IRO Journal on Sustainable Wireless Systems (ISSN: 2582-3167)
www.irojournals.com/irosws/

Challenges and Opportunities in Smart Antenna

W. S. Kiran

ECE Department, Sivaji College of Engineering and Technology, Parasuvaikkal, India

E-mail: ws.kiran@gmail.com

Abstract

The ever-increasing demand for larger bandwidth with seamless and fast data access for commuters resulted in developing new challenges for wireless service providers. With the increasing network mobility, the communication channel based characteristics between base stations and mobile users are changing rapidly. To meet these challenges, smart antennas have become an essential component in the emerging wireless systems. The increasing requirement for increasing stable network performance and reducing electromagnetic pollution has strengthened smart antenna adoption. The primary objective of this research study is to highlight current research works in the area of smart antennas by evaluating the key technologies, service strategies, solutions and its importance in terms of 5G including network coverage enhancement, data speed, and Quality of Service (QoS).

Keywords: 5G Smart Antennas, MIMO, Wi-Fi, Wi-MAX, Cellular Systems

1. Introduction

The expanding growth of smart antenna in wireless networks, combined with the increasing requirement for delivering a stable and reliable network performance has accelerated the process of smart antenna adoption. The growing number of smartphone devices and increased adoption of mobile-connected devices have supported the growth of smart antenna market. In the process of forecasting, the continuously increasing demand for broadband services, ultra-speed communications and cost-effective connected devices have increased the adoption of smart antennas. However, in the recent past, its market growth is declined due to its high cost. With the increasing adoption of Internet of Things (IoT) and Cyber physical Systems (CPS), the mobile networks are expected to integrate smart antenna to provide a better service to the users [1]. Smart antennas can detect and start receiving all types of signals flawlessly. This technology enables secured and fast two-way communication. The technology market is

DOI: https://doi.org/10.36548/jsws.2022.3.003
Received: 12.07.2022, received in revised form: 13.08.2022, accepted: 26.08.2022, published: 05.09.2022

rapidly expanding by moving to 5G networks. Due to various technological advances, industries rely on faster two-way communication. This expands the smart antenna market. The radio frequencies in 5G millimetre wave are considered as the major component of smart antenna market [2].

2. Technology Analysis

2.1 Multiple Antenna Based Model

In contrast to the traditional non-array antenna models with single antenna, smart antenna arrays utilize multiple antennas by employing Multi-Input & Multi-Output (MIMO) technology for forecasting and improving the signal quality at both transmitter and receiver with a minimal cost. Smart antennas provide the most effective coverage for LTE networks. However, when it comes to the 5G networks, smart antennas should also provide a mobility support as it is widely applied to many applications such as voice over 5G, augmented reality, and connected vehicles [3].

Figure 1. Antenna Array

2.2 Beamforming

Beamforming generally represents the higher utilization of the RF signals as per the requirement. 5G based Smart antennas have employed beamforming as the signals at higher frequencies can easily contains attenuation. The utilization of RF signals is more focused on generating a narrow beam rather than spreading the same energy into a broad area.

The smart antenna beamforming pattern will be useful for the handling the signals that travel through a particular distance. However, it will also result in developing attenuation loss and fading while the signal gets hit by the different objects like foliage, cars, buildings and so on. To establish a more directed beam to the user and ensure the optimal signal quality and bandwidth, smart antennas employ Space Division Multiple Access (SDMA) technology

with which more than one user can be allocated to a smart communication channel and within the same cell only by slightly varying the angle [4] as shown in Fig 2.

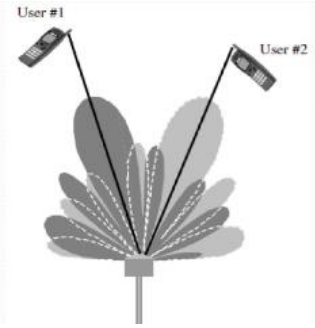

Figure 2. SDMA Technology

Fig 3 shows the real-time simulation of 5G smart antenna, where a network of spatially separated nodes is connected to a common source to provide improved 5G coverage and also optimize the network capacity and handover by remaining more focused on the RF signals.

