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Comparative Study of Various Smart Antennas in Wireless Communication Systems

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Abstract: With an advancement in wireless access technologies, there has been tremendous increase in number of wireless user. So there is need to expand the capacity and network coverage area. To achieve these goals, powerful techniques like smart antennas are utilised. This paper presents the current and future smart antenna technology and discuss different types of smart antenna system using switched beam and adaptive antenna array method.
Keywords: Adaptive Antenna, Digital Signal Processing (DSP), Direction Of Arrival (DoA) estimation, Smart Antenna System(SAs), Switched Beam Antenna

I. Introduction

With the development of worldwide need of data, voice as well as video has brought about many significant modification in infrastructure. Coaxial cable, power line as well as fibre optics possesses specific disadvantages with respect to cost as well as bandwidth. The transmission is established separately above each and every link in wired communication and also in fibre optics, the valuable information is enclosed within a compact area in space creating the system much more reliable as well as efficient. However, this is not the case within the wireless communication where reliability is accomplished upon the expense energy wastage. Transmission over limited ranges needs a substantial amount of area, out of which little portion is obtained through intended customer while rest of portion acts as a interference to the other users of the system.

Particularly two issues have to be overcome in these systems; coverage (methods to maximise the coverage area where there is less demand to ensure that the cost as well as infrastructure decreases) and spectral efficiency (methods for enhancing the total capacity with cheaper costs while keeping the quality within the place wherever need is high)

With the growing innovative network numerous development over last few decades came into limelight including increased interface with air, modulation techniques, deploying of more compact radio cells and combination of distinct types of cells in-hierarchal architecture as well as advanced signal processing. Yet, none of them could entirely make use of multiplicity of spatial channel which comes up due to the fact that each mobile takes up special space. This method of employing space as domain for differentiating spectral plus temporal overlapping signals out of various cellular customers is referred as SDMA. This is hybrid multiple access approach improving FDMA as well as CDMA scheme. It enables several consumers as well as within the similar radio cells to utilize similar frequency as well as time slot. The complete exploration of this approach was achieved via smart antennas.

II. Smart Antennas

The idea of employing numerous antennas along with signal processing for providing cells much more wisely is persisting among several years. In reality diverse level of comparatively expensive SA systems are utilised in defence systems. The appearance of effective low-cost general purpose and digital signal processers in addition to signal-processing algorithms based on smart softwares have enabled smart antennas useful in cellular communication systems. This type of system is offering significant coverage region for every site of cell, lower interference and considerable improvements in capacity.[1]

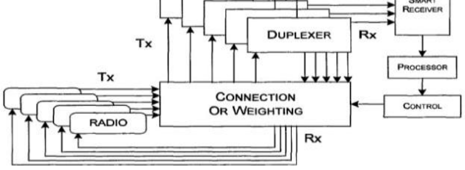

Fig 1: Smart Antenna System

III. Principal of Smart Antenna Systems

In smart antenna, each and every antenna element "perceives" each and every route differently allowing the variety of components to differentiate specific routes with a specific resolution. So, SA transistors may easily encode separate data streams upon various pathways or perhaps combinations of paths and thus improving the data rate or else encode information based upon the pathways which diminish separately so as to safeguard the recipient from catastrophic signal fades, thus giving diversity gain.

