Communication technology and the prospect of 5G

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Abstract. Since the turn of the twenty-first century, our civilization's expansion has accelerated dramatically. Science and technology are becoming increasingly refined and intelligent. In the field of communication, five generations have existed. It is utilized in many regions of the globe. A range of modern communication technologies have made it more practical for both individuals and groups. This essay will cover the history of communication as well as the essential concepts underlying the development of crucial 5g technologies like as non-orthogonal multiple access (noma), ultra-dense hetnets and massive mimo(multiple-input multiple-output). The majority of this paper's sections relate to the sections listed in the table of contents: general characteristic, benefit, development, and outlook. Also what the paper covered includes the mimo-noma system, which combines mimo with noma. For the tendency of it,we can continue to investigate this potential method. In its conclusion, the research examines the possibilities for future growth in the communications industry. Despite some disadvantages, these technologies offer numerous merits. As communication technology advances, artificial intelligence, the internet of things, transportation, and other industries will alter.

Keywords: Communication Technology, 5G, MIMO, NOMA.

1. Introduction

All items' pace of evolution has accelerated due to technological breakthroughs. Communication technology has modernized the five generations of mobile networks in this aspect. Currently, more people than ever before have access to convenience. 5G offers substantial benefits over earlier mobile communication technologies. Massive access, ultralow latency, and high-speed internet are characteristics of 5G communication technology. It can benefit big data, AI, autonomous driving, and the Internet of Things[1]. In addition, it will stimulate the informationalization of the current production and service sectors. 5G was essential for everything from medical delivery to communication during the COVID-19 outbreak. Pandemic has increased capacity by 5G.

Back to the history, Maxwell argued in 1864 that light is a transverse electromagnetic wave using his famous equations. He integrated the concepts of magnetism and electricity. Alexander Graham Bell invented the first telephone in 1876 for the purpose of obtaining a patent[2]. Twenty years old Marconi became aware of Heinrich Hertz's 1894 experiments demonstrating the existence of invisible electromagnetic waves that traveled through the air at the speed of light. In 1895, Marconi also devised the wireless telegraph. Since the 1950s, when the third technological revolution began, advancements have been made in communication technology. In the 1970s, the first generation was born. This catastrophe impeded the evolution of five generations and descendants of communication technology. According to forecasts, it will generate a substantial amount of revenue. It is a significant development in the communication industry.

Over the past two decades, a substantial quantity of cutting-edge, essential technology has been deployed to facilitate the widespread use of 5G technology in numerous areas of our society, including by individuals and organizations. The non-orthogonal multiple access method is the primary means of entry. The typical orthogonal multiple access protocol cannot meet the connectivity needs of user equipment, which include extremely high data rates, extremely low latency, extremely dependable and extremely extensive connectivity. NOMA technology may bypass the multi-user channel's capacity barrier, making it a viable solution for satisfying the aforementioned criteria of 5G wireless systems. Multiple users' signals can be sent over the same time-frequency resource element (RE) using Many Access Non-Orthogonal, which is comparable to a single subcarrier in an OFDMA sign[3]. The second factor is technology, which has several inputs and outputs. MIMO is one of the most current variations of this technology. Point-to-point In a variety of respects, MIMO is not as advantageous as multi-user MIMO. First, because it employs low-cost single-antenna terminals, a dense scattering environment is unnecessary. Second, because each active terminal utilizes every time-frequency bin, resource allocation is simplified because each terminal uses every time-frequency bin.

Contrary to widespread opinion, frequency-division duplex operation and multi-user MIMO with about similar amounts of service antennas and terminals are not scalable technologies. Massive MIMO departs from standard practice by employing an unusually large amount of service antennas across active terminals and by using time-division duplex operation. Increasing the number of antennas improves both the throughput and the efficiency of the radiated energy. This is accomplished by concentrating energy in ever-smaller regions of space. Large MIMO's significant use of low-cost or power units saves latency, simplifies the MAC layer, also offers resistance to purposeful jamming[4].The technology behind dense hetnets is vital. In conjunction with the the number of mobile devices, Internet of Things, human, human-machine, and machine-machine interactions is increasing at an exponential rate.

Consequently, the exponential growth of wireless traffic volumes raises the data burden encountered by wireless networks by a factor of 1,000. For boosting network capacity, network design and cutting-edge wireless technologies are essential. Densifying the deployment of small cells on traditional macrocells is one of the most promising methods for overcoming the aforementioned obstacles. Utilizing the limited bandwidth between cells enhances network capacity and spectrum utilization significantly. Ud-hetnets are a crucial technology for 5G wireless communications[5].

