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A SURVEY ON "MIMO" FOR ENERGY EFFICIENT WIRELESS COMMUNICATION SYSTEM

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ABSTRACT

The outstanding traffic growth of wireless communication network rises both the insufficient network capacity and extreme carbon release. The demerits of long-distance wireless communication system are, limited available frequency, channel capacity, bandwidth, complexity, reliability, transmission dada rate etc. Multiple –input multiple output (MIMO) can improve the spectral efficiency (SE) jointly with the energy efficiency (EE) and has been regarded as a hopeful technique for future wireless communication system. Massive MIMO works with less-priced single antenna terminals, without any need of heavy scattering environment, which is responsible for the system to be energy efficient. There are various methods to make a MIMO system energy efficient. One of them is Antenna selection process, that is necessary for Massive MIMO wireless communication system in both transmitting and receiving end. This paper also indicates some antenna selection methods for the massively distributed antenna system.

Keywords- Antenna selection, energy efficiency(EE), , Massive MIMO, MIMO, spectral efficiency(SE), ,.

I. INTRODUCTION

There are many challenges in wireless system to provide higher dada rate, higher channel capacity within available spectrum, energy efficient system, fewer dropped calls. wireless system engineers have to resolve these problems. This requires new techniques to improve spectral efficiency as well as energy efficiency. MIMO technology promises to provide these capabilities. In MIMO system there are multiple antennas at both the transmitter and receiving terminal to get better the communication. MIMO system has higher spectral efficiency (more bits per second per hertz of bandwidth) and link reliability or Diversity (reduced fading[1]) thus it offers major increment in data rate and system availability without additional bandwidth or transmit power. There are a number of advantages of Multi-user MIMO (Massive MIMO) over conventional MIMO: It uses the cheap low power components, reduced latency, compatible with the media access control(MAC layer) and robustness to intentional jamming. A large number of antennas serving for much smaller number of terminals, To improve the throughput and radiated energy –efficiency, the extra antennas focus energy into ever-smaller regions of space. Massive MIMO also recognized as "Large-scale antenna system, very large MIMO, Hyper MIMO, Full dimension MIMO and ARGOS " brings following improvements in cellular systems- *Data rate increased:* more antennas means, separate data streams can be transmit and simultaneously reception with more terminals at the receiver. *High reliable system :* more antennas, the more separate paths that the radio signal can spread over. *Energy efficiency Improved:* The emitted energy is focused by the base station antenna into the spatial directions where it knows that the terminals are located. *Less interference:* because the base station is able to avoid transmitting into directions where spreading interference would be harmful. Now these days energy saving and environmental protection have become the global requirement thus the energy efficiency of wireless system has become considerably important. This would be major research purpose to design of big energy efficient wireless system.

II. LITERATURE REVIEW

Firstly diversity was introduced by the antenna arrays before 1990s and further the signal response to moderate co-channel interference. This enables the development of techniques: **Beamforming (**Focus electromagnetic energy in desired directions) and **Spatial diversity (**Combination of signals in an antenna array equipped with low correlation elements). Bell Labs developed MIMO in early 1970s, to overcome the bandwidth limitation. At the time, however, the processing power for MIMO system was too costly. Further A.R. Kaye and D.A. George (1970) introduced new ideas, Branderburg and Wyner (1974) and W. van Etten (1975, 1976). Jack Winters and Jack Salz at Bell Laboratories published numerous papers on beamforming related applications in MIMO in 1984 and 1986.

In 1993, Arogyaswami Paulraj and Thomas Kailath introduced the concept of spatial multiplexing (SM) using MIMO for great improvement in wireless broadcast systems. Next In 1996, Greg Raleigh and Gerard J. Foschini proposed new algorithms to MIMO system, in which multiple transmit antennas are located at transmitter to get better link availability effectively. Bell labs further introduced firstly spatial multiplexing(SM) in 1998 to get better performance of MIMO system.

After one year, Gigabit Wireless Inc. and Stanford University proposed first outdoor prototype in 1999. Further in 2002, the first commercial product was produced by Iospan Wireless Inc. (formerly Gigabit Wireless Inc., acquired by Intel) . And a 4x4 MIMO system tested at University of Alberta. MIMO system overcomes the limits of traditional mobile communication system jointly with less price of signal processing.