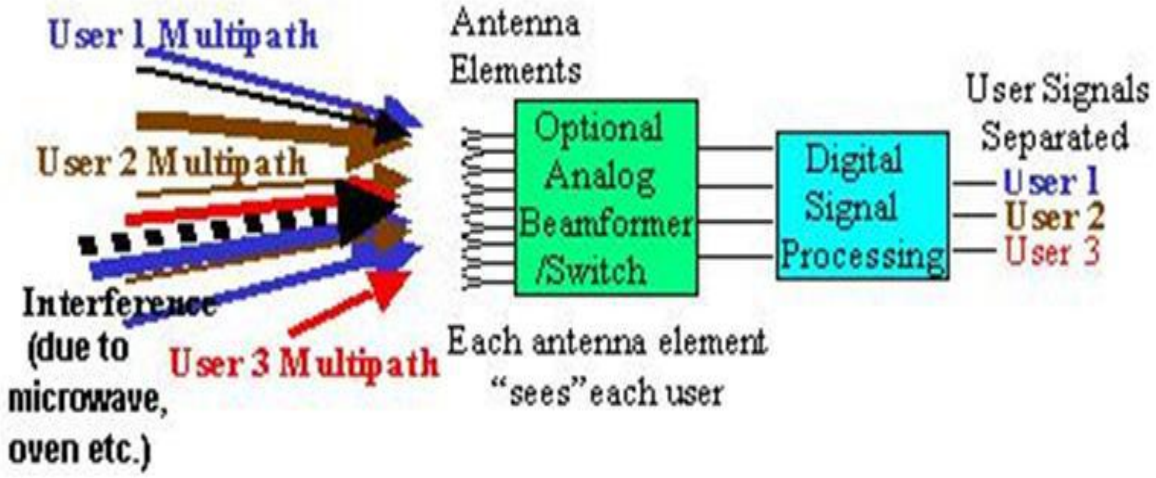

Fig 2: Working of Smart Antenna System

An intelligent antenna receiver is able to decode the information coming from a SA transmitter or perhaps it can easily provide advantage to the preferred signals transferred via conventional transmitters along with reducing the disturbance. There is no need of manually placing the antenna as they get adapted to the environment electronically. SA system integrates an antenna array together with the digital signal processing functionality when co-located with the base station in order to send out as well as acquire in an adaptive manner. This type of integrated system considerably improves the capacity of a wireless link by means of a mixture of array gain, diversity gain as well as decreasing interference. Enhanced capacity converts to improve rate of data for particular amount customers. Basically in response to its own signal environment, this system can modify direction of its radiation patterns. This tends to significantly boost the performance attributes of a wireless system.

IV. Need of Smart Antenna

Wireless communication systems in contrast with wired counter parts offers several distinct challenges like

1) Confined allocated spectrum generates a restriction on capacity

2) Radio propagation environment as well as flexibility of customers provide increase in signal.

3) Fading as well as spreading in space, time and frequency

4) Constrained life of the battery within the mobile gadget creates energy constraints.

Moreover, cellular wireless communication system need to handle interference because of frequency reuse. Study on effective technologies so as to mitigate these consequences are taking place over the past 25 years, since wireless communications are undergoing rapid growth. Among these strategies include multiple access schemes, channel coding as well as equalisation and SA environment. Within the communications systems an antenna is the port by which radio frequency (RF) energy is coupled to the outside world from the transmitter for transmission purposes as well as in opposite direction to receiver for receiving purposes from outside world.

V. Types of Antennas

The various types of smart antennas used with respect to the intelligence level are listed below:

5.1 Switched Beam Antennas

This antenna is used at base station possessing numerous directive antennas or perhaps pre-defined beam of an array. On the basis of received signal power it switches from one beam to an alternative beam. The result is sampled so as to provide the most effective reception beam. This is an improved solution in the direction of the cellular sectorisation wherein each and every cell offers three different 120o Macro-sectors split into Micro-sectors. These Micro-sectors have pre-determined pattern of beam which is chosen based on the weighted sum of the combined antenna array. Such beam possesses maximum sensitivity at centre reducing close to the peripherals. Then chosen beam gets migrated in other direction via altering the current phase to receive maximum signal desired. Here when the mobile station goes into a Macro-sector, a fixed Micro-sector beam is selected based on the finest receiving mode and the antenna system consistently monitor the particular strength of signal to alternative beams. It has many disadvantages like: Since the person steps in the direction away from the centre, the strength of the signal diminishes before it lies in the another fixed beam pattern. It could not differentiate among user signal and the interference signal. In case the noisy signal exists at midest of the beam and the person at the peripherals, the noisy signal will get boosted just like user signal which will decrease the strength of required user signal[2]

5.2 Dynamically Phased Array

Unlike switched beam antenna, this particular SA do not make use of pre-determined fixed beam rather it inspects the user signal by means of monitoring via DoA algorithm. In the case of fixed beam, when signal pass by the middle of the beam and reaches peripherals, the strength of signal diminishes as well as gain decreases while intra-cell handover.

