

Review Article

Emerging Technologies and Their Applications

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How to cite this article:

Sinha T. Emerging Technologies and Their Applications. J Adv Res Wire Mob Telecom 2024; 7(1):9-16.

Date of Submission: 2024-05-13

Date of Acceptance: 2024-06-15

A B S T R A C T

The rapid pace of technological advancement continues to shape our world in profound ways, driving innovation across various sectors. Emerging technologies like artificial intelligence (AI), blockchain, quantum computing, the Internet of Things (IoT), and 5G are not only revolutionizing industries but also changing how we live and work. AI's progress in machine learning and deep learning is transforming healthcare, finance, and retail, while blockchain's decentralized ledger system is enhancing transparency and security in supply chain management, healthcare, and voting systems. Quantum computing promises to solve complex problems at unprecedented speeds, impacting cryptography, drug discovery, and optimization problems. IoT is creating smarter environments by connecting billions of devices, leading to advancements in smart homes, industrial IoT, and healthcare. Meanwhile, 5G technology is set to revolutionize connectivity with its higher speeds, lower latency, and greater capacity, enabling applications such as autonomous vehicles and remote surgery. This review explores the current state, potential applications, and future implications of these cutting-edge technologies, highlighting the transformative potential they hold for various industries and the challenges that must be addressed to fully realize their benefits.

Keywords: Emerging Technologies, Artificial Intelligence (Ai), Blockchain, Quantum Computing, Internet Of Things (Iot), 5G Technology, Smart Cities, Predictive Maintenance

Introduction

The rapid pace of technological advancement continues to shape our world in profound ways, driving innovation across various sectors. In the past decade, we have witnessed a surge in the development and deployment of several groundbreaking technologies, collectively referred to as emerging technologies. These technologies include artificial intelligence (AI), blockchain, quantum computing, the Internet of Things (IoT), and 5G, each of which holds significant potential to revolutionize industries, enhance productivity, and improve the quality of life.

Artificial intelligence, with its subfields of machine learning and deep learning, has achieved remarkable progress, enabling machines to perform complex tasks that traditionally

required human intelligence. This has led to AI's integration into various domains, from healthcare diagnostics to financial services and retail personalization. Similarly, blockchain technology, initially known for underpinning cryptocurrencies, is now being recognized for its broader applications in ensuring transparency, security, and efficiency across diverse fields such as supply chain management and voting systems.

Quantum computing, although still in its early stages, promises to solve problems that are currently beyond the reach of classical computers, potentially transforming industries like cryptography, pharmaceuticals, and logistics. The Internet of Things (IoT) is creating interconnected ecosystems of devices, facilitating smarter homes, cities, and industrial

processes through real-time data exchange and automation. Meanwhile, 5G technology is set to usher in a new era of connectivity with its high-speed, low-latency networks, enabling innovative applications such as autonomous vehicles, remote surgery, and enhanced mobile broadband.

These emerging technologies are not only pushing the boundaries of what is possible but also presenting new challenges and considerations. Ethical issues, data privacy concerns, regulatory hurdles, and the need for new infrastructure are some of the critical aspects that must be addressed as we move forward. This review aims to provide a comprehensive overview of the current state of these technologies, explore their potential applications, and discuss the future implications and challenges associated with their widespread adoption. By examining these aspects, we hope to shed light on the transformative potential of emerging technologies and the steps necessary to harness their benefits for society.¹⁻⁴

Artificial Intelligence (AI)

Current State

Artificial Intelligence (AI) has undergone substantial advancements in recent years, particularly in the realms of machine learning (ML) and deep learning (DL). These technologies have empowered AI systems to perform a variety of complex tasks with impressive accuracy, including natural language processing (NLP), image recognition, and predictive analytics. Modern AI systems can understand and generate human language, recognize objects and faces in images, and even predict future events based on historical data. Significant progress has also been made in reinforcement learning, where AI systems learn optimal behaviors through trial and error.

