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Decoding the Internet of Things: A Comprehensive Survey Paper

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Abstract: The Internet of Things (IoT), a novel technology paradigm that links a wide range of physical devices to the internet, is examined in detail in this survey article. With the ability to collect and share data, this connectivity gives these things the ability to improve many facets of our lives and make well-informed judgments. In-depth applications, difficulties, and possible future developments are all covered in this article along with the development of IoT and its basic components. From the last three decades, what was the role of IoT in solving societal problems and what was the impact of IOT in industry automation? IoT has reshaped industries, impacted society, and laid the foundation for a more interconnected world. Data from articles was analyzed using a variety of statistics to gain insights into the Internet of Things and its general growth.

Keywords: Internet of Things, Sensors, Network.

1. Introduction

A paradigm shift in how technology interacts with the actual world may be seen in the Internet of Things. It consists of an extensive network of interconnected devices, sensors, and sensors that may easily communicate with one another over the internet.

History
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Initially, the internet was mostly utilized for communication between humans, but the Internet of Although the idea has changed greatly since then, the origins of the Internet of Things may be found in its early years. Things have made it feasible for machines to communicate with one another (M2M).The Internet of Things' evolution

1989: MIT's David Nichols and his team created the first Internet of Things gadget in 1989. A little while later, in 1991, John Romkey and Simon Hackett introduced the Internet Toaster. One significant turning point was the accomplishment by Romkey and Hackett of remotely controlling the power of an internet connected toaster [1].

1993: Researchers at the University of Cambridge, including Dr. Quentin Stafford-Fraser, built the first webcam that was accessible online. The Cambridge researchers had to get up from their computers and go get coffee when they needed it. Yet, they frequently discovered the coffee pot was empty. Next, a camera was placed next to the coffee maker by Dr. Stafford-Fraser and his associates, and it began taking three photographs of the pot every minute. This would alleviate everyone's frustration by enabling them to verify if the pot was empty. When it was originally linked to the internet in 1993, this camera was known as the first online webcam [2].

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1999: Internet connected gadgets were starting to become commonplace at this point (pun intended). However, it was still the product of strangely dispersed trials rather than a singular technique. When MIT's Auto-ID Labs co-founder Kevin Ashton first used the term "Internet of Things" in 1999, everything changed rapidly. Ashton believed that RFID technology was essential to the Internet of Things and was a major supporter of it [3].

2007: In 2007, Apple revealed the first iPhone. The Simon Personal Communicator, developed by IBM in 1994, is credited as being the first smartphone. However, despite its limited functionality, the iPhone was the device that brought smartphones to a wider audience [4].

2008: In 2008, there were more linked gadgets than humans on the planet. The Internet of Things (IoT) officially began to take shape at this point since there were enough linked devices to enable the collection of any data, anywhere in the world, if necessary [5].

2009: Fitbit launched its first activity tracker in 2009. The first wearable activity tracker that helped create the contemporary smartwatch was this one [6].

2010: As the decade of the 2010s dawned, IoT benchmarks became increasingly specialized and complex. The underlying technology had advanced to the point where the sub-segments could begin to develop independently [7].

2014: Not just the industrial applications sector benefited from improved and more affordable infrastructure. With the increasing availability of IoT devices, smart cities suddenly became practical. Seoul was the world's first smart city when it was established in 2014. Shortly later, New York, Singapore, and Amsterdam followed suit [8].

2015: Wearable technology made use of the fact that sensors were now widely available and could be incorporated into any type of gadget. With the growing use of smartphones, smartwatches, health monitors, and GPS trackers in 2015, the Internet of Things truly began to take off [9].

2016: IoT platforms began to appear when the technology grew profitable enough to attract the interest of several enterprises. In 2015, AWS unveiled IoT core, and by 2016, it was fully operational. Azure IoT Hub in 2016 and Google IoT Core in 2017 came next [10].

2022: The World Economic Forum named the Internet of Things (IoT) one of the three most important technological advances in 2022 [11].

The data suggests that IoT research is a global phenomenon, with countries from all over the world contributing to the advancement of this field. But when it comes to the quantity of publications published and the overall number of citations, China and the US are by far the two countries leading the field in IoT research. This is likely because these two countries have large and growing economies, and they are committed to investing in research and development [13]. Other notable trends in the data include the strong showing of India, the United Kingdom, and Germany. Due to their significant investments in IoT R&D, these three nations will probably become more significant players in the global IoT market in the years to come [14]. The key milestones were shown in Fig. 1. Table. 1 shows the number of IoT research articles published by the top 10 countries in the world, along with the total citation count for each country. China is the clear leader in IoT research, with over 10,000 articles published and over 195,000 citations. The United States is in second place with over 8,200 articles published and over 152,000 citations. India, the United Kingdom, and Germany follow closely behind with over 2,000 articles published each and over 47,000, 39,000, and 36,000 citations each, respectively [12]. The same information shown in Fig. 2.

The key contributing research articles in last two decades were shown in Table 2. The number of IoT publications has grown steadily from 6,900 in 2012 to 56,200 in 2023 are shown in Fig. 3. The highest growth rate was observed in 2015 with a growth of 36.8%. This indicates a rapidly growing interest in IoT research and development indicated in Table 3. Top 20 research articles/ survey /review articles got higher citations make the IoT research to grow faster the Table. 4 shows the year wise most cited articles. The state of art research facilities must boost the research related to IoT in the specific institute/organization. The top 10 universities/institutions produced the research articles related to IoT were tabulated in Table. 5 and Fig. 3.