5.3 Adaptive Antenna Array

It is widely known as smartest of all. It is a collection of elements of array which varies its own pattern of radiation in accordance with the environment variations. Such changes are usually updated frequently to ensure that it possesses optimum profit towards desired user as well as minimum in the direction of noise of channel and interference so as to enhance SNR of desired signal. Such technique is called as adaptive beam forming or perhaps digital beam forming. It is further categorised into types such as

a) Phased array: Within this technique, merely current phase is varied based on the weights.
b) Adaptive array antenna: This is rigid array wherein both the phase as well as amplitude of the current changes to generate a beam towards preferred direction so as to increase SNR. By using innovative algorithms, the antenna array separate the multipath as well as desired signal and interference. This helps to transfer the beam in the direction of wanted signals and nulls down the interference. Another benefit of this antenna which makes it more effective is its capability to generate spectrum.. By the process of properly differentiating between desired user, interference signal as well as multipath, the adaptive array enables us to utilise channel in the same cell users. Capacity improves by cutting down intra cell as well as inter cell frequency re-use pattern. In switched beam, the beam moves just for wanted signal rather than in reaction to the interfering signal. When the interfering signal approaches close to the middle of beam, it gets similar processing degrading the communication. However ,in adaptive array it can separate the required user and interfering signal. It will eventually band over any two channel user no matter if they are intra cell or perhaps inter cell prior the come too close and intervene against each other.[2]

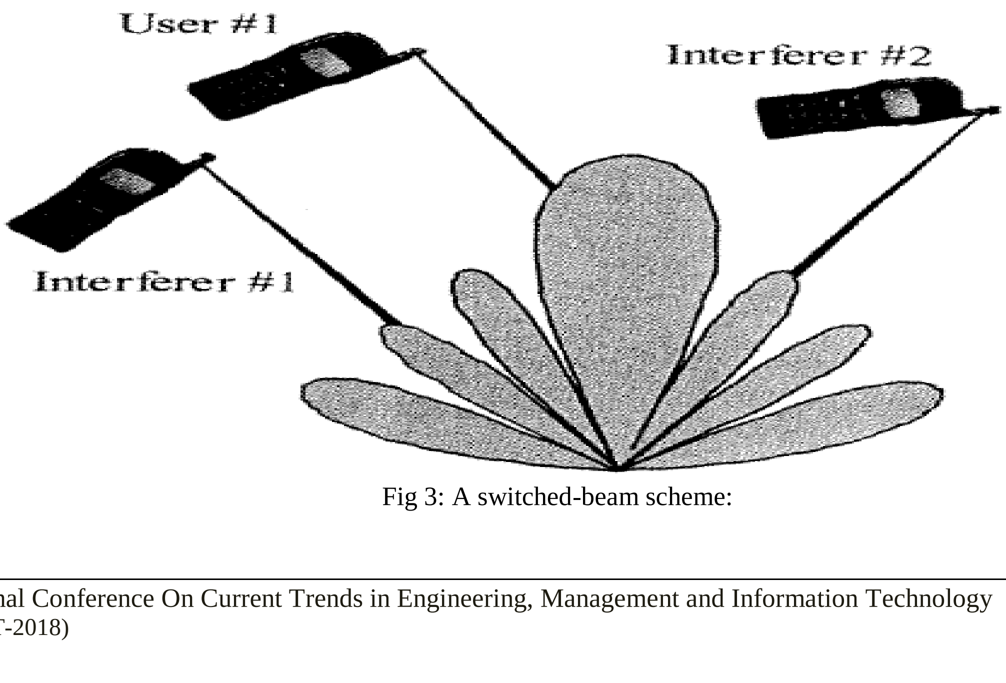

Fig 3: A switched-beam scheme:

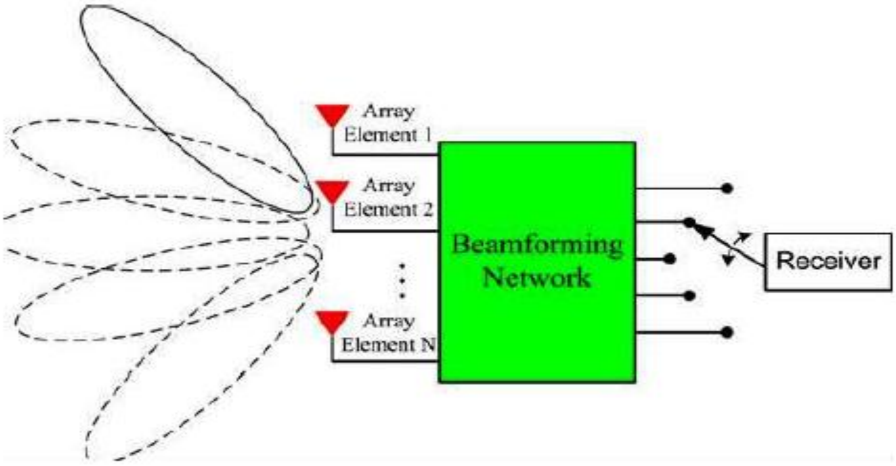

Fig 4: A functional block diagram of Switched Beam Antenna system.

