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Emerging Technologies: Overview

Matthew N. O. Sadiku[1], Samuel A. Ajayi[2], Janet O. Sadiku[3]

[1]Roy G. Perry College of Engineering, Prairie View A&M University, Prairie View, TX, USA
[2]Texas Southern University, Houston, TX, USA
[3]Juliana King University, Houston, TX, USA

ABSTRACT

Emerging technologies are technologies whose development, practical applications, or both are still largely unrealized. They share characteristics like radical novelty, fast growth, prominent impact, uncertainty, with future influence on various industries. They are often perceived as capable of changing the status quo. They include a variety of technologies such as artificial intelligence, nanotechnology, biotechnology, robotics, Internet of things, and 3D printing. Emerging technologies stand as the vanguard of a new era by enabling novel tools and profound reshaping of industries, societies, and individual lives. This paper provides an overview of popular general-purpose emerging technologies.

KEYWORDS: *technology, emerging technologies, artificial intelligence, blockchain, nanotechnology.*

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INTRODUCTION

We are living at the edge of a technological renaissance. Technology is evolving faster than ever, transforming the way we live, work, govern, and grow. Emerging technology is a term generally used to describe a new technology, but it may also refer to the continuing development of an existing technology. Emerging technologies are new or significantly advancing innovations that have the potential to create substantial societal and economic impacts. They span across computing, manufacturing, and life sciences, promising significant transformations in industries by enhancing automation, creating immersive experiences, improving data security, and enabling new forms of creation.

Emerging technologies often introduce entirely new concepts, capabilities, or applications that differ significantly from existing solutions. The specific technologies that are considered "emerging" can change over time. As technologies mature and become more widely adopted, they may no longer be considered emerging. The rapid adoption of recently emerged technologies, such as artificial intelligence, cloud computing, the Internet of things, big data, 3D printing, blockchain, and machine learning, has undoubtedly introduced a wave of conveniences [1].

WHAT ARE EMERGING TECHNOLOGIES?

Technology may be regarded as a collection of systems designed to perform some function. It can help alleviate some of the challenges facing business today. Emerging technology is a term generally used to describe new technology. The term often refers to technologies currently developing or expected to be available within the next five to ten years. Any imminent, but not fully realized, technological innovations will have some impact on the status quo.

Emerging technologies are shaping our societies. They continue to affect the way we live, work, and interact with one another. Emerging technology (ET) lacks a consensus on what classifies them as "emergent." It is a relative term because one may see a technology as emerging and others may not see it the same way. It is a term that is often used to describe a new technology. A technology is still emerging if it is not yet a "must-have" [3]. An emerging technology is the one that holds the promise

of creating a new economic engine and is trans-industrial. ET is used in different areas such as media, healthcare, business, science, education, or defense.

The characteristics of emerging technologies include the following [4]:

- *Novelty:* Emerging technologies are typically new or novel, meaning they have yet to be widely adopted or used. They often represent a significant departure from existing technologies or processes.
- *Potential for Disruption:* Emerging technologies have the potential to disrupt existing markets, industries, or ways of doing things. They may also displace existing businesses or industries.
- *Uncertainty:* Because emerging technologies are still in the early stages of development, there is often a high uncertainty surrounding their future potential and impact. It can be challenging to predict how they will evolve.
- *Rapid Change:* Emerging technologies often evolve rapidly, with new developments and innovations emerging frequently. It can make keeping up with the latest trends and advancements challenging.
- *Interdisciplinary*: Emerging technologies often involve multiple disciplines or fields of study, such as computer science, engineering, and biology. They may require collaboration across different fields and industries to develop their potential fully.

Many emerging technologies arise from the convergence of different technologies and systems, leading to more advanced and integrated solutions. Emerging technologies are worth investigating. They are responsible for developing new products or devices. As emerging technologies continue to evolve, engineering is poised for a transformative future. Emerging technologies have driven innovation and progress in today's rapidly evolving digital landscape. The collective impact of emerging technologies such as artificial intelligence, machine learning, big data, and the Internet of things is undeniably transformative. Some emerging technologies are shown in Figure 1 [5].