5G technology has become a hot topic since a large number of people from all walks of life have a pressing need for better networks. It is advantageous in a range of academic disciplines. 5G system research and standardization will be primarily driven by the market, end-users, and the multitude of applications and cellular operations. According to some of the most significant operators, manufacturers, and consultants in the sector, the Internet of portable electronic items and the internet of things will be the two primary market engines. By analyzing traffic characteristics of each application, user models, and the composition of each application in a deployment scenario, it is possible to identify the key performance indicators (kpis) for common 5G scenarios. These estimations would serve as a good starting point for analyzing potential technologies. The ultimate objective of the design is to provide mobile internet users with a data transfer rate comparable to that of an optical fiber. 5G networks must be able to sustain exceptionally high connection densities while also addressing the diversified needs of businesses such as transportation, healthcare, agriculture, finance, architecture, and environmental protection[6].

This study will draw conclusions on some of the most important 5G technologies now in use by comparing their advantages and disadvantages in light of a tremendous amount of prior research and experiments. The MIMO-NOMA system combines MIMO and NOMA. Then, describe the five generations of communication system technology's future development trends and challenges.

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2. Key technology framework of 5G

2.1. Massive MIMO system

This is capable of meeting the requirements of Massive MIMO, one of the communication technologies known as Large-Scale Antenna Systems. Utilizing correctly determined channel characteristics, numerous physically small, independently controlled antennas enable aggressive multiplexing/demultiplexing for all active users. Adopting time-division duplexing allows massive MIMO to expand according to the number of service antennas. Higher the amount of antennas can improve the throughput, while it shows a decrease tendency on radiant energy, expansion of cell-wide service and simplification of signal processing are possible[7].

This outstanding technology relies on maximizing the numerous antennas which is at the base station to maximize the advanced modulation reward and the modulation scheme in order to simplify signal processing for consumers from all antennas.This enables the base station to provide customers with a higher level of service. The possible benefits of massive MIMO are described in detail below:

Figure 1. The characteristics of the Massive MIMO link.

Massive MIMO boosts the link's stability by boosting diversity gain and fading resistance. When using multicell minimal sum of squares error precoding or combining and spatial channel correlation, it is acceptable for the capacity to grow endlessly as the amount of certain antennas grows, despite the fact that pilot contamination is present. This is because these techniques allow for spatial channel correlation.This is because spatial channel correlation allows for the capacity to grow in tandem with the number of antennas Massive MIMO is a method for optimizing the spectrum efficiency of cellular networks that dynamically integrates a large range of end devices within a single unit.A huge quantity of deployed antennas improves spectrum use, throughput, multiplexing gain, and spatial data streams. Massive MIMO, which experts have shown to be 10 times more spectrally efficient than traditional MIMO, simultaneously provides tens of users with identical time-frequency items.

The amount of power that may be sent is inversely related to the quantity of transmitting antennas due to coherent combining. The transmittable power will drop significantly as the amount of transmit antennas climbs. In addition, increasing the number of broadcasts while simultaneously increasing broadcast power can boost throughput. Each antenna uses a negligible amount of power, measured in milliwatts[8]. As a direct result, the system's energy efficiency and dependability have increased.

Interference and jamming posed by humans are significant obstacles to the development of modern wireless communication networks.Massive arrays of antenna terminals provide an enormous number of features, which can be used by purposeful jammers to generate interference with the signals that are being transmitted.Beamforming also makes Massive MIMO systems intrinsically resistant to attempts at passive eavesdropping, which is a significant advantage. The eavesdropper, on the other hand, has the ability to respond by exploiting either the user's nearby strong channel correlation or the inaccuracy of the channel estimation .

Massive MIMO assists in cutting down on the costs associated with system deployment by doing away with the requirement for cumbersome components. For instance, coaxial cables are utilized to link the various components of a base station (BS). Moreover, Massive MIMO utilises a small number of inexpensive milliwatt amplifiers rather than a large number of expensive high-power amplifiers. In addition, it can triple data transfer rates while tripling radiated power.