Applications

Healthcare

- **Diagnostics:** AI algorithms can analyze medical images, such as X-rays and MRIs, to detect diseases like cancer, often with greater accuracy and speed than human doctors. Companies like Zebra Medical Vision and Aidoc are leading the way in developing AI-based diagnostic tools.
- **Personalized Medicine:** AI can process large datasets of genetic information to tailor treatments to individual patients, optimizing therapeutic outcomes. IBM Watson for Oncology, for example, uses AI to provide personalized cancer treatment recommendations based on patient data and the latest medical research.
- **Drug Discovery:** AI accelerates the drug discovery process by predicting how different compounds will interact with targets in the body. This can significantly reduce the time and cost associated with bringing new drugs to market.

Finance

- **Fraud Detection:** AI systems analyze transaction patterns in real-time to identify and flag potentially fraudulent activities, protecting consumers and financial institutions from significant losses. Companies like Feedzai and Darktrace utilize AI for robust fraud detection.
- **Risk Management:** Financial institutions use AI to assess and manage risk by analyzing vast amounts of data, including market trends, economic indicators, and customer profiles. This allows for more accurate risk assessments and better decision-making.
- **Algorithmic Trading:** AI algorithms execute trades at high speeds, leveraging real-time market data to optimize trading strategies and maximize returns. Firms like QuantConnect and Alpaca provide platforms for developing and deploying AI-driven trading algorithms.

Retail

- **Personalized Shopping Experiences:** AI analyzes customer data to provide personalized product recommendations, enhancing the shopping experience and boosting sales. Amazon and Netflix are well-known for their sophisticated recommendation engines powered by AI.
- **Inventory Management:** AI optimizes inventory levels by predicting demand and automating restocking processes, reducing costs and minimizing stockouts. Companies like ClearMetal and Llamasoft offer AI-driven supply chain solutions.
- **Customer Service:** AI-powered chatbots and virtual assistants provide instant customer support, handling routine inquiries and freeing up human agents to address more complex issues. Solutions like IBM Watson Assistant and Zendesk use AI to enhance customer service.^{5,6}

Future Implications

The continued evolution of AI promises further integration into various aspects of daily life and industry. Key areas of future impact include:

- **Autonomous Vehicles:** AI is crucial for the development of self-driving cars, which rely on machine learning algorithms to navigate and make real-time decisions. Companies like Tesla, Waymo, and Uber are at the forefront of this technology.
- **Human-Computer Interaction:** Advances in AI will lead to more intuitive and seamless interactions between humans and machines, enhancing user experiences in various applications, from virtual assistants to immersive virtual reality environments.
- **AI Ethics and Regulation:** As AI systems become more pervasive, ethical considerations such as bias, transparency, and accountability will become

increasingly important. Ensuring that AI technologies are developed and used responsibly will be a critical challenge for policymakers, developers, and society at large.

Blockchain

Current State

Blockchain technology has rapidly evolved since its inception as the underlying framework for Bitcoin. It is now recognized for its potential far beyond cryptocurrencies, offering a decentralized, immutable ledger system that ensures transparency, security, and efficiency. Blockchains are categorized into public, private, and consortium types, each with distinct features and applications. Public blockchains, like Bitcoin and Ethereum, are open to anyone, while private blockchains restrict access to authorized participants. Consortium blockchains are controlled by a group of organizations, balancing transparency and privacy.

Applications

Supply Chain Management

- **Traceability:** Blockchain enables end-to-end visibility of the supply chain, allowing for the tracking of products from origin to consumer. This transparency helps in identifying and addressing inefficiencies, reducing fraud, and ensuring product authenticity. Companies like IBM and Maersk have developed blockchain-based platforms like TradeLens to enhance supply chain traceability.
- **Efficiency:** By automating and securing transactions, blockchain reduces the need for intermediaries, thus lowering costs and speeding up processes. Smart contracts, which execute automatically when conditions are met, further streamline operations.

Healthcare

- **Patient Records Management:** Blockchain ensures secure and immutable patient records, allowing for seamless sharing of information among healthcare providers while maintaining patient privacy. Projects like MedRec and Guardtime are pioneering the use of blockchain for secure health data management.
- **Drug Traceability:** Blockchain can track pharmaceuticals through the supply chain, combating counterfeit drugs and ensuring that patients receive legitimate medications.