There are two kinds of emerging technologies: general-purpose and specific-purpose. General-purpose technologies apply to a lot of industries and they include artificial intelligence (AI), the Internet of things (IoT), blockchain, Quantum Computing, Robotics, and 3D printing. Specific-purpose technologies apply to specific applications and they include telemedicine for healthcare, magnetic levitation (maglev) for transportation, and automatic license plate recognition (ALPR) for law enforcement. This paper focuses only on general-purpose emerging technologies.

EMERGING TECHNOLOGIES

Examples of emerging technologies include artificial intelligence (AI), blockchain, Internet of things (IoT), big data, quantum computing, 3D printing, and biotechnology. Each technology represents a cornerstone of the future. Popular general-purpose emerging technologies, in alphabetical order, are the following [6-9]:

1. *3D Printing:* This is also known as additive manufacturing. It is a manufacturing techniques that build objects layer by layer from digital models, transforming production processes and enabling rapid prototyping. It allows for the creation of complex, custom objects layer by layer. Combined with Internet technology, 3D printing would allow for digital blueprints of virtually any material product to be sent instantly to another person to be produced on the spot, making purchasing a product online almost instantaneous.
2. *5G Technology:* The fifth generation of mobile networks, 5G, promises significantly faster data download and upload speeds, wider coverage, and more stable connections.

   This is the latest generation of wireless technology, offering faster speeds and lower latency to support new applications like autonomous vehicles and improved connectivity. The expansion of 5G is facilitating transformative technologies like IoT, augmented reality, and autonomous vehicles by providing the high-speed, low-latency connections they require. This technology is crucial for enabling real-time communications and processing large amounts of data with minimal delay. Private and hybrid 5G networks are gaining traction as enterprise companies seek more control over their connectivity solutions. As 5G technology becomes embedded in consumer and enterprise applications, it will drive wider economic growth.
3. *Artificial Intelligence:* Artificial intelligence (AI) is the sub intelligence exhibited by machines or software, and the branch of computer science that develops machines and software with animal-like intelligence. It constitutes systems designed to simulate human intelligence, allowing machines to learn, reason, and perform tasks such as complex decision-making, predictive analytics, and generating new content. AI drives new

capabilities in automation, data analysis, and content generation. The central objectives of AI research include reasoning, knowledge, planning, learning, natural language processing, perception and the ability to move and manipulate objects. Generative AI is dominating as a key technology, reshaping industries through its ability to create highly sophisticated and human-like content, from text and images to audio and complex simulations.

4. *Big Data:* Data is one of the biggest byproducts of the 21st century. Almost everything we do produces data, from swiping credit cards to emailing. Every company generates data, whether consciously or unconsciously. Data can be a company's most valuable asset. For example, big data provides valuable insights into customers that companies can use to refine their marketing, advertising, and promotions to increase customer engagement and conversion rates. An organization can glean important insights, risks, patterns or trends from big data. As its name implies, big data is a structured, semi-structured, and unstructured data, which is very big, fast, and comes in many forms. Big data refers to the huge volume of data that is being generated around the world and holds humongous information. It comes from a variety of sources such as sensors, social media sites, smart phones, Internet, emails, ecommerce transactions, weather data, medical records, insurance records, RFID devices, video sharing, etc.

5. *Biotechnology:* This field is developing new therapies and methods for biological challenges, including engineered living therapeutics. It uses living organisms or their byproducts, including advancements in gene therapy, stem-cell therapy, and synthetic biology, to develop new products and treatments. Advances in biotechnology are revolutionizing agriculture by enabling the development of crops with enhanced traits, such as increased resistance to pests and diseases, better nutritional profiles, and higher yields.

6. *Blockchain:* Initially developed for Bitcoin, blockchain technology is finding new applications beyond cryptocurrency. Industries are adopting blockchain for its ability to provide transparency, enhance security, and reduce fraud. This distributed ledger technology is transforming how data is managed and secured, particularly in finance and supply chains. It is set to revolutionize how we manage data, conduct transactions, and build trust across industries. Its decentralized nature brings transparency, security and efficiency, making it a game changer in sectors like finance, healthcare, supply chain, and governance.