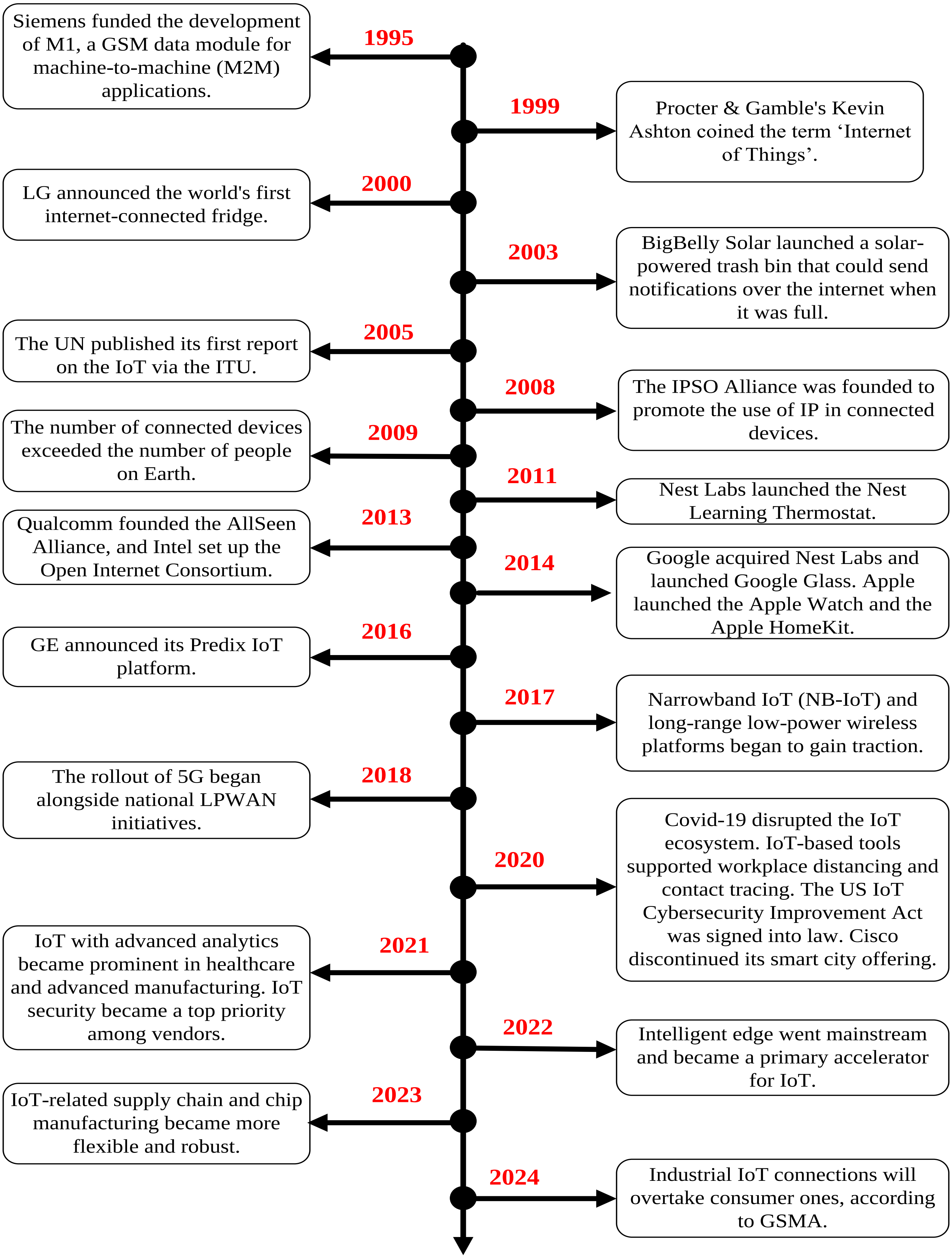

Fig. 1: IOT Development time line.

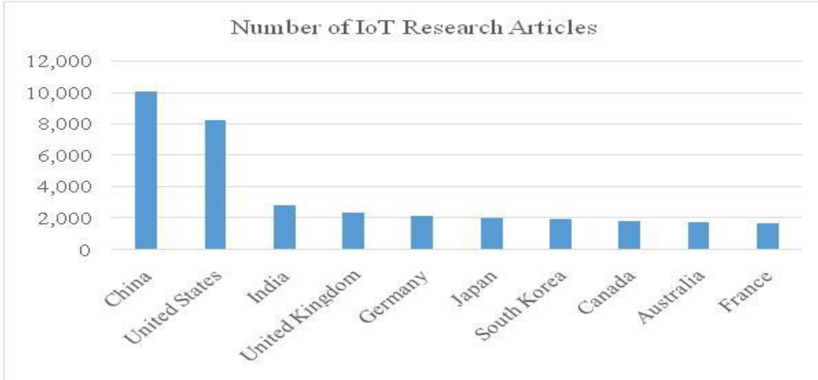

Fig. 2: Top 10 countries significantly contributing the IoT research

Table. 1: Top 10 countries having the highest number of research articles and citations.

S. No	Country	Number of IoT Research Articles	Total Citation Count
1	China	10,030	1,95,320
2	United States	8,210	1,52,400
3	India	2,810	47,610
4	United Kingdom	2,340	39,290
5	Germany	2,150	36,280
6	Japan	2,030	34,270
7	South Korea	1,960	32,260
8	Canada	1,840	30,250
9	Australia	1,750	28,240
10	France	1,690	26,230

Table 2: Last two decades' key contributors to the IoT research

Year	Authors	Title	Innovation
1999	Mark Weiser	"The computer for the 21st Century" [15]	Pioneering the concept of ubiquitous computing, laying the foundation for the IoT
1999	Kevin Ashton	"Internet of Things" [16]	Initially used in a Procter & Gamble presentation, the term "Internet of Things"
2005	Cisco Systems	"Cisco Internet of Everything (IoE) White Paper" [17]	conceived of the "Internet of Everything" and expanded its definition to encompass all linked gadgets.
2008	McKinsey & Company	"A Manager's Handbook on the Internet of Things " [18]	gave a thorough rundown of the IoT environment and its possible effects.
2014	Gartner	"The Internet of Things: A Strategic Overview" [19]	The Internet of Things has been characterized as "a network of physical devices, vehicles, buildings and other items embedded with electronics, software, sensors, actuators, and connectivity which enables these objects to connect and exchange data".
2015	Forum for World Economy	"The Worldwide Web of Things: Perceptives to Quicken Implementation" [20]	Provided a roadmap for accelerating the deployment of the IoT
2016	McKinsey Global Institute	"Unleashing the Internet of Things' Potential" [21]	identified the main challenges and possibilities confronting the Internet of Things and its potential for economic growth.
2017	Deloitte	"The Internet of Things: An Emerging Revolution" [22]	investigated the potential for the Internet of Things to transform industries and create new commercial opportunities.
2019	IBM	"The Internet of Things for the Year 2020 and Later" [23]	provided a comprehensive analysis of the IoT trends and issues for 2020 and beyond.
2020	Gartner	"IoT Trends and Predictions for 2021 and Beyond" [24]	Identified key IoT trends and predictions for the future of the technology