The wide variety of antennas that are currently available makes the processing of signals much easier. In order to achieve this goal, interference, rapid fading, uncorrelated noise, and thermal noise are reduced as much as possible. In addition, the conditions for optimal propagation exist when the channel replies of the base station and the user terminal diverge (mutually orthogonal, ie the dot product is zero). When dealing with non-orthogonal channel vectors, significant signal processing is required in order to eliminate interference as much as possible. Channel hardening are among the most crucial elements that must be incorporated into large base station antenna arrays. As the array of antennas approaches infinity, the Massive MIMO channel matrix begins to converge on the predicted value. As the size of the channel gain matrix increases, the nondiagonal elements of Gram's matrix get less meaningful than their diagonal counterparts.Techniques for channel estimation and detection can benefit from this characteristic. In this scenario, the basic matching filter (MF) is really near to being perfect. For this to be accurate, however, both the scattering array and the antenna array must be of sufficient size. In circumstances with tolerable propagation conditions and coupled fading channels, then, better detection techniques are desirable[9].

2.2. Non-Orthogonal Multiple Access(NOMA)

Looking forward to 5G of wireless communication networks would live up to expectations and fulfill requests that have not been addressed up to this point.Thus, NOMA has garnered much interest in last a few years as a possible solution to these issues. Non-orthogonal resource allocation allows NOMA to handle a greater number of users than typical OMA systems. Implementing sophisticated inter-user interference cancellation necessitates a more complex receiver. Standard OMA techniques such as TDMA, OFDMA, CDMA, and FDMA are applied for 1G to 4G wireless networks to allocate multiple users to orthogonal radio resources. These techniques are utilized in the frequency-, time-, and code-domains as well. With FDMA, the receiver can take up every bit of data transmitted by users over each frequency channel. Similar to TDMA, each user gets their own time slot, allowing receivers in the time domain to easily distinguish between their signals. Thanks to CDMA, numerous individuals are willing to exchange the same time-frequency resources simultaneously. Additionally, the symbols that are broadcast by multiple users can be turned into orthogonal spread spectrum sequences, such as Walsh-Hadamard codes. Multi-user detection can therefore employ a low-complexity decorrelation receiver. OFDMA is a clever combination of FDMA and TDMA that uses a time-frequency grid to distribute radio resources orthogonally. Orthogonal resource allocation has the theoretical benefit of preventing user intervention in OMA systems. Consequently, it is possible to identify the signals of various users using detectors with linearly challenging low-complexity-. In conventional OMA systems, the availability of orthogonal resources severely restricts the overall number of supported users. This becomes a severe limitation when 5G requires extensive connectivity.

Furthermore, what OMA cannot operate at the total estimated rate for multi-user wireless networks has been demonstrated. Besides, NOMA, which provides multi-user capacity via time-sharing or rate-splitting, is examined in more depth in the following section. Recent study has concentrated on NOMA as a method to get around the OMA issue that was described earlier. Due to non-orthogonal resource allocation, NOMA is able to manage a wider variety of people. This is the definition which belongs to the acronym NOMA. NOMA's non-orthogonal resource allocation allows it to serve a greater number of customers than the number of orthogonal resource slots that are currently accessible. Advanced inter-

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user interference cancellation may do this by increasing the complexity of the receiver, for as by implementing exponential or polynomial order processing complexity. Even when OMA approaches are employed, this remains true. Traditional NOMA was developed in the 1980s. This interference can be lowered, however, by only those detectors that have enough power for several users.Consequently, the NOMA concept is intriguing. Nomas for the power domain can be differentiated from nomas for the code domain in a general sense. In power-domain NOMA, users receive varying power levels based on the quality of their channels while sharing the same time-frequency-code resources.Power-domain NOMA differentiates between users by successive interference cancelation out interference and taking into account the relative levels of power that each user brings to the receiver.

2.3. Ultra-Dense Hetnets

It has been proposed that Ud-hetnets, also known as ultra-dense heterogeneous networks, could be used to boost the capacity of the networks that would be used by the upcoming generation of wireless communications[5]. A cutting-edge network that integrates wifi, 4G, LTE, and UMTS with a number of additional wireless access technologies is known as the 5G wireless network. The moderate but persistent shrinking of the cellular range in recent years has resulted in a significant gain in spectral efficiency. The expression "spectral efficiency has greatly enhanced" arose from this. The location of the site is less likely to be available as the cell coverage area shrinks, and the challenge of additional cell division rises. Increasing the site deployment density is the only option to deploy more low-power nodes because it is the only thing that can make it feasible. Ultra-dense heterogeneous networks will necessarily result in some problems, even if they have the potential to dramatically improve power efficiency and spectrum efficiency. Despite the fact that they have the capacity to do so, this is the situation. From the perspective of the physical layer, the requirement of multi-rate access is a crucial element to take into account. For example in the case, simultaneous support for high-speed multimedia services and low-speed sensor networks must be provided. In the context of heterogeneous networks, ultra-dense heterogeneous networks need an air interface that has a scalable frame structure in order to enable access to a broad variety of frequency bands.