III. MULTIPLE ANTENNA SYSTEM

Communication model or multiple antenna systems can be divided in to four parts – SISO, SIMO, MISO and MIMO.

SISO:

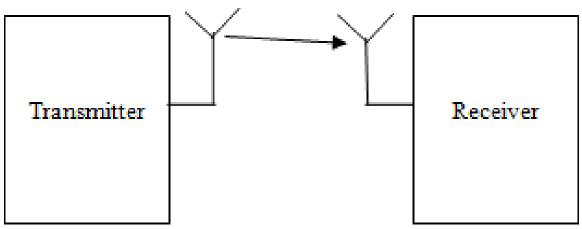

Fig.1- Single Input Single Output (SISO)[28]

This technology is known as Single Input Single Output (SISO). Having one antenna at transmitter and one at the receiver gives no diversity technique. Both the transmitter and the receiver have one RF chain (that's coder and modulator). SISO is relatively simple and easy to implement and it has been used age long since the birth of radio technology. It is mainly used in radio and TV broadcast and our personal wireless technologies (e.g. Wi-Fi and Bluetooth).

SIMO:

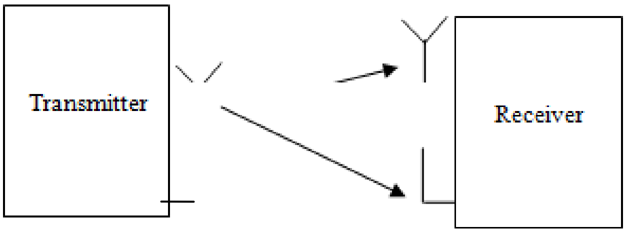

Fig.2- Single Input Multi Output (SIMO)[28]

One antenna at the transmitter, two antennas at the receiver (SIMO)gives a receive diversity technique[2]. To pick up performance, a multiple antenna technique has been introduced. The receiver can either prefer the finest antenna to receive a good signal or merge signals from all antennas in such a way that maximizes SNR (Signal to Noise Ratio). The first technique is known as switched diversity or selection diversity and later is known as maximal ratio combining (MRC).

MISO:

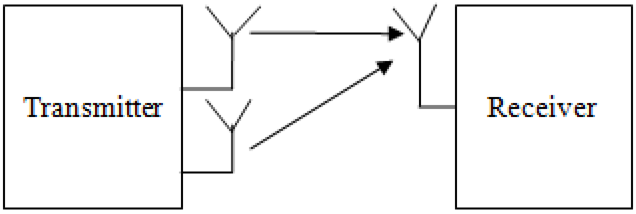

Fig.3- Multi Input Single Output (MISO)[28]

Two antennas at the transmitter, one antenna at the receiver (MISO)gives a transmit diversity technique[2]. A technique known as Alamouti STC (Space Time Coding) is in use at the transmitter with two antennas. STC enables the transmitter to transmit signals (information) both in time and space, meaning the information is transmitted by two antennas at two different times successively. Multiple antennas (each with an RF chain) of either SIMO or MISO are typically located at a base station (BS). This way, the price of providing either a receive diversity (in SIMO) or transmit diversity (in MISO) can be shared by all subscriber stations (SSs) served by the BS.

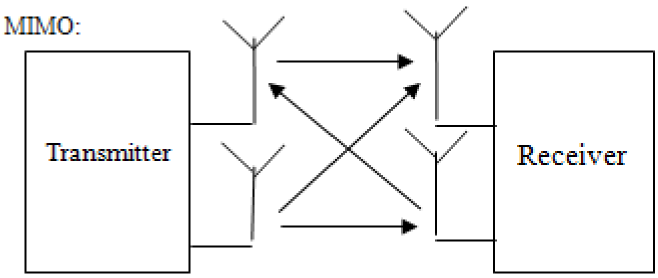

Fig.4- Multi Input Multi Output (MIMO)- size2x2[28]

To multiply throughput of a radio link, multiple antennas (and multiple RF chains accordingly) are put at both the transmitter and the receiver. This system is referred to as Multiple Input Multiple Output (MIMO). A MIMO system with same number of antennas at both the transmitter and the receiver in a point-to-point (PTP) link is able to multiply the system throughput linearly with every additional antenna. For example, a 2x2 MIMO will double the throughput. Two antennas at both the transmitter and the receiver side uses transmit and receive diversity.