Table 3: Year-wise total number of publications related to IoT from 2012 to Present

Year	Number of IoT Publications
2012	6,900
2013	10,200
2014	14,300
2015	19,800
2016	26,400
2017	34,200
2018	43,100
2019	52,500
2020	63,200
2021	75,100
2022	88,300
2023	95000
2024	10500
2025(April)	35000(Estimated Value)
2025	110000(Estimated Value)

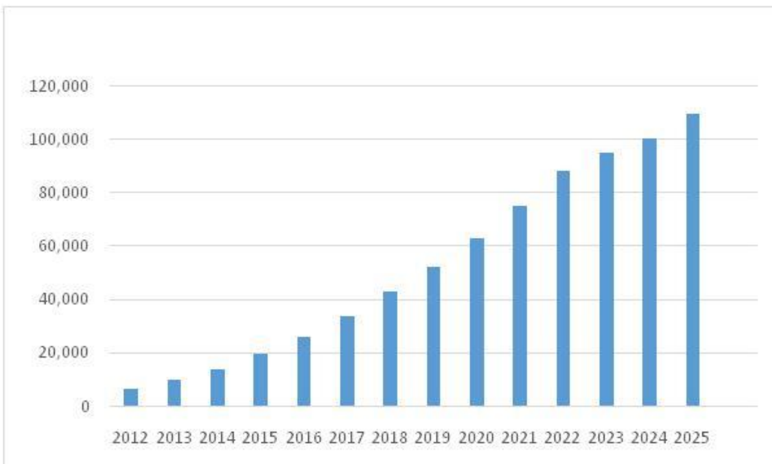

Fig. 3: Number of IOT publications from 2012 to 2022.

Table. 4: Top 20 research/ review/ survey articles related to IoT based on citations.

Rank	Title	Year	Authors	Citations
1	Internet of Things: A survey [25]	2010	Luigi Atzori et al.	19,340
2	From Machine-to-Machine to Internet of Things: Convergences and Evolution [26]	2014	Ovidiu Vermesan et al.	16,420
3	Internet of Things: A new paradigm for revolutionizing human-computer interaction [27]	2016	Anthony J. Fieldman	13,210
4	Internet of Things: Opportunities and Challenges [28]	2016	Dinesh Agrawal et al.	12,900
5	Fog Computing: An Internet of Things and Analytics Platform [29]	2017	Flavio Bonomi et al.	26,650
6	A Survey of Fog Computing for the Internet of Things [30]	2017	Diego Lopez et al.	18,320
7	An Architectural Survey of IoT Middleware [31]	2018	M. Yannuzzi et al.	13,410
8	The Point Where Cloud Computing and the Internet of Things Collide [32]	2015	Dimitrios M. Anagnostopoulos et al.	16,210
9	The Internet of Things: From R&D to Commercial Implementation [33]	2016	Henning Sundmaeker et al.	14,900
10	Internet of Things: Prospects, Uses, and Research Issues [34]	2012	Dieter Miorandi et al.	11,790
11	Healthcare-Related Internet of Things Enabling Technologies, Protocols, and Applications [35]	2015	Luigi Atzori et al.	15,100
12	Internet of Things: From Wearable Computing to	2016	Jim Yuan et al.	13,890

	Smart Cities [36]			
13	Internet of Things: A survey [37].	2010	Dario Giusto et al.	12,780
14	An Overview of the Protocols, Applications, and Supporting Technologies of the Internet of Things [38]	2014	Antonio Iera et al.	15,670
15	Internet of Things: Opportunities and Challenges for Ambient Intelligence [39]	2014	Marco Compagno et al.	11,560
16	Internet of Things: A Synopsis of Facilitating Technologies, Difficulties, and Uses [40]	2016	Abhay Tripathi et al.	10,450
17	Internet of Things: Principles and Paradigms [41]	2016	Rajkumar Buyya et al.	12,340
18	An Introduction of the Internet of Things' Basic Security Concerns, Technologies, and Concepts [42]	2014	Carsten Bormann et al.	11,230
19	An overview of the Internet of Things (IoT), its design principles, and its possible uses [43]	2013	J. Gubbi et al.	14,920
20	Opportunities, Difficulties, and Uses of the Internet of Things [44]	2016	U. R. Jung et al.	10,810

Table. 5: Top 10 universities around the world publishing articles related to IoT

Rank	Institution	Number of IoT Research Articles	Total Citation Count
1	Chinese Academy of Sciences	1,540	28,920
2	University of California, Berkeley	820	16,340
3	Tsinghua University	710	14,230
4	Nanyang Technological University	680	13,120
5	University of Surrey	650	12,010
6	University of Cambridge	620	10,900
7	University of Oxford	600	9,890
8	Southeast University	580	8,780
9	Peking University	560	7,670
10	King's College London	540	6,560

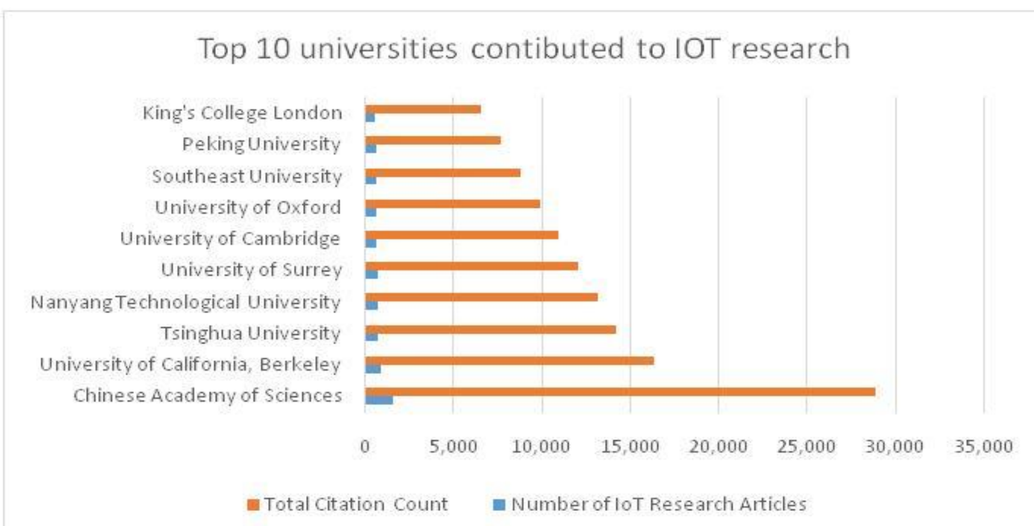

Fig. 4: Top 10 universities around the world publishing articles related to IoT.