7. *Cloud Computing:* The recent emergence of cloud computing is one of the major advances in the history of computing. Cloud computing is a computing paradigm for delivering computing services (such as servers, storage, databases, networking, software, analytics, and more) over the "the cloud" with pay-as-you-go pricing. The term "cloud" denotes "the Internet," so that "cloud computing" is also called "Internet computing." Cloud computing is a means of pooling and sharing hardware and software resources on a massive scale. Users and businesses can access applications from anywhere in the world at any time. Companies offering these computing services are called cloud providers and typically charge for cloud computing services based on usage. Cloud technology is one of the globally recognized emerging technologies in the new millennium that are most likely to change people's lives.

8. *Cybersecurity:* This focuses on next-generation defenses against evolving threats. With growing cyber threats, advancements in AI-powered security measures are crucial for protecting sensitive data and systems, ensuring privacy and trust. As digital systems become more interconnected, robust cybersecurity becomes critical for maintaining the integrity of data and operations. Cybersecurity is no longer just an IT concern; it has become a boardroom priority. As digital ecosystems expand and businesses adopt more advanced technologies, the scale and sophistication of cyber threats are rising in parallel. Cybersecurity is no longer about firewalls and protocols; it is about trust, resilience, and confidence in a world where disruption is constant.

9. *Digital Twin:* Digital twins are virtual replicas of physical devices for simulation, monitoring, and maintenance. They are extensively used in manufacturing, automotive, and urban planning to optimize operations and predict potential issues. By using data to mirror real-world situations, digital twins can be deployed to create, fine-tune, or entirely reimagine nearly any complex process or system, including supply chains, public transit systems, and assembly lines. By analyzing data trends, digital twins can forecast maintenance needs or operational disruptions, helping to mitigate risks.

10. *Drones:* Drones are the next wave of technological advance that can make a huge impact on almost all industries. They have become widely used for both recreational and commercial purposes worldwide. Specialists in many industries are exploiting the unique flexibility and observational capabilities of drones to improve industrial processes and operational efficiency. Drones have evolved in the past few years to become exceptionally versatile across practically every industry. The reason drones are being adopted by various industries is because they make good business sense and for their multitasking capabilities. A drone, also known as unmanned aerial vehicle (UAV), is a pilotless aircraft. It may be regarded as a small aircraft that can fly without a human pilot, usually made of lightweight materials, that can be remotely controlled or fly autonomously. A typical drone is shown in Figure 2 [10].

11. *Edge Computing:* Rather than relying on a central data center, edge computing processes data closer to the source where it is generated, reducing latency and improving response times for applications like autonomous vehicles. This is particularly important for applications requiring real-time processing and decision-making without the latency that cloud computing can entail.

12. *Gamification:* Gamification is applying game mechanics and game design techniques to engage and motivate people to achieve their goals. It taps into the basic human desires and needs of the users' impulse which revolves around the concept of status, achievement, competition, and reward. Game elements are the building blocks of gamification. Although gamification does not equal "playing games," everyone should play games a few times a month. Personal digital devices has made educational games accessible to everyone. The uses of gamification are universal and can be applied in any situation. Gamification has become a new trend in the game industry.

13. *Green Technology:* Among the most important emerging technologies shaping business today are those aimed at solving the climate crisis. Green technology is designed to cut emissions, reduce waste, and make energy cleaner and more efficient. Innovations in green energy technologies focus on enhancing the efficiency and reducing the costs of renewable energy sources such as solar, wind, and bioenergy.

14. *Immersive Technologies:* Immersive technologies create virtual environments or overlay digital information onto the real world, used for enhanced training, entertainment, and product demonstrations. These technologies are set to transform industries like retail, real estate, and education by enhancing how users visualize products, learn, and interact with their environments. Extended reality (XR) is an umbrella term that encompasses augmented reality (AR), virtual reality (VR), and mixed reality (MR). With improvements in display resolutions, motion tracking, and interactive elements, virtual reality (VR) is becoming increasingly prevalent in gaming, training, and therapeutic contexts. A typical VR training simulation is shown in Figure 3 [11].

15. *Internet of Things:* At its simplest, IoT refers to networks of physical devices—machines, vehicles, sensors, even everyday objects—that are embedded with software and connectivity so they can collect and exchange data. IoT enhances customer experience by enabling personalized services and products tailored to individual needs. For example, IoT technology in smart cities involves the integration of various sensors and devices that collect data to manage assets, resources, and services efficiently. Rather than being another layer of technology, IoT is becoming the nervous system of modern enterprises. The IoT continues to evolve, bringing new innovations that enhance connectivity and automation across industries. Looking ahead, IoT is set to move beyond efficiency and become a driver of strategic insight and innovation. Figure 4 shows some applications of IoT [12].