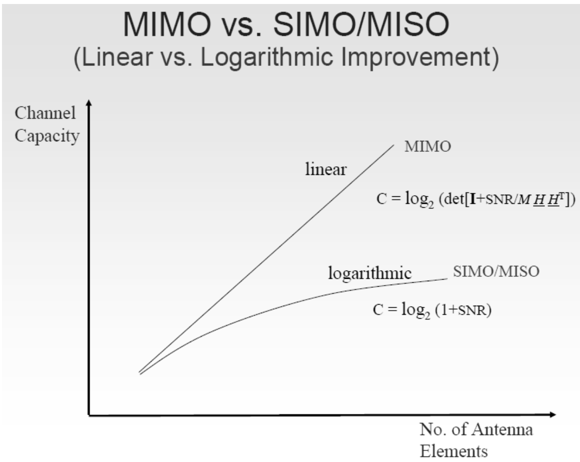

Fig. 5: MIMO v/s SIMO & MISO[30]

IV. MIMO SYSTEM

MIMO can be sub-divided into three main categories, Precoding, Spatial multiplexing (SM), and Diversity coding.

Precoding[3] It is multi-layer beam forming in a narrow sense or all spatial processing at the transmitter in a wide-sense. In (single-layer) beam forming each transmit antenna transmits the same signal with appropriate phase (sometimes gain) in such a manner that the signal power is maximized at the receiver. The payback of beam forming are to raise the signal gain from constructive combining and to reduce the multipath fading effect.

In the absence of scattering, beam forming results in a well distinct directional pattern, but in usual cellular conventional beams are not a good analogy. When the receiver has multiple antennas, the transmit beam forming cannot concurrently maximize the signal level at all of the receive antenna and Precoding is used. Note that Precoding requires dada of the channel state information (CSI)[4] at the transmitter. **Spatial multiplexing (SM),**[5] Requires MIMO antenna configuration. In spatial multiplexing, a high rate signal is divided into multiple lower rate streams and each stream is transmitted from a different transmit antenna in the same frequency channel. If these signals appear at the receiver antenna array with suitably different spatial signatures, the receiver can separate these streams, forming parallel channels for free.

Spatial multiplexing is a very influential technique for increasing channel capacity at higher **Signal to Noise Ratio (SNR)**. The maximum number of spatial streams is restricted by the lesser in the number of antennas at the transmitter or receiver. Spatial multiplexing can be used with or without transmit channel knowledge.

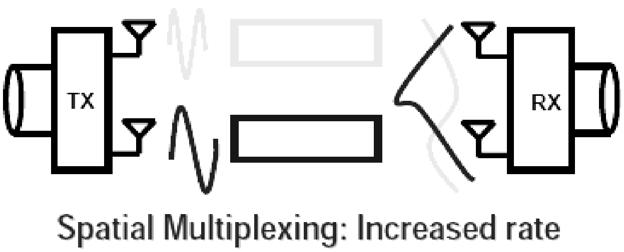

Fig.6 Spatial Multiplexing[28]

Diversity Coding- Techniques are used when there is no channel knowledge at the transmitter. In diversity [6] methods a single stream (dissimilar multiple streams in spatial multiplexing) is transmitted, but the space-time codings are used to encode the data. The signal is emitted from each of the transmit antennas using certain principles of full or near orthogonal coding. Diversity gives the independent fading in the multiple antenna links to improve signal diversity.

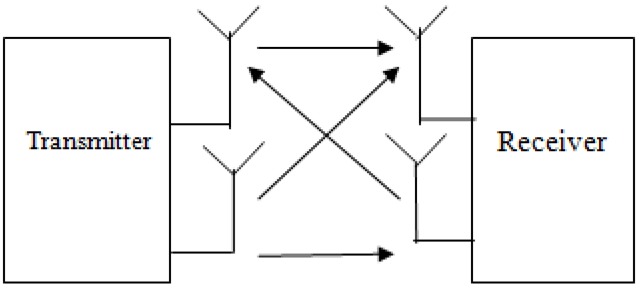

Fig.7: Spatial Diversity

V. CHANNEL CAPACITY

A MIMO channel [7] with nT transmitters and nR receivers is normally represented as a matrix **H** of dimension nR × nT, where each of the coefficients [**H**]i,j represents the transfer function from the jth transmitter to the ith receiver. We denoted

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the symbol transmitted from the jth transmitter by xj, and collect all such symbols into an nT-dimensional vector **x**. With this details, the matrix model of the channel is

$$\mathbf{Y} = \mathbf{Hx} + \mathbf{W}, (1)$$

Where **W** is a vector of additive noise, and **Y** is the vector of received data, with an element in **W** and **Y** for each receive antenna.