2. Key Components of IoT

2.1. Sensors and Actuators

These are the actual hardware components that function as actuators and gather data via sensors. Actuators and sensors are essential to the Internet of Things ecosystem because they are the fundamental elements coordinating the smooth transition between the digital and physical domains. Sensing devices carefully collect data regarding variations in the ambient temperature, humidity, light, and motion.

After that, they transform these observations into digital data or electrical signals. Actuators work together to bridge the gap between digital insights and physical responses by executing concrete actions based on this data. The interdependent relationship serves as the foundation for the operation of Internet of Things applications, facilitating intelligent and adaptable systems in various fields. Actuators convert the data collected by sensors into practical actions, thereby defining the ever-changing field of IoT innovation. Sensors offer constant monitoring and data collection [45-46].

2.2. Connectivity

IoT devices rely on various communication protocols, including Wi-Fi, Bluetooth, Zigbee, LoRa, and cellular networks. Connectivity is necessary in the Internet of Things for smooth device-to-device communication via a variety of protocols. Important communication channels that help IoT devices exchange data include Wi-Fi, Bluetooth, Zigbee, LoRa, and cellular networks. While Bluetooth is best for low-power, short-range connections, Wi-Fi guarantees high-speed local network connectivity. In low-power, low-data-rate applications, Zigbee shines, enabling effective communication in smart homes. For IoT applications spanning large areas, LoRa's low power, long-range communication capabilities are ideal. Because cellular networks offer worldwide coverage, Internet of Things devices can send data anywhere in the world. The wide range of applications for communication protocols [47-48].

2.3. Data Processing

Data is either processed and analyzed instantly or at a later time to extract valuable insights. In the IoT ecosystem, data processing is a crucial step where gathered data is carefully analyzed to extract insightful information. The critical step in extracting meaningful information from the vast amount of data generated by Internet of Things devices is this processing phase, which can be completed offline or in real-time. The system's agility is increased by real-time processing, which makes it possible to react quickly to shifting circumstances. On the other hand, comprehensive analysis and long-term trend identification are possible with offline processing. This data processing step enables businesses and applications to make informed decisions, optimize operations, and Harness the complete potential of the Internet of Things by extracting pertinent insights [49-50].

2.4. Cloud Computing

IoT data is often stored and processed in the cloud, enabling scalability and accessibility. Considering the Internet of Things, the cloud is essential because it acts as a central hub for processing and storing data, allowing for scalability and accessibility. Cloud-based IoT data processing and storing provides a scalable solution that makes it possible to manage the ever-increasing amount of data produced by connected devices effectively. With the flexibility and accessibility this approach offers, users can access and evaluate data from any location. Utilizing cloud infrastructure within the Internet of Things (IoT) ecosystem improves system performance overall, makes collaboration easier, and gives applications the computational power they need to handle large and changing data sets [51-52].

2.5. Edge Computing

Edge devices, like gateways and edge servers, handle data in proximity to its origin, thereby minimizing latency. Edge computing is a key element of the Internet of Things. It is the processing of data close to its source utilizing devices like edge servers and gateways. This decentralized method handles data closer to the point of generation, which significantly reduces latency. Serving as middlemen, edge devices perform preliminary data analysis locally before sending only pertinent data to centralized systems. This improves IoT application responsiveness while also reducing the strain on cloud infrastructure. Edge computing, which lowers latency and optimizes data processing, is essential in the Internet of Things environment when prompt decision making and real-time insights are required [53-54].

2.6. Security

IoT security is a critical concern, as these devices can be vulnerable to cyberattacks. Security is a paramount consideration in the IoT landscape, given the susceptibility of these devices to potential cyberattacks. The interconnected nature of IoT introduces vulnerabilities that, if exploited, can compromise data integrity, user privacy, and overall system functionality. Strong IoT security requires putting in place safeguards like encryption, authentication procedures, and frequent software upgrades. Safeguarding against unauthorized access and data breaches is crucial in protecting sensitive information generated and transmitted by IoT devices. Building trust, protecting privacy, and promoting the dependable and safe operation of linked devices remain important priorities as the IoT ecosystem grows [55-56].

3. IoT Applications

IoT has found applications across various domains, including,

3.1. Smart Cities

IoT technologies are used to enhance urban infrastructure, transportation, and public services. IoT-powered smart cities optimize public services, transportation, and infrastructure to transform urban living. Connected devices and sensors enable the real-time collection and analysis of data, which enable effective waste management, responsive public services, and traffic management. This integration encourages sustainability and connectedness while improving the general functioning of the city. As residents experience an enhanced quality of life, cities become more resilient and livable. Smart Cities serve as a showcase for the Internet of Things' revolutionary potential to create intelligent, networked urban environments [57-59].

3.2. Healthcare

IoT makes it possible to monitor patients remotely, wearable medical technology, and provide better healthcare. IoT in healthcare enables wearable medical devices, improved patient delivery, and remote patient monitoring. Healthcare practitioners can remotely monitor and analyze vital signs thanks to real-time patient data collection from connected devices and sensors. Wearable technology tracks health and fitness metrics, which helps with preventive healthcare. In addition to improving patient outcomes, IoT integration in healthcare also expedites procedures, boosts diagnostic capabilities, and encourages a patient-centric approach to treatment [60-62].

3.3. Agriculture

Using real-time weather, soil, and crop monitoring, precision farming leverages the Internet of Things (IoT). Farmers can use the data collected by interconnected devices and sensors to optimize crop health, fertilizer use, and irrigation. This strategy driven by data enhances both crop yield and quality, reduces resource wastage, and enhances decision-making. Farmers can implement more environmentally friendly and productive practices by utilizing IoT in agriculture. This allows for precise field management that boosts output while protecting the environment [63-65].