Voting Systems

- **Transparency and Security:** Blockchain can create tamper-proof voting systems, ensuring the integrity of electoral processes. It provides a transparent and immutable record of votes, which can be independently verified by anyone. Blockchain-based voting systems,

such as Voatz and FollowMyVote, have been piloted in various elections to enhance trust and security.

- **Accessibility:** Blockchain voting systems can potentially increase voter participation by enabling secure remote voting, making it easier for people to vote from anywhere.

Finance

- **Cross-Border Payments:** Blockchain facilitates faster and cheaper cross-border transactions by eliminating intermediaries and reducing processing times. Ripple and Stellar are notable blockchain platforms that focus on improving the efficiency of international payments.
- **Decentralized Finance (DeFi):** Blockchain supports the creation of decentralized financial applications that operate without traditional banks. DeFi platforms like Uniswap and Aave offer services such as lending, borrowing, and trading directly on the blockchain, providing greater financial inclusion and reducing reliance on centralized institutions.

Future Implications

The potential of blockchain extends into numerous sectors, promising to enhance security, transparency, and efficiency across various domains. Future implications include:

- **Interoperability:** For blockchain to achieve widespread adoption, interoperability among different blockchain networks is crucial. Efforts are underway to develop standards and protocols that enable seamless communication between various blockchains.
- **Regulation and Standardization:** As blockchain technology matures, regulatory frameworks will need to evolve to address issues such as compliance, security, and consumer protection. Establishing global standards will be essential to ensure consistent and secure implementation across industries.
- **Scalability:** Current blockchain networks face scalability challenges, particularly in handling a high volume of transactions. Solutions such as sharding, sidechains, and off-chain processing are being explored to enhance blockchain scalability without compromising security or decentralization.⁷⁻¹⁰

Challenges and Considerations

Despite its promising applications, blockchain technology faces several challenges:

- **Scalability:** Blockchain networks, especially public ones, struggle with processing a high volume of transactions quickly. Scaling solutions, such as the Lightning Network for Bitcoin or Ethereum's transition to a proof-of-stake consensus mechanism, aim to address these limitations.

- **Energy Consumption:** The proof-of-work consensus mechanism used by many blockchains, including Bitcoin, consumes significant amounts of energy. Transitioning to more energy-efficient consensus mechanisms, like proof-of-stake, is a key focus for reducing the environmental impact.
- **Regulation:** The regulatory environment for blockchain and cryptocurrencies is still evolving. Governments and regulatory bodies are working to establish frameworks that protect consumers and ensure compliance while fostering innovation.
- **Interoperability:** Ensuring seamless communication between different blockchain platforms is essential for broader adoption. Efforts such as the Interledger Protocol (ILP) aim to facilitate interoperability among diverse blockchain systems.

Quantum Computing

Current State

Quantum computing leverages the principles of quantum mechanics to perform computations far beyond the capabilities of classical computers. Utilizing quantum bits (qubits) that can exist in multiple states simultaneously through superposition and entanglement, quantum computers can solve complex problems with unprecedented speed. Although still in its early stages, significant progress has been made in developing quantum algorithms and hardware, with leading companies like IBM, Google, and Microsoft pushing the boundaries of what is possible.

Applications

Cryptography

- **Breaking Classical Encryption:** Quantum computers could potentially break widely used encryption methods, such as RSA and ECC, by efficiently factoring large numbers or solving discrete logarithm problems. This poses a significant threat to current cryptographic systems, necessitating the development of quantum-resistant algorithms.
- **Quantum Key Distribution (QKD):** Quantum mechanics principles enable QKD, which allows for the secure exchange of cryptographic keys. Any attempt to eavesdrop on the key exchange would disturb the system, alerting the parties involved. Projects like the Chinese satellite Micius have demonstrated the practical implementation of QKD.

Drug Discovery

- **Molecular Simulation:** Quantum computers can simulate molecular structures and interactions at a quantum level, vastly improving the speed and accuracy of drug discovery. This capability allows

researchers to model complex biomolecules and predict their behavior, accelerating the development of new medications. Companies like IBM and startups like Qubit Pharmaceuticals are exploring quantum computing's potential in this field.