An important tool for characterizing any communication channel is capacity [8]. In a single-user channel, capacity is the maximum amount of information that can be transmitted as a function of available bandwidth given a restraint on transmitted power. In single-user MIMO channels, it is common to assume that there is a constraint on the total power broadcast by all transmits antennas. For the multi-user MIMO channel, the problem is somewhat more compound.

Given a restraint on the total transmitted power, it is possible to allocate varying fractions of that power to different users in the network, so a single power constraint can give up many different information rates for a two-user channel. The maximum capacity for user A is achieved when 100 percent of the power is allocated to user A; for user B the maximum capacity is also obtained when it has all the power. For every possible power distribution there is realizable information rate, which results in the capacity regions the bigger one for the case where both users have approximately the same maximum capacity, and the other for a case where they are different (due, e.g., to user B's channel being attenuated relative to user A). For *K* users, the capacity region is characterized by a *K*-dimensional volume. The maximum achievable throughput of the entire system is considered by the point on the curve that maximizes the sum of all of the users' information rates, and is called to as the *sum capacity* of the channel.

VI. ANTENNA SELECTION PROCESS

Increasing the number of antennas in wireless system always gives benefit as a theoretical point of view. That is why, current novel showed that by increasing the number of TX antennas up to several hundreds, we can get very high SE [9]. Also it is expected that the radiation power is reducible according to the channel gain increment. Current base station (BS) consumes 60% _ 80% of energy in whole cellular networks [10]. It is easily expected that if we use LS-MIMO in BS, we can reduce the radiation power, consequently reduce BS power consumption. As base station has large number of antennas, and large scale base station antennas mean large scale RF chains, so the total power consume of RF chains can be nothing to sneeze at. previous works on antenna selection are mainly intense on traditional MIMO systems with a few antennas in base station. Antenna selection methods are typically categorized based on selection criteria. Maximization of capacity and maximization of post equalization signal to interference plus noise ratio are the most common criterion. The norm based algorithm [11] is a sub-optimal antenna selection approach that selects the transmit antennas corresponding to the columns of channel gain matrix with the largest Euclidean norm.

A optimal antenna selection algorithm based on capacity maximization is presented in Ref. [12]. It uses matrix inversion as a recursion for capacity computation, which increases its complexity. Ref. [13] proposes another near optimal antenna selection method with lower complexity. The process begins with an empty set and adds antennas iteratively based on its capacity contribution. To the best of our knowledge, there are few papers about the topic of antenna selection in the case of Massive MIMO wireless systems. The authors in Ref. [14] only consider fast fading and show that the method of selecting optimal transmit antenna subset is random selection as the number of selected antennas are fixed and satisfy a certain threshold. A low complex algorithm to choose the best transmit antenna with two restrained conditions in a massively distributed antenna system is proposed in Ref. [15].

VII. BENEFITS OF MASSIVE MIMO SYSTEM

Massive MIMO can boost the capacity 10 times or more and simultaneously, get better the radiated energy-efficiency [16] in the order of 100 times. The capacity increase results from the aggressive spatial multiplexing used in massive MIMO. The basic principle that enables the vivid increase in energy efficiency possible is that with large number of antennas, energy can be focused with extreme sharpness into small regions in space, The physics behind this is coherent superposition of wavefronts. By appropriately determining the signals sent out by the antennas, the base station can make sure that all wave fronts collectively emitted by all antennas add up constructively at the locations of the proposed terminals, but destructively (randomly) almost everywhere else. Fig.8(from [16]) depicts the fundamental trade off between the energy efficiency in terms of the total number of bits (sum-rate) transmitted per Joule per terminal receiving service of energy spent, and spectral efficiency in terms of total number of bits (sum-rate) transmitted per unit of radio spectrum consumed.