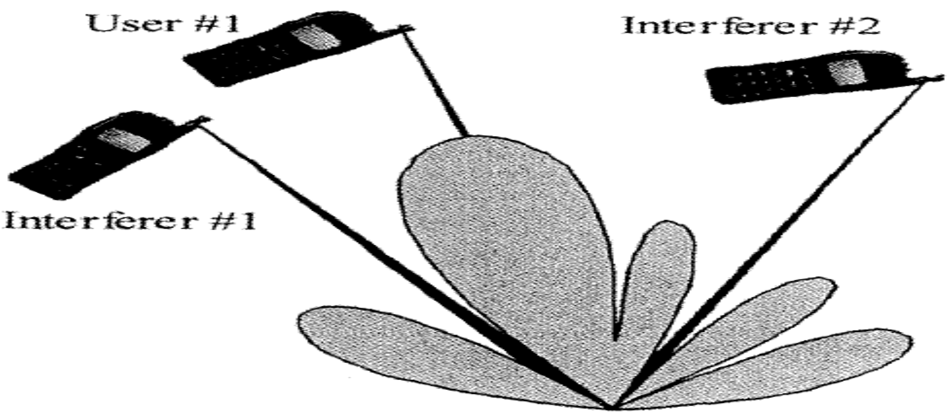

Fig 5: An adaptive-array scheme

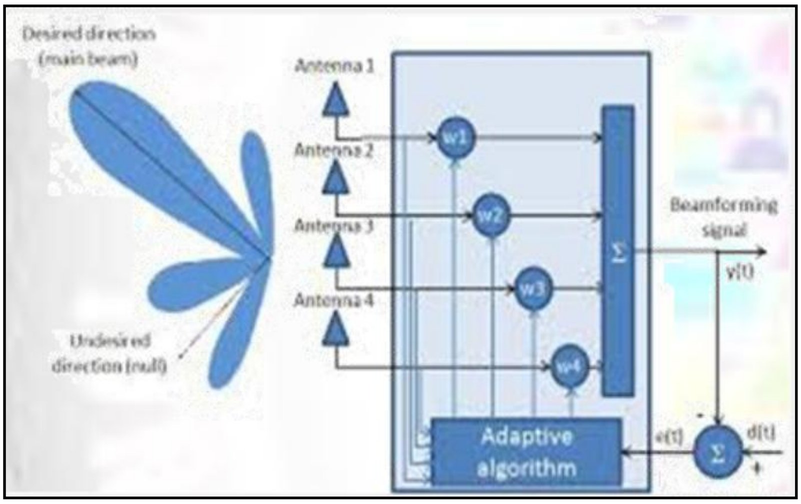

Fig 6: A functional block diagram of an Adaptive Array Antenna system

Table 1- Features and Benefits of Smart Antenna

Feature	Benefit
Signal Gain—Inputs from multiple antennas are combined to optimize available power required to establish given level of coverage.	Better Range / Coverage—Focusing the energy sent out into the cell increases base station range and coverage. Lower power requirements also enable a greater battery life and smaller/lighter handset size.
Interference Rejection—Antenna pattern can be generated toward cochannel interference sources, improving the signal-to-interference ratio of the received signals.	Increased Capacity—Precise control of signal nulls quality and mitigation of interference combine to frequency reuse reduce distance (or cluster size), improving capacity. Certain adaptive technologies (such as space division multiple access) support the reuse of frequencies within the same cell.
Spatial Diversity—Composite information from the array is used to minimize fading and other undesirable effects of multipath propagation.	Multipath Rejection—can reduce the effective delay spread of the channel, allowing higher bit rates to be supported without the use of an equalizer, improved bit error rate (due to decreased amount of multipath and ISI).
SDMA- SDMA continually adapts to the radio environment through intelligent / smart antenna.	Providing each user with uplink and downlink signals of the highest possible quality and can adapt the frequency allocation to where the most users are located.
Power Efficiency—combines the inputs to multiple elements to optimize available processing gain in the downlink (toward the user)	Reduced Expense—Lower amplifier costs, power consumption, and higher reliability will result. Lower power consumption reduces not only interferences but also reduces RF pollution (ease health hazard). It will also result in reduction of scares energy resource (diesel consumption) and save foreign currency.