3. MIMO and NOMA combination as MIMO-NOMA

As a direct result of the proliferation of 5G applications, numerous cutting-edge technologies have been created and developed. All of these cutting-edge technologies were developed specifically to enhance 5G communication. It is common knowledge that the multiple access (MA) technique known as NOMA is capable of making efficient use of the available spectrum[10]. Multiple consumers can be serviced simultaneously at the identical time, frequency, or code by utilizing the power domain to give multiple access. This is made possible by utilizing the power domain that facilitates the accomplishment of this purpose. In designed to motivate a fair trade-off for the system's processing and the users' fairness, NOMA offers additional authority to users whose channels are in poor condition.This is done to promote a balanced relationship between the two. This is done in an effort to entice a greater number of users to participate in the system. Initial system deployments in cellular networks have demonstrated that NOMA offers more spectrum efficiency than other techniques. This conclusion was reached when NOMA's superiority to other approaches was demonstrated. To attain a high level of spectrum efficiency, NOMA and MIMO-based communication techniques were implemented [11] .

Massive MIMO systems are anticipated to include NOMA as an enhanced variation of MIMO-NOMA in the near future with a concentration on the millimeter-wave band. 30-300 ghz mmwave communications offer a potential answer to the issue posed by 5G's exponentially rising capacity needs[12]. Not only does mmwave have a bandwidth that is orders of magnitude larger, but it also has a shorter wavelength, enabling for more antennas to be packed into the same physical area. This is because mmwave has a shorter wavelength than other radio frequencies. In the world of wireless networking, mmwave exists. The employment of millimeter-scale Wave technology to increase system capacity is capable of resulting in an expansion of MIMO amplitude, according to scientific findings.

3.1. Merits of mmwave MIMO-NOMA

By combining the MIMO and NOMA techniques, the MIMO-NOMA section provides a comprehensive summary of a large range of challenges that are associated with the 5G wireless communication system and other relevant domains. Having extensive connectivity, very minimal latency, and a high level of reliability are only some of the problems that need to be overcome. It is highly likely that integrating NOMA and MIMO, which is an acronym that stands for multi-input, multi-output technology, will be able to considerably increase the efficiency and effectiveness of the system as a whole. The ever-increasing volume of data and information has resulted in massive access demands that are beyond the capabilities of the OMA technology that is used in the 4G wireless mobile communication system. These demands have been brought about by the proliferation of mobile devices. This is due to the fact that there are now only a limited number of spectrum resources that can be utilized. The reason for this is that there are only so many spectrum resources available. This occurs as a direct consequence of the limited quantity of spectrum resources that are at one's disposal at any given time. Like a direct result of this occurrence, the NOMA, protocol was developed to enhance the reliability of communications in areas with a large population density. NOMA is an acronym for "Non-Orthogonal Multiple Access." Numerous users can share the same time and frequency resources by the NOMA protocol, which in turn enables them to do so. This sharing is made feasible by the fact that the NOMA protocol exists. In order to build the MIMO-NOMA technology, a combination of the NOMA and MIMO technologies was applied, which is utilized in communication systems of the 5G. MIMO stands for MIMO. There is a consensus among most people that the research and development of air interfaces simply cannot move forward unless they make use of this technology. Research is currently being conducted on MIMO-NOMA because it has the potential to significantly improve spectral efficiency while simultaneously reducing latency. This is why the research is being conducted. This is the reason why it is being looked into. It would appear from the results of theoretical research that 4G orthogonal multi-user MIMO systems would not be able to achieve the same level of capacity as 4G MIMO-NOMA systems. Multiple users can be separated into multiple groups in MIMO-NOMA depending to the applications that they utilize. This can be accomplished through the employment of a variety of transmission powers or distinct channel codes. In the first method, a SIC receiver is utilized, whereas in the second method, a joint iterative multi-user decoding is utilized.