- **Protein Folding:** Understanding protein folding is critical for developing treatments for diseases like Alzheimer's and Parkinson's. Quantum computing can provide insights into protein folding processes that are currently beyond the reach of classical computers.

Optimization Problems

- **Logistics and Supply Chain:** Quantum algorithms can optimize complex logistical problems, such as route planning and supply chain management, more efficiently than classical algorithms. This can lead to significant cost savings and operational improvements. Companies like Volkswagen and D-Wave have conducted research on quantum optimization for traffic management.
- **Financial Portfolio Management:** Quantum computing can optimize investment portfolios by analyzing a vast number of potential combinations and scenarios, providing more accurate and efficient solutions. Financial institutions like Goldman Sachs and JPMorgan Chase are investigating quantum computing applications for risk management and trading strategies.^{11, 12}

Material Science

- **New Material Discovery:** Quantum computers can model the properties of new materials at an atomic level, enabling the discovery of materials with unique characteristics for use in various industries, from electronics to renewable energy. This capability can lead to breakthroughs in developing superconductors, catalysts, and other advanced materials.
- **Battery Technology:** Quantum simulations can improve battery technology by understanding and optimizing the chemical processes within batteries, leading to longer-lasting and more efficient energy storage solutions.

Future Implications

The future implications of quantum computing are vast and transformative. Key areas of impact include:

- **Advanced Artificial Intelligence:** Quantum computing could significantly enhance machine learning and artificial intelligence by solving optimization problems and processing large datasets more efficiently. This could lead to more advanced AI systems with improved capabilities in areas like natural language processing, image recognition, and autonomous systems.

- **Climate Modeling:** Quantum computers can simulate complex climate models with greater accuracy, providing better predictions and helping to develop more effective strategies for combating climate change.
- **Secure Communications:** Quantum communications, leveraging principles like entanglement and QKD, could provide ultra-secure communication channels resistant to eavesdropping and hacking.

Challenges and Considerations

Despite its promise, quantum computing faces several critical challenges:

- **Hardware Development:** Building stable and scalable quantum hardware is a significant challenge. Qubits are prone to errors due to decoherence and environmental interference. Advances in quantum error correction and the development of more robust qubit designs are essential for creating practical quantum computers.
- **Software and Algorithms:** Developing quantum algorithms that can effectively leverage quantum hardware is still in the early stages. There is a need for more research and development to create algorithms that can solve real-world problems efficiently.
- **Interdisciplinary Expertise:** Quantum computing requires expertise in quantum physics, computer science, and engineering. Building a workforce with the necessary interdisciplinary skills is critical for advancing the field.
- **Access and Cost:** Quantum computing resources are currently limited and expensive. Ensuring broader access to quantum computing capabilities and reducing costs will be necessary for widespread adoption and innovation.^{13,14}

Internet of Things (IoT)

Current State

The Internet of Things (IoT) refers to the interconnected network of physical devices that collect and exchange data through the internet. These devices, often equipped with sensors, software, and other technologies, range from household items like smart thermostats to industrial machinery and medical devices. IoT enables real-time data collection and analysis, leading to smarter environments in homes, cities, and industries. The proliferation of IoT devices is supported by advancements in wireless communication, data analytics, and cloud computing.

Applications

Smart Homes

- **Automation:** IoT devices like smart thermostats (e.g., Nest), lighting systems (e.g., Philips Hue), and security cameras (e.g., Ring) automate and enhance

the convenience of household tasks. These devices can be controlled remotely via smartphones or voice assistants like Amazon Alexa and Google Assistant.

- **Energy Efficiency:** Smart home devices monitor and optimize energy usage, reducing costs and environmental impact. For example, smart thermostats learn user preferences and adjust heating and cooling to optimize energy consumption.

Industrial IoT (IIoT)

- **Predictive Maintenance:** IoT sensors on industrial equipment monitor performance and detect anomalies, predicting failures before they occur. This proactive approach reduces downtime and maintenance costs. Companies like Siemens and General Electric leverage IIoT for efficient predictive maintenance.
- **Process Optimization:** IIoT enables real-time monitoring and optimization of manufacturing processes, improving efficiency and productivity. Sensors track variables such as temperature, humidity, and machinery performance, providing valuable data for optimizing operations.