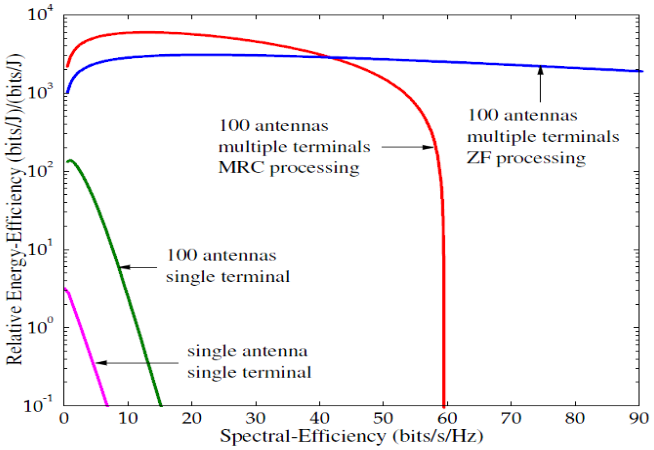

Fig 8 Relative Energy Efficiency V/S Spectral Efficiency[29]

a reference system with one single antenna serving a single terminal (purple),a system with 100 antennas serving a single terminal using conventional beam forming (green) a massive MIMO system with 100 antennas simultaneously serving multiple (about 40 here) terminals (red, using maximum-ratio combining; and blue, using zero forcing [17]). Massive MIMO can be built with low-cost, low-power components [18]. With massive MIMO, expensive ultra-linear 50 Watt amplifiers used in conventional systems are replaced by hundreds of low-price amplifiers with output power in the mille-Watt range. The contrast to classical array designs, which use few antennas fed from high-power amplifiers, is significant.

A massive MIMO system has a large extra degrees of freedom. For example, with 200 antennas serving 20 terminals, 180 degrees of freedom are unused. These degrees of freedom can be used for hardware-friendly signal shaping. In particular, each antenna can transmit signals with very small peak-to-average ratio [27] or even constant envelope [28] at a very self-effacing fine in terms of increased total radiated power. Such (near-constant) envelope signalling facilitates the use of extremely low-priced and power-efficient RF amplifiers.

Massive MIMO enables a significant fall of latency on the air interface. The performance of wireless communications systems is normally restricted by fading. The fading can cause to be the received signal strength very small at some times. This happens when the signal sent from a base station moves through multiple paths before it reaches the terminal, and the waves resulting from these multiple paths interfere destructively. It is this fading that enable it hard to build low-latency wireless links. If the terminal is intent in a fading dip, it has to wait until the propagation channel has adequately changed until any data can be received. Massive MIMO relies on the law of large numbers and beam forming in order to avoid fading dips, so that fading no longer limits latency.

Massive MIMO increases the robustness both to accidental man-made interference and to intentional jamming . Due to the scarcity [20] of bandwidth, spreading information over frequency just is not feasible so the we have only way of improving robustness of wireless communications is to use multiple antennas. Massive MIMO offers many excess degrees of freedom that can be used to cancel signals from intentional jammers. If massive MIMO is implemented by using uplink pilots for channel estimation, then smart jammers could cause destructive interference with modest transmission power. However, more clever implementations using joint channel estimation and decoding should be able to considerably reduce that problem.

VIII. LIMITING FACTORS OF MASSIVE MIMO

Channel Reciprocity

TDD operation relies on channel reciprocity. There appears to be a reasonable agreement that the propagation channel itself is basically reciprocal, unless the propagation is affected by materials with odd magnetic properties. However, the hardware chains in the base station and terminal transceivers may not be reciprocal between the uplink and the downlink. Calibration of the hardware chains does not seem to comprise a grave problem and there are calibration based solutions that have already been experienced to some extent in practice. Specifically, [21] treats reciprocity calibration for a 64-antenna system in some detail and claims a successful experimental implementation.

Pilot Contamination

Ideally each terminal in a Massive MIMO system is assigned an orthogonal uplink pilot sequence. However the maximum number of orthogonal pilot sequences that can survive is upper bounded by the duration of the coherence interval divided by the channel delay-spread. In [22],for a typical operating situation, the maximum number of orthogonal pilot sequences in a one millisecond coherence interval is approximate to be about 200. It is easy to tire out the available supply of orthogonal pilot sequences in a multi-cellular system. The effect of re-using pilots from one cell to another, and the related negative consequences, is known as “pilot contamination”.