VI. Applications of Smart Antenna

A SAs can do creating of send/acquire beams for the cellular interest. Also it is possible to put special nulls towards undesirable interfaces. This kind of functionality enables you to enhance the overall performance of mobile communication system.

6.1 Increases Antenna Gain

The smart antenna transmit as well as receive beams hence the smart antennas carries an increased gain than the usual standard omni directional antenna. The increased gain enables to improve the effective coverage or it can enhance the receiver sensitivity that can lower the transmit power as well as electromagnetic radiations within the network.

6.2 Decreased Inter-Symbol-Interference (ISI)

Multiple propagation within cellular radio environments contribute to ISI. Utilising transmit as well as receive beams which are guided in direction of cellular of interest decreases the amount of multipath as well as ISI.

6.3 Decreased Co-Channel Interference (CCI):

Smart antenna transmitters discharge smaller amount of interference by means of transmitting RF Power towards the desired direction. Also smart antennas receiver can easily deny interference by seeking in the direction of the desired source. Therefore, smart antennas are equipped for reducing CCI. Considerably, decreased CCI could be used as an advantage by SDMA. The same frequency band could be reused within additional cells. This method is referred as channel reuse by means of spatial separation. Several signals reaching the base station can be separated by separated by base station receiver until and unless their angular separation is greater than the transmit \ receive beam width. The beams which are batched in the same way make use of the same frequency band. This energy is known as channel reuse by means of angular separation.

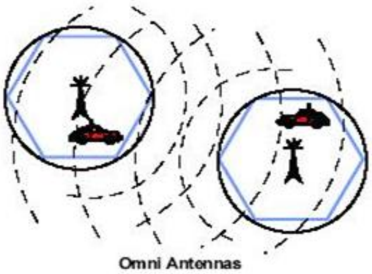

Fig 7: Omni- Directional Antenna

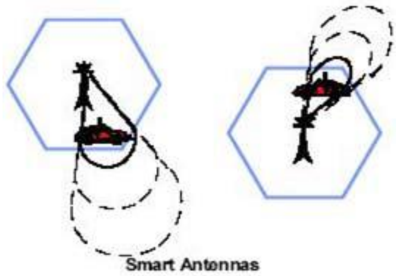

Fig 8: Smart Antenna

VII. LITERATURE SURVEY

Comparison of Different State of Art

Authors	Year	Ref	Parameters	Techniques	Strengths	Limitations
Michael Chryssomallis	June 2000	[3]	Spread delay and multipath fading	*SMI*Algorithm, *CMA algorithm, Conjugate Gradient Method*	If with TDMA and CDMA we will use smart antennas with space proccssing, there can be substantial additional improvement	1) In order to achieve high frequency reuse, TDMA systems will need multiple anleniias on the handsct 2) Interference problem is more worse on theUplink as compared to the downlink
Alpesh U. Bhobe	2000	[4]	Capacity, Hardware, Flexibility	Switched beam and adaptive antenna arrays	High performance is achieved in handover, ability to support high data rates and better coverage in difficult areas	The performance of the system based on spot beam was not efficient
Martin Wagner	2004	[5]	Tolerance, dual slant polarization	4x 4 dual polarized, multiband array integrated with calibration network	In order to achieve performance, weight, and cost, the antenna integrates multiple progressive technologies	The problem of hand over is not carried out properly
Pieter van Rooyen	2006	[6]	Accuracy	Multi-loop antenna	There is reduction in multiple access interference, enhancement in the performanceof system in terms of throughput, satisfy QoS constraints	linear precoding suffers from noise enhancement and hence poor power efficiency
Xianming Qing,	2007	[7]	Reception Condition and Environment Influence	Reflection smart algorithm	The performance of the system in terms of data rate was quite good	A large reflector cannot efficiently raise the performance of similar smart antenna with its own indicate software.
Hai-Tao Liu	2011	[8]	The antenna height and the distance among driven as well as folded monopoles	Electronically Steerable Parasitic Array Radiator (ESPAR) antenna	1) The folded monopole ESPAR antenna achieves a gain of 4 dBi and a front-back ratio larger than 14 dB. 2) The antenna is able to perform beamforming	Though it has low size, low power consumption but it is not very efficient in terms of data rate
Ankit Dalela	April 2013	[9]	time diversity, frequency diversity and	Adaptive antenna array beamforming	Smart antenna techniques are introduced whose radiation pattern can be varied without changing it mechanically	Conclusions about how best to upgrade a network in a best way are not easily made