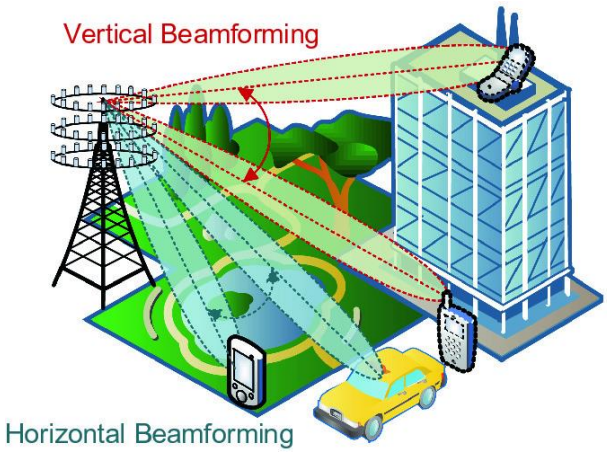

Figure 3. Real-Time Implementation of SDMA based 5G Smart Antenna [5]

The 5G spectrum has two different bands, namely FR1 and FR2, wherein FR1 defines the sub 6GHz frequency spectrum band and FR2 defines the millimetre wave spectrum band. With the smart antenna and advanced beamforming techniques, the FR1 will play a major role in wireless network communication in 2027, despite that the FR2 will become three times advanced and fast at a market CAGR of about 37.65% [6].

2.3 Network Optimization

The implementation of smart antenna enhances the 5G network coverage and optimization by only focusing on the RF signals. With the advanced switch-based mechanism

and adaptive array models, smart antennas increase the network service mobility, 5G hand-over and connectivity by establishing a continuous connection and user experience. For supporting the smart mobile services, IoT systems and establishing communications in mission-critical applications, 5G networks need smart antennas to handle the millimetre wave radio frequency propagation. However, higher frequencies necessitate higher coverage and power as the radio frequency signal fades more when compared to low frequency signal.

This pose the requirement of incorporating more magnitude of antennas than it is required for 4G and LTE. For instance, in the near future the United States of America will increase the total number of antennas employed in the country from 30,000 to 3,00,00 [6]. The 5G smart antennas will be present virtually at all the places but this will not completely satisfy the requirements of futuristic networks.

2.4 Smart Surface Internetworking

As the manufacturing of compact smart antennas are still in the research and development phase, the MIMO based smart antennas are fast growing and it finds its applications in the smart surfaces such as walls, buildings, clothes, etc. The pre-fabricated smart antennas in these surfaces will enhance the communication range and also facilitate the implementation of self-adaptive antennas to modify and transmit the RF signals from transmitter to receiver.

Fig 4 shows the application of 5G smart antenna systems by embedding the smart antenna receivers in various smart surfaces. This will enhance the network security, coverage and capacity. The smart surface internetworking will also develop potential opportunities for enabling wireless on-demand services in the real-time applications such as localization, embedded computing, and positioning.

Figure 4. Surface Internetworking with Smart Antennas

The smart antenna combinations can be adjusted in a flexible manner to increase the signal strength specifically in the obstacle-prone direction. This technique will increase the speed of Wi-Fi devices despite the network attenuation challenges. In the obstacle prone direction, the antenna directions can be adjusted by using multipath beamforming methods to leverage uncompromised network services to the end-user.

3. Opportunities for Smart Antennas in Different Scenarios

3.1 Network Enhancement in Complex Obstacle Prone Wireless Environment

In a confined office space with partitioned meeting rooms, smart antennas can be employed to increase the wireless network coverage. Fig 5 shows the scenario in which the signals require to penetrate through walls, where the directional beams struggle to penetrate through it. In such situations, smart antennas can be employed to bypass the obstacles by using the multipath propagation models by eliminating the signal attenuation [7].