Healthcare

- **Remote Patient Monitoring:** IoT medical devices, such as wearable fitness trackers (e.g., Fitbit) and remote monitoring systems (e.g., Medtronic), collect real-time health data, enabling continuous monitoring of patients' conditions. This data can be shared with healthcare providers for timely intervention.
- **Smart Medical Devices:** IoT-enabled medical devices, such as insulin pumps and heart monitors, offer personalized treatment by adjusting settings based on real-time data. These devices improve patient outcomes and reduce the need for frequent hospital visits.

Smart Cities

- **Traffic Management:** IoT sensors monitor traffic conditions in real-time, optimizing traffic flow and reducing congestion. Smart traffic lights and adaptive signal control systems adjust timings based on traffic patterns, improving efficiency. Cities like Barcelona and Singapore are implementing IoT solutions for smarter traffic management.
- **Environmental Monitoring:** IoT devices monitor air quality, water quality, and other environmental factors, providing data for managing urban environments. This data helps in identifying pollution sources and implementing mitigation strategies.

Agriculture

- **Precision Farming:** IoT sensors monitor soil conditions, weather patterns, and crop health, enabling farmers to

optimize irrigation, fertilization, and pest control. This leads to higher yields and more sustainable farming practices. Companies like John Deere and Agribotix are at the forefront of precision agriculture.

- **Livestock Monitoring:** IoT devices track the health and activity of livestock, providing insights for improving animal welfare and productivity. Wearable sensors monitor vital signs and behavior, alerting farmers to any abnormalities.

Future Implications

The expansion of IoT will lead to more integrated and intelligent systems, enhancing efficiency and quality of life across various sectors. Key future implications include:

- **Interoperability:** Ensuring seamless communication between diverse IoT devices and platforms is critical for maximizing the benefits of IoT. Standardization efforts are necessary to achieve interoperability and facilitate widespread adoption.
- **Security and Privacy:** With the increasing number of connected devices, securing IoT networks against cyber threats is paramount. Ensuring data privacy and protection through robust security measures will be essential for building trust in IoT systems.
- **AI Integration:** Combining IoT with artificial intelligence will enable more advanced data analytics and automation. AI can analyze the vast amounts of data generated by IoT devices, providing actionable insights and enabling predictive capabilities.

Challenges and Considerations

Despite its promising applications, IoT faces several challenges:

- **Scalability:** Managing the exponential growth of IoT devices and the data they generate requires scalable infrastructure and efficient data management solutions. Cloud computing and edge computing are critical for handling large-scale IoT deployments.
- **Standardization:** The lack of universal standards for IoT devices and communication protocols hampers interoperability and integration. Developing and adopting global standards is necessary to ensure seamless operation across different IoT systems.
- **Energy Consumption:** Many IoT devices rely on battery power, posing challenges for long-term sustainability. Innovations in low-power technologies and energy harvesting are needed to extend the lifespan of IoT devices and reduce environmental impact.
- **Data Management:** The vast amounts of data generated by IoT devices require efficient storage, processing, and analysis. Developing advanced data management techniques and infrastructure is essential for deriving meaningful insights from IoT data.¹⁵⁻¹⁷

5G Technology

Current State

5G, the fifth generation of mobile network technology, offers significantly higher speeds, lower latency, and greater capacity than its predecessors. It is designed to support a vast number of connected devices and deliver enhanced mobile broadband, ultra-reliable low-latency communications, and massive machine-type communications. With rollout efforts underway globally, 5G networks are being deployed by major telecommunications companies, and the first commercial services have begun to appear in urban areas.

Applications

Enhanced Mobile Broadband

- **High-Speed Internet:** 5G provides faster internet speeds, enabling seamless streaming of high-definition video, quick downloads, and enhanced browsing experiences. This is particularly beneficial in urban areas with high data traffic.
- **Augmented Reality (AR) and Virtual Reality (VR):** The low latency and high bandwidth of 5G make AR and VR applications more feasible, enabling immersive experiences in gaming, education, and training. Companies like Google, Facebook, and Microsoft are exploring AR/VR opportunities with 5G.