16. *Machine Learning:* Machine learning (ML) is the discipline that gives computers the ability to learn without being explicitly programmed. It is part of artificial intelligence. It assists computers in estimating future events and modelling based on experiences gained from previous information. Machine learning (ML) focuses on how computers "learn" from data. It allows computers to learn from past examples and to detect hard-to-discern patterns from large data sets. It describes a class of algorithms which learn model parameters from a set of training data with the purpose of accurately predicting outcomes for previously unseen data.

17. *Nanotechnology:* Nanotechnology (or nanotech) involves manipulating matter at the atomic and molecular levels, enhancing or creating materials and devices with novel properties. The earliest widespread description of nanotechnology referred to the particular technological goal of precisely manipulating atoms and molecules for

fabrication of macroscale products, also now referred to as molecular nanotechnology.

18. *Natural Language Processing:* NLP is an area of research and application began in the 1950s as the intersection of artificial intelligence (AI) and linguistics. Since then, NLP research has been focusing on tasks such as machine translation, information retrieval, text summarization, question-answering, information extraction, and opinion mining. The late 1980s witnessed a revolution in NLP with the introduction of machine learning algorithms and statistical techniques for language processing. Machine learning approaches extract statistical information from large amounts of documents and learn the rules of language without explicitly listing them. Natural language processing (NLP) refers to the application of computational techniques to the understanding and generation of human language. It is the field of study that focuses on the interactions between human language and computers. It is a computational approach to text analysis. It is the application of a wide range of computational techniques for the understanding, automatic analysis, and representation of human language.
19. *Quantum Computing:* This is a new type of computing that uses quantum-mechanical phenomena to solve complex problems far beyond the capabilities of classical computers. It is developing powerful computing capabilities that can solve complex problems currently impossible for conventional computers. It is a technology with the potential to revolutionize industries such as healthcare, manufacturing, finance, and more. With exponential speed, quantum computers enable the optimization and simulation of systems like logistics, financial portfolios, and composite designs.
20. *Robotics:* Robotics is the branch of technology that deals with the design, construction, operation, and application of robots. It involves the creation and use of machines that can perform tasks, from simple automation to complex, autonomous operations, to assist or augment human activities. Robotics deals with automated machines that can take the place of humans in dangerous environments, factories, warehouses, or kitchens. Robotics technology has evolved to create machines that can perform complex tasks autonomously or with minimal human oversight. Robotics is moving far beyond the factory floor. Once limited to assembly lines, robots are now entering warehouses, hospitals, farms, and even customer-facing environments. Figure 5 shows how robot is used in electronic manufacturing [13].
21. *Smart Technologies:* Everything that we do, starting from the start of the day to the end involves some kind of technology. Smart ideas seem to be the answer to many contemporary challenges. Smart technology refers to the integration of computing and telecommunication technology into other technologies that did not previously have such capabilities. From smartphones to smart homes, smart technology is essential in today's fast-paced lifestyle. Smart technologies like Siri and Alexa have become staples in our homes, making life easier and more automated.
22. *Software-Defined Networking:* The needs of business have surpassed the network's ability to provide service. The rising demands for cloud-based mobility, social media, server virtualization, and big data services require a new approach. Software-defined networking (SDN) provides that approach. SDN addresses the failure of the traditional networks to support the dynamic, scalable computing and storage needs of today's applications. SDN achieves this by separating or decoupling network control from data forwarding. SDN is complemented by virtualization technologies such as network function virtualization (NFV).
23. *Sustainability:* Sustainable technology is a pivotal trend as organizations increasingly prioritize eco-friendly innovations to combat climate change and minimize environmental impact. This trend encompasses developing and using technologies that reduce energy consumption, lower carbon emissions, and promote circular economy practices. The push for sustainable technology is driven by growing consumer awareness, stricter regulatory mandates, and the need for businesses to demonstrate corporate social responsibility.
24. *Wearables:* A wearable device is any device that is worn comfortably on the body and enables user interaction. It is typically integrated into the clothing or attached to the body of a person to enhance human performance. It often includes smart devices that can be worn on the body or attached to clothes. Wearable devices have been around for centuries. The first one was introduced in the 1660s by the Qing Dynasty. Since then the popularity of wearables has shifted from royalty to the healthcare industry. Wearable computing is a natural evolution of the smartphone technology that has become so ubiquitous and indispensable