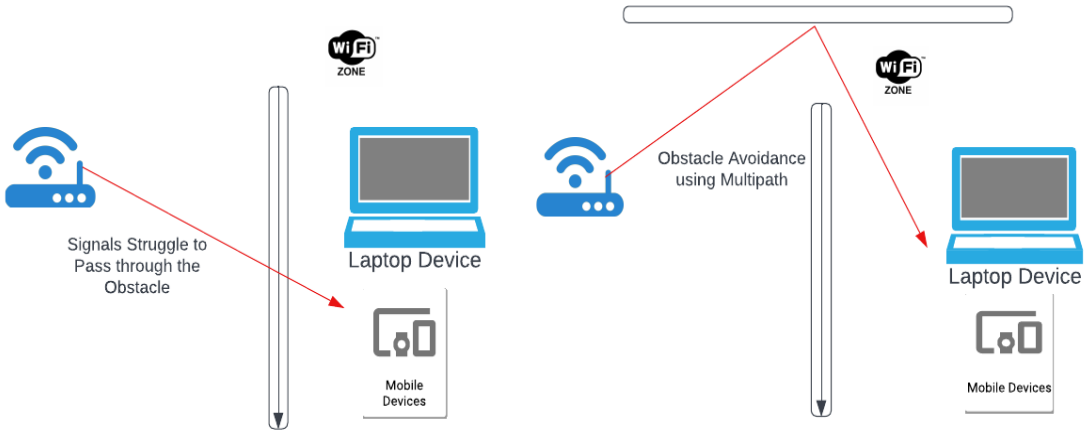

Figure 5. Multipath propagation

3.2 Network Coverage in Long Distance Scenarios

Without any confined office space, in the open-office environment, when the connected mobile terminal moves far away from the base station as shown in Fig 6, there will be difficulties in transmitting and receiving the signals. The recently adopted smart antennas with intelligent algorithms select the appropriate directional antenna array beam depending on the end-user location within 40 Meters /7–7.3 MHz [8] by replacing the traditional antennas. The adaptive array beam of smart antennas delivers high gain and long-distance coverage even at the network edge.

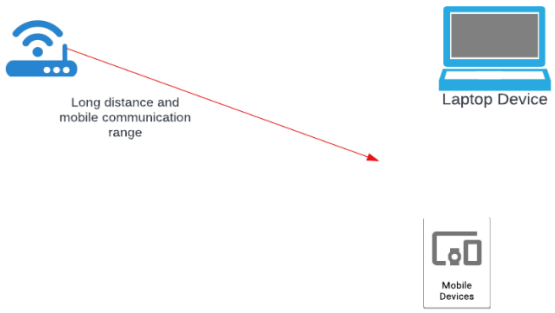

Figure 6. Long Distance Communication

3.3 Network Coverage for Concurrent Users in High-User Density Environment

The office environment with high user density and small obstacles as shown in Fig 7, the smart antenna models based on MIMO technology can enhance the data transmission efficiency. In the scenario mentioned below in Fig 7, the smart antenna technology MU-MIMO uses the same direction beam for the different users present in the same direction [9]. This approach highly increases the number of signals received by the end users by reducing the interference that occur in different directions.

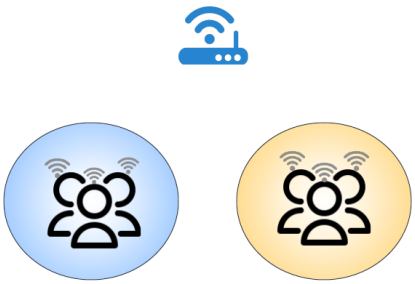

Figure 7. High User Density Environment

4. Challenge faced by Smart Antennas

4.1 COVID-19 Impact

Even though smart antennas have created potential opportunities that are covered under the regular communication spectrum. The COVID-19 impact has adversely affected the smart antenna market. However, in the initial days of pandemic, smart antennas have played an indispensable role in enabling remote work, and securing the fast signal transactions. As the pandemic progressed, the manufacturing of smart antennas has also been affected. This has led the R&D to expand the smart antenna applications in the untapped areas. The smart

antenna products developed after the pandemic are more reliable, efficient and attractive by remaining compatible to the future frequency bands.

4.2 Multipath Delay

Multipath condition occurs when the radio signal transmitted gets reflected by some other physical objects. This creates different signal paths along with the original channel path between base station and the end-user. This in turn results in generating undesired out-of-phase reflected signals, which is known as fading [16].