3.4. Manufacturing

Process optimization in manufacturing is greatly aided by IoT-driven automation and predictive maintenance. Smart sensors and networked devices gather data in real time, allowing automated control systems to increase productivity and reduce downtime. Using this data, predictive maintenance can foresee equipment failures, minimizing unscheduled downtime and extending the life of machinery. Cost-effectiveness, increased productivity, and streamlined operations are all facilitated by the integration of IoT in manufacturing, which creates a more responsive and flexible production environment. Traditional manufacturing processes are revolutionized by this data-driven approach, opening the door for Industry 4.0 developments [66-68].

3.5. Retail

IoT technologies are driving innovations in the retail industry, including personalized shopping experiences, smart shelves, and inventory management. Product availability is tracked by sensors and networked devices, which automates inventory management and replenishment procedures. By offering up-to-date product information, smart shelves improve customer experiences. IoT-driven analytics enable personalized shopping experiences by customizing recommendations based on user preferences and behavior. Businesses can increase customer satisfaction, streamline processes, and maintain their competitiveness in the ever-changing world of modern commerce by utilizing IoT in retail [69-71].

3.6. Energy Management

IoT is essential to energy management because it helps to optimize grid management and energy consumption. Real-time data on energy consumption is collected by sensors and networked devices, which allows smart systems to examine and modify consumption trends. This data-driven strategy promotes sustainability objectives, decreases waste, and increases efficiency. IoT also assists with grid management by enabling the integration of renewable energy sources and providing insights into demand changes. Organizations can achieve improved resource utilization, cost savings, and a more resilient and sustainable energy infrastructure by implementing IoT in energy systems [72-74].

3.7. Home Automation

Smart homes use IoT devices in home automation to improve convenience, security, and energy efficiency. Complete home security systems include linked devices like door locks, sensors, and smart cameras. Appliances, lighting controls, and thermostats with Internet of Things connectivity optimize energy use and foster efficiency. Furthermore, smart home applications provide automation and remote control, increasing residents' comfort and convenience. The incorporation of IoT into home automation revolutionizes living areas by providing cutting-edge features that address energy conservation objectives, security concerns, and the need for automated and simplified daily life [75-77].

3.8. Blockchain

IoT and blockchain integration transforms industries with transparent, secure, and efficient applications. IoT sensors, recording supply chain movements on a blockchain, ensure logistics transparency. Smart contracts, activated by IoT devices, automate processes in agriculture and beyond. Asset tracking benefits from real-time monitoring, securely stored on blockchain for transparency. In manufacturing, IoT sensors guarantee product quality with immutable data on blockchain. Healthcare utilizes IoT for secure data, while blockchain ensures transparent and private patient record management. The synergy of IoT and blockchain enhances security and efficiency, revolutionizing processes across sectors [78-80].

4. Challenges in IoT

Security vulnerabilities, scalability issues, interoperability challenges, data management complexities, and evolving regulations present hurdles to the widespread adoption and seamless integration of IoT technologies across various domains and industries. Fig. 5, describes the challenges in IOT.

Fig. 5: Challenges in IoT research

4.1. Security and Privacy

The security and privacy of devices are crucial components of the Internet of Things since they might be hacked, which presents serious hazards to personal data. The interconnected nature of IoT creates vulnerabilities that can be exploited, leading to unauthorized access or manipulation of sensitive information. To overcome these challenges, it is imperative to implement robust security mechanisms including encryption, secure authentication, and regular software updates. To further protect personal data, it is imperative to guarantee user understanding and compliance with privacy legislation. Balancing the innovative potential of IoT with stringent security measures is imperative to foster trust, mitigate risks, and uphold the privacy rights of individuals [81-82].

4.2. Scalability

Scalability poses a significant logistical challenge in IoT, given the management of billions of devices and the associated data. The proliferation of connected devices continues to grow rapidly, scaling infrastructure to accommodate this growth becomes complex. Challenges include network congestion, data storage, and processing capacity. Efficient solutions involve cloud-based architectures, edge computing, and optimized communication protocols. Balancing scalability with performance and cost-effectiveness is crucial to ensure the seamless integration and sustained growth of the IoT ecosystem, allowing it to evolve and meet the demands of an ever-expanding network of interconnected devices [83].

4.3. Interoperability

With so many different devices and protocols needing to function together effectively, interoperability is a major difficulty in the Internet of Things. The coexistence of various manufacturers and communication standards can hinder seamless connectivity and data exchange. Achieving interoperability involves the adoption of standardized communication protocols, open architectures, and collaboration among industry stakeholders. Interoperable IoT systems make sure that devices from many suppliers may collaborate and interact with one other efficiently, which promotes an ecosystem that is linked and coherent. Resolving interoperability issues is crucial to utilizing IoT to its fullest, enabling diverse devices to collaborate harmoniously and deliver integrated and impactful solutions [84-85].

4.4. Data Management

Data management is a critical aspect of IoT, demanding robust storage and processing capabilities due to the massive amounts of generated data. The sheer volume and variety of data from interconnected devices necessitate efficient storage solutions, often leveraging cloud-based platforms. Additionally, advanced data processing technologies, including edge computing, are essential for real-time analysis and deriving meaningful insights. Implementing effective data governance, security protocols, and ensuring compliance with privacy regulations are vital components of comprehensive data management strategies in the IoT landscape, ensuring the secure, organized, and insightful use of the copious data generated by connected devices [86-87].

4.5. Power Consumption

In IoT (Internet of Things) device design, managing power consumption and optimizing energy efficiency are critical. Numerous Internet of Things devices depend on finite power sources, such as energy harvesting systems or batteries. Striking a delicate balance between functionality and energy efficiency is essential to ensure extended battery life and reliable performance. This challenge underscores the need for continuous innovation in designing devices that operate sustainably and efficiently within the constraints of their power sources. The duration and general success of IoT applications across a range of areas are facilitated by these efforts [88-89]

4.6. Regulatory Issues

IoT is subject to evolving regulations concerning data privacy and security. As the interconnected network of devices continues to expand, policymakers globally are developing and updating regulations to address the unique challenges posed by IoT. These regulations aim to safeguard user privacy, establish standards for data security, and define responsibilities for data handling and breaches. Compliance with evolving legal frameworks is crucial for IoT stakeholders to ensure ethical data practices, mitigate cybersecurity risks, and foster trust among users. The dynamic nature of IoT necessitates ongoing collaboration between industry stakeholders and regulators to adapt to emerging privacy and security concerns [90-92].