in education, business, and medicine. We wear wrist watches to know the time. Perhaps the most crucial bit of wearable tech accessible today is Google Glass. Advanced wearable devices now continuously monitor various health metrics like heart rate, blood pressure, and even blood sugar levels

These are just some popular examples. Other emerging technologies include advanced materials, genetic engineering, and neuromorphic computing.

BENEFITS

Emerging technologies are expected to bring about transformative changes, creating new opportunities, and potentially disrupting existing industries. Some believe that emerging technologies could and will eliminate poverty and abolish suffering. Remarkable innovations emerge from research labs every year, creating unprecedented opportunities to address humanity's greatest challenges. Generative AI models create new content like text, code, images, video, protein sequences, and more. They learn the underlying patterns of vast datasets. Other benefits of emerging technologies include the following [1,14]:

- *Collaboration:* Technologies like 5G networks, cloud computing, and video conferencing platforms are making communication and collaboration easier and faster than ever before. This fosters better global connections and remote work opportunities.
- *Productivity:* Automation, artificial intelligence, and the IoT can streamline processes, reduce errors and free up human workers to focus on more complex tasks. This can lead to significant gains in efficiency and productivity across various industries. Emerging technologies such as AI are not only enhancing productivity but also revolutionizing how businesses approach problem-solving, customer engagement, and creative processes, making tools more accessible and versatile across various sectors.
- *Robot Service*: Due to the convergence of labor shortages and rising automation demand, service robot exports are increasing. As a result, pilot projects are quickly transitioning into full-scale implementations. They increase throughput and open up completely new revenue sources for early adopters. Polyfunctional and humanoid robots switch tasks on the fly to replace today's single-purpose machines with adaptable, AI-driven companions while collaborative robots work safely next to people.
- *Industry Adoption:* Global shipments of AR/VR headsets have increased significantly. In a world where innovation continually redefines the norm, heavy industries are not exempt from the transformative wave of disruptive technologies. To train one million associates across the US, Walmart supplied 17,000 VR headsets. This improved customer service ratings and accelerated onboarding.
- *Process Industries:* While many industries can be grouped under broad umbrellas like heavy, process, or service industries, some stand out for their distinct nature and influence. As technology permeates these sectors, it ushers in a blend of innovations tailored to their specific challenges and opportunities. Process industries are known for their role in the production of necessities like chemicals, pharmaceuticals, and food products. These sectors, integral to the backbone of global supply chains, are characterized by complex and large-scale production processes. They are prime candidates for the integration of emerging technologies.
- *Service Industries:* Service industries, recognized as the pillars of modern economies, are where many individuals directly encounter the benefits of emerging technologies. This arena is marked by its focus on consumer interaction, experience enhancement, and efficient service delivery. Innovations in technology are crafting a renewed vision for each sector within the service industries.
- *Nano Products:* Nano-enabled goods are becoming essential in semiconductors, health, and clean energy devices due to declining fabrication costs, AI-accelerated materials discovery, and pressing decarbonization objectives.
- *Integration:* Emerging technologies will not stand isolated. They will become seamlessly integrated into our daily lives, working in harmony. We will see more homes, cars, and entire cities becoming "smart," communicating and operating autonomously to enhance our quality of life.
- *Personalization:* Emerging technologies will have a deeper understanding of individual preferences. From healthcare treatments tailored to an individual's genetic makeup to personalized learning experiences in education, technology will cater to each person's unique needs and desires. Rather than replacing humans, future technologies will focus on augmenting human capabilities, as illustrated in Figure 6 [14]. In education, personalized learning platforms and virtual reality can create more engaging and effective learning experiences.

- *Democratization of Technology*: Access to technology will become more widespread, breaking down traditional barriers. Innovations in cloud computing and open-source platforms will further ensure that even small enterprises or individuals in remote locations harness the power of high-end technological tools.