3.2. General summary of MIMO-NOMA

In order to fulfil the ever-increasing expectations for decreased latency, comprehensive connectivity, and high dependability, the communication networks of the future will need to be equipped with novel problem-solving strategies. It is essential that these objectives be attained. MIMO-NOMA, which stands for MI or Output, NOM method, is a fascinating combination of the NOMA and MIMO concepts. It is a mechanism that enables multiple access in non-orthogonal directions. As a result of this feature, the system's energy efficiency and throughput can be enhanced. Additionally, it is relevant to the iot, in which some consumers want timely services to transmit extremely small packets. On the other hand, it can be proved that the system's performance is negatively impacted by variable channel conditions and a highly complex spatial structure, both of which make its application more challenging. This is something that a human could detect. Due to the interaction between these two components, the system will not operate as efficiently as it normally would. Regardless of the circumstance, advancements in communication technology will be necessary in the near future to compensate for current deficiencies.

4. Conclusion

This article provides a synopsis of some of the most significant 5G technologies currently available. The three different types are called NOMA, MIMO, and Ultra-Dense hetnets. These many technical developments each have their own distinguishing characteristics. Some of them are efficient, but others, despite their usefulness, have downsides, such as high resource consumption or ineffective use of them. In the interim, as development proceeds, these many technologies can also be combined to make a more complex Function. This can be done by integrating them. One particularly good example of this is the

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MIMO-NOMA scheme. The development of these technologies is, without a shadow of a doubt, something that will unquestionably raise the general level of technology and considerably contribute to the progression of human society. In any event, the scopes of these technologies' prospective applications in the fields of artificial intelligence, the internet of things, intelligent medical care, and transportation are rather expansive.

References

[1] *International Journal of Frontiers in Engineering Technology*, 2021. Intelligent Logistics Tracking System Based on Wireless Sensor Network. 3(10).

[2] MIMS, III, F., 1980. Alexander Graham Bell and the Photophone: The Centennial of the Invention of Light-Wave Communications, 1880–1980. *Optics News*, 6(1), p.8.

[3] Zeng, J., Lv, T., Liu, R., Su, X., Peng, M., Wang, C. And Mei, J., 2018. Investigation on Evolving Single-Carrier NOMA Into Multi-Carrier NOMA in 5G. *IEEE Access*, 6, pp.48268-48288.

[4] Larsson, E., Edfors, O., Tufvesson, F. And Marzetta, T., 2014. Massive MIMO for next generation wireless systems. *IEEE Communications Magazine*, 52(2), pp.186-195.

[5] Li, Y., Zhang, Y., Luo, K., Jiang, T., Li, Z. And Peng, W., 2018. Ultra-Dense hetnets Meet Big Data: Green Frameworks, Techniques, and Approaches. *IEEE Communications Magazine*, 56(6), pp.56-63.

[6] Yifei, Y. And Longming, Z., 2014. Application scenarios and enabling technologies of 5G. *China Communications*, 11(11), pp.69-79.

[7] Marzetta, T., 2015. Massive MIMO: An Introduction. *Bell Labs Technical Journal*, 20, pp.11-22.

[8] Rusek, F., Persson, D., Buon Kiong Lau, Larsson, E., Marzetta, T. And Tufvesson, F., 2013. Scaling Up MIMO: Opportunities and Challenges with Very Large Arrays. *IEEE Signal Processing Magazine*, 30(1), pp.40-60.

[9] Albreem, M., Juntti, M. And Shahabuddin, S., 2019. Massive MIMO Detection Techniques: A Survey. *IEEE Communications Surveys & Tutorials*, 21(4), pp.3109-3132.

[10] Ding, Z., Schober, R. And Poor, H., 2016. A General MIMO Framework for NOMA Downlink and Uplink Transmission Based on Signal Alignment. *IEEE Transactions on Wireless Communications*, 15(6), pp.4438-4454.

[11] Shin, W., Vaezi, M., Lee, B., Love, D., Lee, J. And Poor, H., 2017. Coordinated Beamforming for Multi-Cell MIMO-NOMA. *IEEE Communications Letters*, 21(1), pp.84-87.

[12] Chen, N., Sun, S., Kadoch, M. And Rong, B., 2016. SDN Controlled mmwave Massive MIMO Hybrid Precoding for 5G Heterogeneous Mobile Systems. *Mobile Information Systems*, 2016, pp.1-10.