Pilot contamination as a basic observable fact is not really specific to massive MIMO, but its effect on massive MIMO appears to be much more deep than in classical MIMO [22,23]. In ref. [22] it was argued that pilot contamination constitutes final limit on performance, when a large number of antennas is increased without limit, at least with receivers that rely on pilot-based channel judgment. While this argument has been contested recently [24], at least under some precise assumptions on the power control used, it appears likely that pilot contamination must be dealt with in some way. This can be done in several ways:

- We can optimize the allocation of pilot waveforms. One possibility is to use a low level aggressive frequency re-use factor for the pilots —. This pushes mutually-contaminating cells farther. It is also possible to organize the use of pilots or adaptively allocate pilot sequences to the different terminals in the network [25].
- Clever channel estimation algorithms [26], or even blind techniques that avoid the use of pilots altogether [27], may eliminate the effects of pilot contamination. The most promising direction seems to be blind techniques that jointly estimate the channels and the payload data.
- New precoding techniques are used in network structure, such as pilot contamination precoding [24], can utilize supportive transmission over a array of cells—beyond the beam forming operation—to nullify, the directed interference that results from pilot contamination. Unlike coordinated beam forming over multiple cells which requires estimation of the actual channels between the terminals and the service-arrays of the contaminating cells, pilot-contamination precoding requires only the equivalent slow-fading coefficients. Practical pilot-contamination precoding remains to be developed.

Radio Propagation and Orthogonality of Channel Responses

Massive MIM relies to a large degree on a property of the radio environment known as favourable propagation. Simply said, favourable propagation means that the propagation channel responses from the base station to different terminals are sufficiently different. To analyze the behaviour of massive MIMO systems, channel measurements [5] have to be performed using realistic antenna arrays.

This is so because the channel behaviour using large arrays differs from that typically knowledgeable using conventional smaller array.

The most important differences are that (i) there would be large scale fading over the array and (ii) the small-scale signal statistics may also change over the array. Of course, this is also true for physically smaller arrays with directional antenna elements pointing in various directions.

IX. FUTURE SCOPE

Massive MIMO renders many conventional problems in communication theory less relevant, it uncovers many new problems that need research:

-Fast and distributed, coherent signal processing. Massive MIMO arrays produce huge amounts of base band data that need be processed in real time. This process will have to be simple, and simple means linear or nearly linear.

-Defy of low-cost hardware.

Forming hundreds of RF chains, up/down converters, A/D–D/A converters, and so forth, will require wealth of scale in manufacturing comparable to what we have seen for mobile handsets.

-Internal power expenditure

Massive MIMO have the potential to reduce the radiated power thousand times, and at the same time radically improve data rate. But , the total power consumed must be under consideration, that includes the price of baseband signal processing. Much research must be invested into highly parallel, perhaps dedicated, hardware for the baseband signal processing.

- Channel classification

Massive MIMO has some additional properties of the channel, in its place of conventional MIMO. For massive MIMO systems it is necessary to have channel models that reproduce the true behaviour of the radio channel, i.e. the propagation channel including effects of realistic antenna arrangements. It is also important to build up more smart analytical channel models. Such models need not necessarily be correct in every fine detail, but they must capture the essential behaviour of the channel.

-Cost of reciprocity calibration.

TDD will require reciprocity calibration. How often must this be done and what is the best way of doing it? What is the cost, in terms of time and frequency resources needed to do the calibration.

-Pilot contamination.

It is likely that pilot contamination imposes much more strict boundaries on massive MIMO than on conventional MIMO systems. We discussed some of the issues in detail, and outlined some of the most relevant research directions.

X. CONCLUSION

This paper highlights that MIMO system will improve channel capacity, Bandwidth, high data rate, power requirement, bit error rate, size, complexity and reliability of connectivity in available limited frequency resources. Massive MIMO system as a core technology for future 4G cellular system. This paper raises some method of antenna selection for energy efficient transmission in massive MIMO system. In the end section it also gives researchers both in academic world and industry a goldmine of completely new research problems to solve as future scope.

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