CHALLENGES

Emerging technologies, while holding promise for a brighter, more efficient future, come with their set of challenges and ethical dilemmas. Critics of the risks of technological change warn that some of these emerging technologies could pose dangers, perhaps even contribute to the extinction of humanity itself. AI and machine learning models unintentionally perpetuate biases present in their training data, leading to unfair or discriminatory outcomes. With systems making autonomous decisions, ensuring transparency in how they operate and holding them accountable becomes a significant concern. Other challenges include [7,16]:

- *Data Privacy*: The vast amount of data collected by emerging technologies raises serious privacy concerns. This data could be misused for surveillance, social control or even blackmail. As data becomes the new oil, concerns about who has access to this data, and how it is used, become paramount. Ensuring data privacy and informed consent is crucial. Balancing innovation with responsibility will be the key to ensuring that these technologies benefit society at large without compromising on fundamental values and rights.
- *Ethics:* Much ethical debate centers on issues of distributive justice in allocating access to beneficial forms of technology. Some thinkers oppose the continuing development of advanced technology partly out of fear that its benefits will be distributed unequally in ways that could worsen the plight of the poor.
- *Social Isolation:* A rise in technology use can correlate with a decline in face-to-face interactions. This has engendered concerns regarding the impact of technology on the maintenance of social connections, necessitating a balanced approach that fosters both technological integration and meaningful human interaction.
- *Legal Challenges:* Emerging technologies have generated new opportunities while creating new legal challenges, particularly related to copyrights, trademarks, patents, royalties, and licensing. For example, the development of new communication technologies and media has given rise to novel issues relating to the digital reproduction and distribution of copyrighted works.
- *Job Displacement:* Technological advancements render certain job roles obsolete, leading to economic and social implications. Some critics argue that as information technology advances, robots, and other forms of automation will ultimately result in significant unemployment as machines and software begin to match and exceed the capability of workers to perform most routine jobs. As robotics and artificial intelligence advances, even many skilled jobs may be threatened.
- *Use of Resources:* As innovation drives economic growth, and large economic rewards come from new inventions, a great deal of resources (funding and effort) go into the development of emerging technologies. Research and development is directed towards the advancement of technology in general, and therefore includes development of emerging technologies. AI-related electricity consumption was expected to increase by 50% annually from 2023 to 2025. This necessitated a shift to architectures that provide more computation per joule.

CONCLUSION

Technological advances are shaping the way we produce, construct, and operate. These technologies are critical to humanity's future and will define the next decades. Understanding these technologies is imperative for everyone, not just for scientists and engineers. From AI optimizing production lines to IoT devices ensuring real-time monitoring and quality control, the impact of these technologies is far-reaching. In the rapidly evolving environment, emerging technology acts as both a disruptor and an enabler.

Staying ahead of emerging technologies is crucial for future-proofing your career. This can determine whether an organization leads the market or lags behind. As emerging technologies pave the way forward, it is up to us to harness their potential responsibly and ensure a brighter, more inclusive, and sustainable tomorrow. More information about emerging technologies can be found in the books in [17-30] and a related journal*: Journal on Emerging Technologies.*