5. Conclusion

Numerous facets of our lives have already been significantly impacted by the Internet of Things. It is still developing, and there are plenty of interesting opportunities ahead. It will be essential to address security and privacy issues as technology develops. The massive volumes of data produced by IoT devices can be analyzed using AI and advanced analytics to drive further innovation. IoT is poised to revolutionize industries, enhance healthcare, improve urban planning, and make our lives more convenient and efficient. Its continued growth and integration into our daily lives make it a field of immense importance and potential.

Conflict of Interest

The authors declared "No conflict of Interest"

References

[1] J. Romkey "Toast of the IoT: The 1990 interop internet toaster", *IEEE Consumer Electronics Magazine*, Vol. 6, No. 1, pp. 116-119, 2017. https://doi.org/10.1109/MCE.2016.2614740

[2] T. Y. Chuang and W. F. Chen "Effect of computer–based video Games on children: An Experimental study", *First IEEE International workshop on digital games and intelligent toy and enhanced learning,* pp. 114-118, 2007. https://doi.org/10.1109/DIGITEL.2007.24

[3] L. Atzori, A. Iera, and G. Morabito "The Internet of Things: a survey", *Information system frontiers,* Vol. 54, pp. 2787-2805, 2010. https://doi.org/10.1016/j.comnet.2010.05.010

[4] V. Rajaraman, "A concise history of the internet-1". *Indian academic of sciences,* Vol. 27, No. 11, pp. 1841-1856, 2022. https://doi.org/10.1007/s12045-022-1483-2

[5] N. Epley, S. Akalis, A. Waytz, and J. T. Cacioppo "Creating social connection through inferential reproduction: Loneliness and perceived agency in gadgets, gods, and greyhounds", *Psychological science*, Vol. 19, No. 2, pp. 114-120, 2008. https://doi.org/10.1111/j.1467-9280.2008.02056.x

[6] A. Henriksen, M. H. Mikalsen, A. Z. Woldaregay, M. Muzny, G. Hartvigsen, L. A Hopstock, & S. Grimsgaard "Using fitness trackers and smartwatches to measure physical activity in research: analysis of consumer wrist-worn wearables", *Journal of medical Internet research*, Vol. 20, No. 3, art. no. e110, 2018. https://doi.org/10.2196/jmir.9157

[7] M. Skilton, and F. Hovsepian "The technology of the 4th industrial revolution", *The 4th Industrial Revolution: Responding to the Impact of Artificial Intelligence on Business*, pp.29-68, 2017. https://doi.org/10.1007/978-3-319-62479-2_2

[8] O. S. Herion "The role of smart cities for the realization of the sustainable development goals", In *Sustaining our Environment for Better Future: Challenges and Opportunities*, pp. 209-257, 2019. https://doi.org/10.1007/978-981-13-7158-5_13

[9] S. M. R Islam, D. Kwak, MD. H. Kabir, M. Hossain, & K. S. Kwak, "The internet of things for health care: a comprehensive survey", *IEEE Access*, Vol. 3, pp. 678-708, 2015. https://doi.org/10.1109/ACCESS.2015.2437951

[10] A. Ravulavaru "*Enterprise Internet of Things Handbook: Build end-to-end IoT solutions using popular IoT platforms*. Packt Publishing Ltd.

[11] M. Francisco and B. OLinnér "AI and the governance of sustainable development. An idea analysis of the European Union, the United Nations, and the World Economic Forum", *Environmental Science & Policy*, Vol. 150, 103590, 2023. https://doi.org/10.1016/j.envsci.2023.103590

[12] S. Bradshaw and P. N. Howard "Challenging Truth and Trust: A Global Inventory of Organized Social Media Manipulation", Computational *Propaganda Research Project* 1, pp. 1-26, 2018.

[13] A. Firdaus, M. F. A. Razak,A. Feizollah, I. A. T. Hashem, M. Hazim, and N. B. Anuar "The rise of "blockchain": bibliometric analysis of blockchain study", *Scientometrics*, Vol. 120, pp. 1289-1331, 2019. https://doi.org/10.1007/s11192-019-03170-4

[14] M. A.P. Jara, E. Ruiz, R. Gil,E. Sancristóbal, C. Molina, & M. Castro, "Smart Grid: Assessment of the past and present in developed and developing countries", *Energy strategy reviews*, Vol. 18, pp. 38-52, 2017. https://doi.org/10.1016/j.esr.2017.09.011

[15] S. Barns "Platform urbanism: Negotiating platform ecosystems in connected cities", *Springer Nature,* 2019.

[16] A. K. Singh, N. Firoz, A. Tripathi, K. K. Singh, P. Choudhary, and P.C.Vashist, "Internet of things: From hype to reality", In *An industrial IoT approach for pharmaceutical industry growth* ,Vol.2,pp. 191-230,2020. https://doi.org/10.1016/B978-0-12-821326-1.00007-3

[17] A. Raj and S. Prakash "Internet of Everything: A survey based on Architecture, Issues and

Challenges", *2018 5th IEEE Uttar Pradesh Section International Conference on Electrical, Electronics and Computer Engineering (UPCON)*, pp. 1-6, 2018. https://doi.org/10.1109/UPCON.2018.8596923

[18] L. Guedes and M. O. Júnior "Artificial intelligence adoption in public organizations: a case study", *Future Studies Research Journal: Trends and Strategies*, Vol. 16, No. 1, p. e860, 2024. https://doi.org/10.24023/FutureJournal/2175-5825/2024.v16i1.860

[19] S. Singh and N. Singh "Internet of Things (IoT): Security challenges, business opportunities & reference architecture for E-commerce", In *2015 International conference on green computing and internet of things (ICGCIoT),* pp. 1577-1581, 2015. https://doi.org/10.1109/ICGCIoT.2015.7380718

[20] A. Saint "Where next for the Internet of internet of things?" *Engineering & Technology*, Vol. 10, No. 1, pp. 72-75, 2015. https://doi.org/10.1049/et.2015.0111

[21] V. Krotov "The Internet of Things and new business opportunities", *Business Horizons,* Vol. 60, No.6, pp. 831-841, 2017. https://doi.org/10.1016/j.bushor.2017.07.009