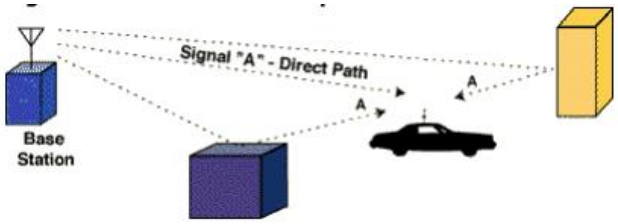

Figure 8. Multipath Delay [10]

One of the primary drawbacks that limit antenna is co-channel interference. To combat this challenges, Smart antennas should not only consider the directionality of end-users but also the direct null values and intentional signal transfer to undesired users.

4.3 Role of India in Developing Smart Antenna Applications

India is currently in the process of replacing the traditional antenna system with the smart antenna systems. This effort has been initiated to maintain the highly dynamic utilization of antenna services. The emerging ICT companies in India are using smart antennas to develop their own product solutions and use cases.The reduced smart antenna manufacturing cost is the main boom for the development of smart antennas in India. The cost remains lower since India is using the older frequency range and generation. An analysis has been made on the recent smart antenna systems, technologies, applications and its advantages are depicted in table 1.

Table 1. Analysis on recent smart antenna systems

System Model	Technique Used	Developed By	Advantages	Applications
Massive-element antenna systems technology	Multibeam multiplexing technology	Mitsubishi Electric Corporation [12]	50 times faster data transmission speed, stress free communication	Real Time 5G Network Realization

64-element, single-polarization 5G phased array antenna	A planar antenna with multiple beam widths	Keysight Technologies [13]	Covers 27.5 to 30 GHz frequency band	Portable solution for measuring and analyzing 5G interface
Multiband antenna with slim footprint	600 MHz solutions	Ericsson AB	Optimal gain performance, lower radio frequency and better throughput	In Rural areas with more surrounding objects
5G-powered smart antenna	4-element design, dual-band and dual polarized and high-performance reflection	Huawei Technologies Co. Ltd [6]	Narrow Beam, Longer Coverage	5G communication systems
Smart Transmit 3.0	Snapdragon X70 Modem-RF System	Qualcomm Technologies, Inc., [14]	Improved, Robust and Reliable Connectivity	5G Standalone mmWave connection
Massive MIMO Adaptive Antennas	AirScale massive MIMO Adaptive Antennas supporting high RF bandwidths, up to 400 MHz	Nokia Corporation [15]	Beamforming optimized solutions ranging from dense-urban capacity to wide-area coverage.	5G network deployments
5G antenna	5G millimeter wave solution integrating RF, antenna, beamforming, and control algorithms	Movandi [11]	Performance Improvement	1. Content delivery 2. Virtual and augmented reality 3. Massive Internet of Things 4. Mission-critical vehicle-to-vehicle.
Non- line-of-sight (NLOS) backhaul system	Transport systems for multimode 3G/4G/Wi-Fi cells	BLiNQ [11]	Network-wide intelligence and adapts to complex and dynamic environments	HetNet applications.
Software-defined antenna	Holographic Beam Forming (HBF) technology	Pivotal Commware [11]	Increase in network speed, capacity, and spectral efficiency	Access-in-Motion connectivity, broadband wireless access, defence communication
Distributed antenna systems	Wideband, PIM resistant, Full MIMO technology	Zinwave [11]	Active one layered system	In-building wireless and IP applications

Smart Antenna System	2 x LTE 698-3800MHz (MiMo)	Sierra Wireless [17]	Fixed LTE MIMO antenna	Ideal for IoT applications
Smart radar and 5G antenna system	Adaptive metamaterials and Artificial Intelligence	Metawave [11]	Accurately determine the location and speed of all road objects	Autonomous vehicles and wireless communication

From the aforementioned table, it is evident that the smart antennas have become popular in recent years especially for the deployment of 5G applications. The enhancement of antenna signal processing for example: Qualcomm's smart transmit 3.0 has become another significant advancement. The development of NonLine-of-Sight backhaul system, massive MIMO adaptive antennas, 2xLTE 698-3800MHz (MIMO), dual-band, dual polarized high performance reflection systems design, planar antenna with multiple beamwidths, and multibeam multiplexing technology, which have already evolved into the real-time applications are the ideal examples for the progress of smart antenna systems.