Autonomous Vehicles

- **Vehicle-to-Everything (V2X) Communication:** 5G supports V2X communication, allowing vehicles to communicate with each other, traffic signals, and road infrastructure in real-time. This enhances safety and efficiency in autonomous driving. Projects like C-V2X (Cellular Vehicle-to-Everything) are leveraging 5G for smart transportation systems.
- **Real-Time Data Processing:** 5G enables the real-time processing of data from sensors and cameras, essential for the safe operation of autonomous vehicles. Companies like Tesla, Waymo, and Uber are integrating 5G technology into their autonomous vehicle platforms.

Remote Surgery

- **Telemedicine:** 5G's ultra-reliable low-latency communications allow surgeons to perform operations from remote locations with minimal delay, improving access to specialized medical care. Trials and demonstrations, such as those conducted by Ericsson and China Mobile, have showcased the potential of 5G in remote surgery.
- **Robotic Surgery:** Robotic systems can be controlled more precisely over 5G networks, reducing the risk of complications and improving surgical outcomes.

Smart Cities

- **Infrastructure Management:** 5G supports the deployment of sensors and IoT devices across urban infrastructure, enabling real-time monitoring and management of utilities, traffic, and public services. Smart city initiatives in cities like Singapore, Barcelona, and Stockholm are leveraging 5G for improved urban management.
- **Public Safety:** Enhanced communication networks improve emergency response times and coordination, making cities safer. 5G-enabled cameras and sensors can provide real-time surveillance and incident detection.

Industrial Automation

- **Smart Manufacturing:** 5G enables real-time monitoring and control of manufacturing processes, increasing efficiency and reducing downtime. Factories can implement advanced automation and robotics, leading to more flexible and responsive production lines.
- **Predictive Maintenance:** IoT devices connected via 5G can provide continuous monitoring of equipment health, predicting and preventing failures before they occur. This reduces maintenance costs and improves operational reliability.

Future Implications

The deployment of 5G technology will have far-reaching implications across various sectors. Key future implications include:

- **Economic Growth:** 5G is expected to drive significant economic growth by enabling new business models, services, and innovations. According to estimates, 5G could contribute trillions of dollars to the global economy over the next decade.
- **Healthcare Transformation:** Beyond remote surgery, 5G will facilitate the widespread adoption of telemedicine, remote monitoring, and personalized healthcare, improving patient outcomes and reducing healthcare costs.
- **Environmental Impact:** 5G can contribute to more efficient resource management and energy consumption in smart cities and industries, supporting sustainability efforts.

Challenges and Considerations

Despite its transformative potential, 5G technology faces several challenges:

- **Infrastructure Costs:** The rollout of 5G networks requires significant investment in new infrastructure, including more densely packed small cell sites and upgraded core networks. This is a considerable financial burden for telecom operators.
- **Spectrum Allocation:** 5G operates on a variety of frequency bands, including low, mid, and high (millimeter-wave) bands. Efficient spectrum allocation and management are crucial to maximizing the benefits of 5G while avoiding interference with existing services.
- **Security and Privacy:** With the increased connectivity and data flow, ensuring robust security measures to protect against cyber threats is essential. Privacy concerns also arise with the vast amounts of data generated and transmitted by 5G networks.
- **Health Concerns:** There are ongoing public concerns and debates about the potential health effects of exposure to higher-frequency radio waves used in 5G. Scientific research and regulatory oversight are necessary to address these concerns.¹⁸⁻²⁰

Conclusion

5G technology is poised to revolutionize connectivity and drive innovation across numerous sectors. Its high-speed, low-latency, and high-capacity networks enable a wide range of applications, from enhanced mobile broadband and autonomous vehicles to remote surgery and smart cities. While significant challenges remain, ongoing investments and advancements in technology and infrastructure are paving the way for widespread 5G adoption. As these challenges are addressed, 5G will play a crucial role in shaping the future of connectivity, economic growth, and societal advancement.

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