[22] R. S. Jha and P.R. Sahoo "Internet of things (IoT)–enabler for connecting world", *ICT for competitive strategies*, pp. 1-7, 2020. https://doi.org/10.1201/9781003052098

[23] J. P. Shim, R. Sharda, A. M. French, R. A. Syler and K.P Patten "The Internet of Things: Multi-faceted research perspectives", *Communications of the Association for Information Systems*, Vol. 46, No. 1, 2020. https://doi.org/10.17705/1CAIS.04621

[24] I. Kregel, J. Koch, and R. Plattfaut "Beyond the hype: robotic process automation's public perception over time", *Journal of organizational computing and electronic commerce*, Vol. 31, No. 2, pp. 130-150, 2021. https://doi.org/10.1080/10919392.2021.1911586

[25] L. Atzori, A. Iera and G. Morabito "The Internet of Things: A survey", *Computer networks*, Vol. 54, No. 15, pp. 2787-2805, 2020. https://doi.org/10.1016/j.comnet.2010.05.010

[26] V. Gazis "A survey of standards From Machine-to-Machine to the Internet of Things", *IEEE Communications surveys and tutorials,* Vol. 19, No. 1, pp. 482-511, 2017. https://doi.org/10.1109/COMST.2016.2592948

[27] A. Dix "Human-computer interaction, foundation and new paradigms", *Journal of visual languages and computing,* Vol. 42, pp. 122-134, 2017. https://doi.org/10.1016/j.jvlc.2016.04.001

[28] S. Nizetic and P. Solic *et al,* "The Internet of Things (IOT): Opportunities, issues and Challenges towards a smart and sustainable future", *Journal of Cleaner Production,* Vol. 274, pp. 122877, 2020. https://doi.org/10.1016/j.jclepro.2020.122877

[29] F. Bonomi, R. Milito, P. Natarajan, and J. Zhu "Fog Computing: A Platform for Internet of Things and Analytics", *Big Data and Internet of Things: A Roadmap for Smart Environments*, Vol. 546, pp. 169-186, 2014. https://doi.org/10.1007/978-3-319-05029-4_7

[30] C. Pulifitco, E. Mingozzi, O. Rana *et al* "Fog Computing for the Internet of Things: A Survey", *ACM Transactions and on internet technology,* Vol. 19, No. 2, pp. 1-41, 2019. https://doi.org/10.1145/3301443

[31] J. Zhang and M. Ma *et al*.," Middleware for the Internet of things: A Survey on requirements, enabling technologies and solutions", *Journal of system architecture,* Vol. 117, art. no. 102098, 2017. https://doi.org/10.1016/j.sysarc.2021.102098

[32] E. Cavalkante and J. Peresia et al., "On the interplay of Internet of Things and Cloud Computing: A Systematic mapping study", *Computer communications*, Vol. 89-90, pp. 17-33, 2016. https://doi.org/10.1016/j.comcom.2016.03.012

[33] C. Perera and M. Chen et al "A survey on the Internet of Things: From industrial Market perspective", *IEEE Access*, Vol.2, pp. 1660-1679, 2015. https://doi.org/10.1109/ACCESS.2015.2389854

[34] D. Miorandi, S. Sicari, F. D. Pellegrini and I. Chlamtac "Internet of things: Vision, applications and research challenges", *Ad Hoc networks*, Vol. 10, No. 7, pp. 1497-1516, 2012. https://doi.org/10.1016/j.adhoc.2012.02.016

[35] M. M. Dhanavijay and S. C. Patil "The Internet of Things: A survey of enabling technologies in Healthcare and its applications", *Computer networks*, Vol. 153, pp. 113-131, 2019. https://doi.org/10.1016/j.comnet.2019.03.006

[36] K. K. Bhardwaj and S. Banyal "Internet of Things based smart city design using fog computing and fuzzy logic", *Sustainable cities and society,* Vol. 79, art. no. 103712, 2022. https://doi.org/10.1016/j.scs.2022.103712

[37] A. A. Fuquaha and M. Guizani et al "The Internet of Things: A survey on enabling technologies protocols and applications", *IEEE Communications Surveys & Tutorials*, Vol. 12, No. 4, pp. 2347-2376,2015. https://doi.org/10.1109/COMST.2015.2444095

[38] A. Iera, C. Floerkemeier and G. Morabito "The Internet of Things: A survey", *Computer networks*, Vol. 75, pp. 2787-2805, 2010. https://doi.org/10.1016/j.comnet.2010.05.010

[39] H. F. Atlam, R. J. Walters and G.B.Wills "Internet of Things: Opportunities and Challenges", 2018 3rd cloudification of the internet of the things, pp. 1-6, 2018. https://doi.org/10.1109/CIOT.2018.8627114

[40] A. Colakovic and M. Hadzialic "Internet of Things: An review of Enabling Technologies, Challenges, and open research issues", *Computer networks*, Vol. 144, pp. 17-39, 2018. https://doi.org/10.1016/j.comnet.2018.07.017

[41] S. Tayyaba and W. Khalid et al "Principles and Paradigms in IOT- based healthcare using RFID", *Healthcare paradigms in the internet of things Ecosystem*, pp. 251-269, 2021. https://doi.org/10.1016/B978-0-12-819664-9.00011-9

[42] D. M. Mena, L. Papapanagiotou and B. Yang "Internet of Things: Survey on security", *Information security journal: A Global perspective,* Vol. 27, No. 3, pp. 162-182, 2018. https://doi.org/10.1080/19393555.2018.1458258

[43] J. GubbiBuyya, R. Marusic, S. Marusic and M. Palaniswami "Internet of Things (IoT): A vision, architectural elements, and future directions", *Future generation computer systems*, Vol. 29, No. 7, pp. 1645-1660, 2013. https://doi.org/10.1016/j.future.2013.01.010

[44] M. Dohler and A. Grieco et al "Internet of Things in the 5G Era: Enablers, Architecture, and Business Models", *IEEE Journal on Selected Areas in communications,* Networks, Vol. 34, No. 3, pp. 510-527, 2016. https://doi.org/10.1109/JSAC.2016.2525418

[45] O. Vermesan & P. Friess, "Physical, Digitizing the Industry Internet of Things Connecting the Ptal *and Virtual Worlds*, CRC Press, 2022.