			spatial diversity			because every operator has a unique set of constraints such as what frequencies are available
Giriraj Prajapati	Sep 2013	[10]	gain, smith chart radiation pattern for 3GHZ frequency band.	Artificial immune system	1) SA systems can fasten the beams for receiving towards desired incoming signals. 2) The inclusion of appropriate delay in time would facilitate the constructive summation of the output signal, hence increasing signal power	1) Applying smart antennas into a CDMA system. 2) The theory of the time delay smart antenna system could be investigated to prove that this can in fact be done.
Prerna Saxena*,	2014	[11]	Beamwidth, null depth	*LMS Algorithm, SMI Algorithm, RLS Algorithm, CGM Algorithm*	1) The effect of number of antenna elements (M) on beamforming is analyzed that with increase in M, there is reduction in beamwidth 2) CGM algorithm has the fastest convergence and greatest null depths ensuring good performance.	LMS algorithm has a very slow rate of convergence.
Keerthi A Kumbar	June 2015	[12]	Mean square error, computational complexity	MUSIC (Multiple Signal Classifier) ESPRIT (Estimation of Signal Parameters via Rotational Invariance Techniques)	1) Greater resolution and accuracy is achieved by DoA estimation using MUSIC algorithm 2) MUSIC algorithm offers high resolution	The efficiency of the system is not upto required standard
JIAN A. ZHANG	Febr uary 2015	[13]	Pure Beamforming and AoA estimation	mm-Wave hybrid arrays	For overall performance and hardware feasibility, the localised array proves to be the best.	A wideband array involving analog tapped delay line has much higher complexity
Ms.Snehal N. Shinde1	Dec 2015	[14]	radiation pattern ,mean square error ,convergence rate	Sample Matrix Inversion (SMI) Algorithm:, Conjugate Gradient Method (CGM) Algorithm, Block Based Normalized Least Mean Square (BBNLMS)Algorith m, Recursive Least Square (RLS) Algorithm:	In short adaptive beamforming algorithms we have enhanced signal reception ensuring maximum gain as it zeros out the interference which result in more throughput and improved system performance.	Instead of using only smart antenna we can use smart antenna with cognitive radio and analyse respective algorithms.

Parneet Kaur	October 2015	[2]	SINR ratio , finite impulse response (FIR) filter	Digital Beam Forming implementation of CDMA	Smart Antenna are the best technique to enhance strength of signal, capacity and coverage	1) Many challenges occur like in power consumption, size and diversity. 2) In handsets multiple antennas raises the cost and decreases the battery life
Bakshi Bhagyashri Renukadas	2016	[15]	*Increased Antenna Gain,* *Decreased inter symbol interference*	Recursive Least Square Algorithm (RLS)	1) The interference in the narrow beams is removed, that enable multiple customers to be connected with the same cell at the same time using same frequencies 2) Effectively reduce the consumption of power that reduces RF pollution and save scarce resource	The focus on the spot fading has not been made.

VIII. Conclusion

To conclude we can say smart antenna system are the antennas with intelligence and the pattern of radiation can be changed without mechanical practise. The advantage and disadvantage of two types smart antennas were discussed. Diversity techniques can be used to improve the performance of the radio channel. Without any increase in transmit power using appropriate adaptive algorithm such as RLS, the beamforming can be obtained. Smart antenna can efficiently reduce a power consumption and avoid RF pollution. Without the use of smart antennas, the required performance of future cellular system cannot be think of even. The existing algorithms used do not provide the high capacity and coverage as and when required. So in near future we will evaluate more algorithms to overcome these issues.

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