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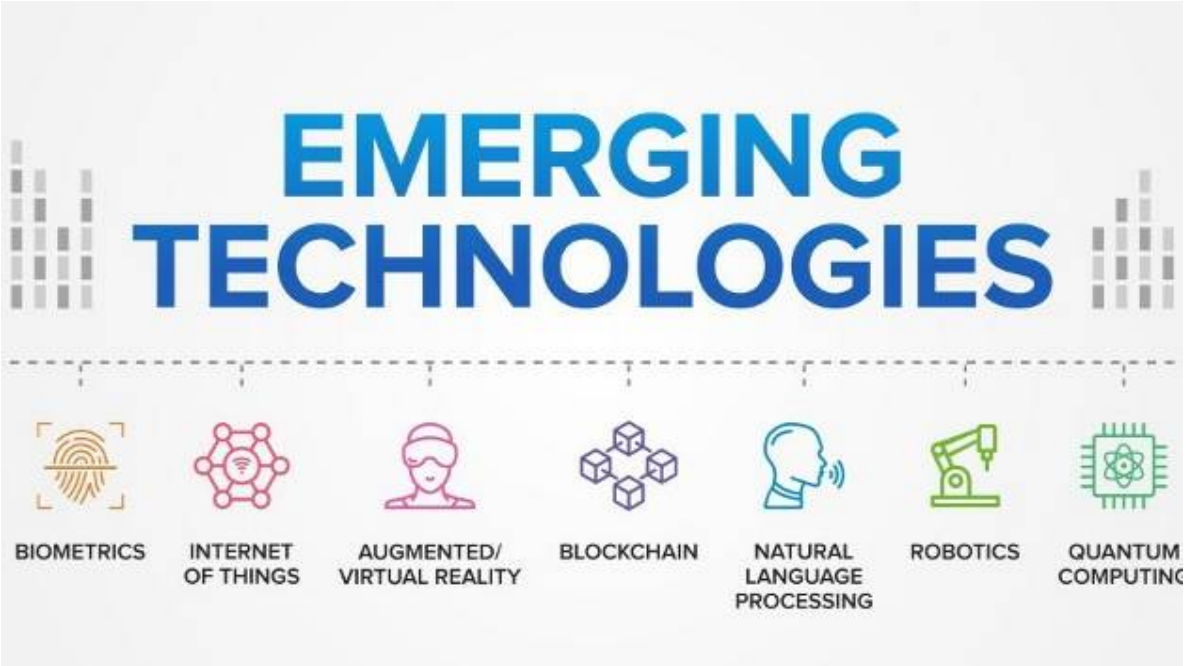

Figure 1 Some emerging technologies [5].

Figure 2 A typical drone [10].

Figure 3 A typical VR training simulation [11].