5. Summary and Future Research Directions

In this research study, a comprehensive analysis on the technologies, benefits and more recent smart antenna systems is given. The successful implementation of smart antennas depends upon the specific characteristics at the initial stage of the future wireless systems. In this perspective, the emerging trend in the smart antenna domain is adaptability, dynamic channel propagation, multipath propagation & multi-user technology, network optimization, and surface internetworking techniques have been discussed. Moreover, the emerging challenges due to COVID-19 crisis, and multipath delay and inter-symbol interferences have also been discussed along with the market trending technologies. The future research directions will be initiated on designing and developing smart antennas to expand and extend the global network coverage.

References

[1] Kishore, Nawal, and Anupama Senapati. "5G smart antenna for IoT application: A review." International Journal of Communication Systems: e5241.

[2] Jabbar, Abdul, Qammer H. Abbasi, Nadeem Anjum, Tahera Kalsoom, Naeem Ramzan, Shehzad Ahmed, Piyya Muhammad Rafi-ul-Shan, Oluyemi Peter Falade, Muhammad

Ali Imran, and Masood Ur Rehman. "Millimeter-Wave Smart Antenna Solutions for URLLC in Industry 4.0 and Beyond." Sensors 22, no. 7 (2022): 2688.

[3] Tubbal, Faisel, Ladislau Matekovits, and Raad Raad. "Antenna Designs for 5G/IoT and Space Applications." Electronics 11, no. 16 (2022): 2484.

[4] Britto, Elizabeth Caroline, Sathish Kumar Danasegaran, Susan Christina Xavier, A. Sridevi, and Abdul Rahim Sadiq Batcha. "Study of Various Beamformers and Smart Antenna Adaptive Algorithms for Mobile Communication." In Smart Antennas, pp. 111-130. Springer, Cham, 2022.

[5] Davydov, Vadim, Grigoriy Fokin, Vitaly Lazarev, and Sergey Makeev. "Space Division Multiple Access Performance Evaluation in Ultra-Dense 5G Networks." In Internet of Things, Smart Spaces, and Next Generation Networks and Systems, pp. 86-98. Springer, Cham, 2020.

[6] https://www.giiresearch.com/report/min1065455-5g-smart-antenna-market-by-type-switched-multi.html

[7] https://info.support.huawei.com/info-finder/encyclopedia/en/Smart+Antenna.html

[8] https://en.wikipedia.org/wiki/Amateur_radio_frequency_allocations

[9] Chen, Li, Zhiqin Wang, Ying Du, Yunfei Chen, and F. Richard Yu. "Generalized transceiver beamforming for DFRC with MIMO radar and MU-MIMO communication." IEEE Journal on Selected Areas in Communications 40, no. 6 (2022): 1795-1808.

[10] http://www.cs.binghamton.edu/~vinkolar/directional/smart_ant.pdf

[11] https://tracxn.com/d/trending-themes/Startups-in-Telecom-Antennas

[12] https://www.mitsubishielectric.com/en/about/rd/research/highlights/communications/5g.html

[13] https://www.keysight.com/in/en/product/85571A/5g-phased-array-antenna.html

[14] https://www.qualcomm.com/news/releases/2022/05/qualcomm-unveils-new-features-snapdragon-x70-modem-rf-system#:~:text=Smart%20Transmit%203.0%20extends%205G,enjoy%20faster%2C%20more%20reliable%20connectivity.

[15] https://www.nokia.com/networks/mobile-networks/airscale-radio-access/active-antennas/

[16] Senapati, Anupama, B. Shivalal Patro, Kriangkrai Sooksood, and Sushanta Kumar Mohapatra. "Performance of Smart Antenna Under Different Fading Conditions." Wireless Personal Communications 124, no. 2 (2022): 1493-1509.

[17] https://www.sierrawireless.com/router-solutions/antennas/

Author's biography

W. S. Kiran is from ECE Department of Sivaji College of Engineering and Technology, Parasuvaikkal, India. Her area of interest included wireless sensor networks, routing algorithms, network design, mobile networks and optimization algorithms**.**