency.. The justification of some of these vital parametric changes is solved by objectives of massive MIMO counterparts. It is argued that 5G systems must not follow 2G-4G network designs, but must integrate previously used architectures into new paradigms to exploit Machine intelligence by layering various protocol stack for Device-to-Device (D2D) connectivity or by introducing smart caching discussed in previous section .While this Each of these designs require a change at the layered node level component change by implying architectural level multi-hop for massive MIMO based next generation wireless cellular Earlier the generations from 2G to 4G were built on the design primitive by completing control at the infrastructural level of site. Some probabilistic approaches can be assumed b unleashed by allowing the devices to play smart roles and, then think to enhance 5G's design accounting for an increase in machine's intelligence at end user's level. These technologies are named as

a. Higher interference rejection.
b. Intelligence for smarter machines
c. User level local caching

CONCLUSION

From this review paper it is concluded that adaption of massive-MIMO for 5G is an evolutionary challenge which would affect major change in component design for cellular systems and component design. Graphical study of antenna arrays show that more and more users can be provides services in denser cellular networks. The system model describes that emerging technologies such as these would have potential functions for transmission and reception purposes. Massive MIMO technique would inculcate more efficiency in present cellular systems when number of antennas is increased with advanced signal processing tools laid out in downlink model. Massive-MIMO may require major architectural changes, in particular in the design of macro base stations, and it may also lead to new types of deployments.

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