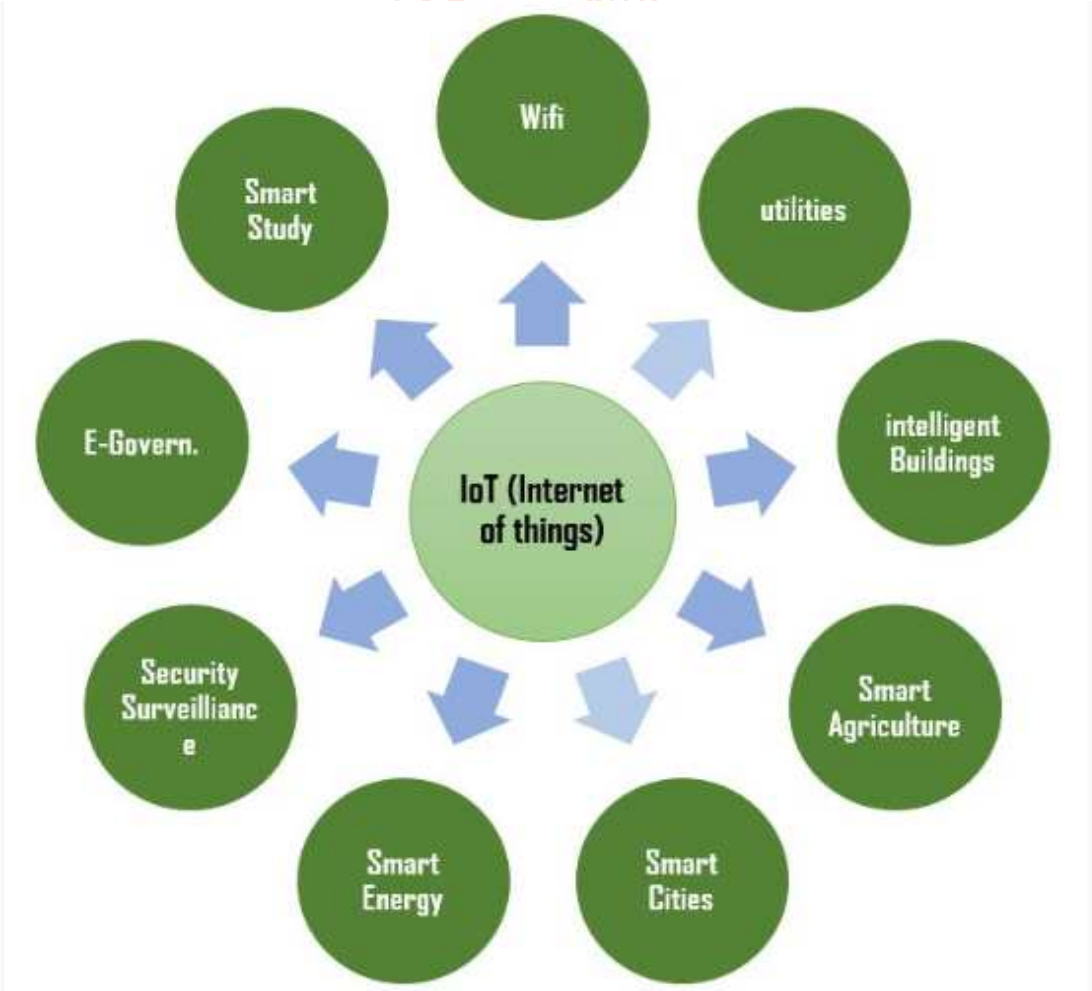

Figure 4 Some applications of IoT [12].

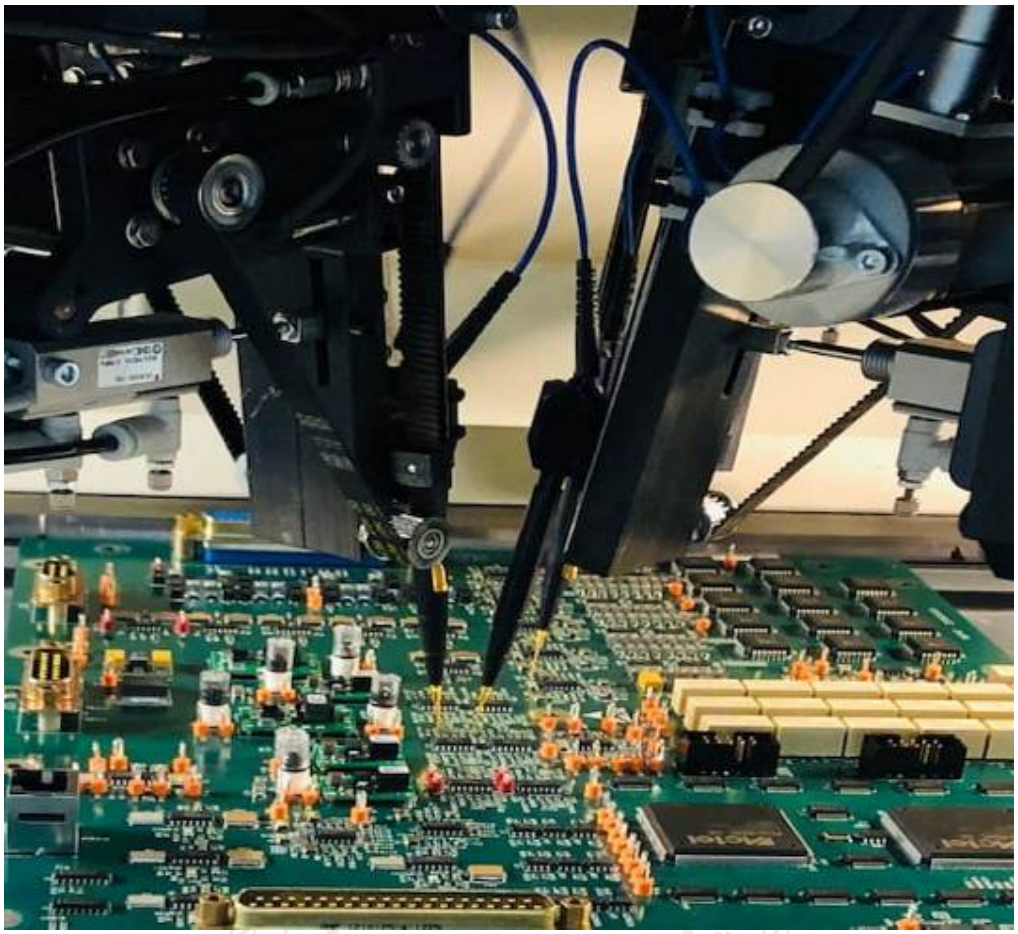

Figure 5 Robot is used in electronic manufacturing [13].

Figure 6 Future technology will collaborate with humans [15].