[46] H. Kabir, M. L. Tham and Y. C. Chaung "Internet of robotic things for mobile robots: concepts, technologies, challenges, applications, and future directions", Digital communications and networks, Vol. 9, No. 6, pp. 1265-1290, 2023. https://doi.org/10.1016/j.dcan.2023.05.006

[47] M. Mansour, A. Gamal, A. I. Ahmed, L. A. Said, A. Elbaz, N. Herencsar, and A. Soltan, "Internet of things: a comprehensive overview on protocols, architectures, technologies, simulation tools, and future directions", *Energies*, Vol. 16, No. 8, pp.3465, 2023. https://doi.org/10.3390/en16083465

[48] A. A. Fuqaha, M. Guizani, M. Mohammadi, M. Aledhari, M. Ayyash "Internet of things: A survey on enabling technologies, protocols, and applications", *IEEE communications surveys & tutorials*, Vol.17, No.4, pp. 2347-2376, 2015. https://doi.org/10.1109/COMST.2015.2444095

[49] R. A. A Habeeb, F. Nasaruddin, A. Gani, I.A.T. Hashem, E. Ahmed, and M. Imran, "Real-time big data processing for anomaly detection: A survey", *International Journal of Information Management*, Vol. 45, pp. 289-307, 2019. https://doi.org/10.1016/j.ijinfomgt.2018.08.006

[50] N. C. Real, P. Ruivo and T. Oliveira "Leveraging internet of things and big data analytics initiatives in European and American firms: Is data quality a way to extract business value?", *Information & Management*, Vol. 57, No. 1, pp. 103141, 2020. https://doi.org/10.1016/j.im.2019.01.003

[51] A. Čolaković and M. Hadžialić "Internet of Things (IoT): A review of enabling technologies, challenges, and open research issues", *Computer networks*, Vol. 144, pp. 17-39, 2018.

https://doi.org/10.1016/j.comnet.2018.07.017

[52] A. Botta, W. D. Donato, V. Persico, and A. Pescapé "Integration of cloud computing and internet of things: a survey", *Future generation computer systems*, Vol. 56, pp. 684-700, 2016. https://doi.org/10.1016/j.future.2015.09.021

[53] W. Yu, F. Liang, X. He, W. G. Hatcher, C. Lu, J. Lin, and X. Yang, "A survey on the edge computing for the Internet of Things", *IEEE Access*, Vol. 6, pp. 6900-6919, 2017. https://doi.org/10.1109/ACCESS.2017.2778504

[54] T. Qiu, J. Chi, X. Zhou, Z. Ning, M. Atiquzzaman, and D. O. Wu "Edge computing in industrial internet of things: Architecture, advances and challenges", *IEEE Communications Surveys & Tutorials*, Vol. 22, No.4, pp. 2462-2488, 2020. https://doi.org/10.1109/COMST.2020.3009103

[55] P. Malhotra, Y. Singh, P. Anand, D. K. Bangotra, P. K. Singh, and W. C. Hong "Internet of things: Evolution, concerns and security challenges", *Sensors*, Vol. 21, No. 5, pp. 1809, 2021. https://doi.org/10.3390/s21051809

[56] H. Allioui and Y. Mourdi "Exploring the full potentials of IoT for better financial growth and stability: A comprehensive survey", *Sensors*, Vol. 23, No. 19, pp. 8015, 2023. https://doi.org/10.3390/s23198015

[57] P. Bellini, P. Nesi and G. Pantaleo "IoT-enabled smart cities: A review of concepts, frameworks and key technologies" *Applied Sciences*, Vol. 12, No. 3, pp. 1607, 2022. https://doi.org/10.3390/app12031607

[58] M. Bauer, L. Sanchez and J. Song "IoT-enabled smart cities: Evolution and outlook", Sensors, Vol. 21, No.13, pp. 4511, 2021. https://doi.org/10.3390/s21134511

[59] B. N. Silva, M. Khan, and K. Han "Towards sustainable smart cities: A review of trends, architectures, components, and open challenges in smart cities', *Sustainable cities and society*, Vol. 38, pp. 697-713, 2018. https://doi.org/10.1016/j.scs.2018.01.053

[60] M. A. Khafajiy, T. Baker, C. Chalmers, M. Asim, H. Kolivand, M. Fahim, and A. Waraich, "Remote health monitoring of elderly through wearable sensors", *Multimedia Tools and Applications*, Vol. 78, No.17, pp. 24681-24706, 2019. https://doi.org/10.1007/s11042-018-7134-7

[61] A. Haleem, M. Javaid, R. P. Singh, and R. Suman," Medical 4.0 technologies for healthcare: Features, capabilities, and applications", *Internet of Things and Cyber-Physical Systems*, Vol. 2, pp. 12-30, 2022. https://doi.org/10.1016/j.iotcps.2022.04.001

[62] M. Talal, A. A. Zaidan, B. B. Zaidan, A. S. Albahri, A. H. Alamoodi, O. S. Albahri, K. I. Mohammed "Smart home-based IoT for real-time and secure remote health monitoring of triage and priority system using body sensors: Multi-driven systematic review", *Journal of Medical Systems*, Vol. 43, pp. 1-34, 2019. https://doi.org/10.1007/s10916-019-1158-z

[63] D. K. Singh, R. Sobti, A. Jain, P. K. Malik, and D. N. Le "LoRa based intelligent soil and weather condition monitoring with internet of things for precision agriculture in smart cities", *IET Communications*, Vol. 16, No. 5, pp. 604-618, 2022. https://doi.org/10.1049/cmu2.12352

[64] P. Sanjeevi, S. Prasanna, B. Siva Kumar, G. Gunasekaran, I. Alagiri and R. V. Anand, "Precision agriculture and farming using Internet of Things based on wireless sensor network", *Transactions on Emerging Telecommunications Technologies*, Vol. 31, No. 12, 2020. https://doi.org/10.1002/ett.3978

[65] M. Javaid, A. Haleem, R. P. Singh, and R. Suman "Enhancing smart farming through the applications of Agriculture 4.0 technologies", *International Journal of Intelligent Networks*, Vol. 3, pp. 150-164, 2022. https://doi.org/10.1016/j.ijin.2022.09.004

[66] M. Majid, S. Habib, A. R. Javed, M. Rizwan, G. Srivastava, T. R. Gadekallu, and J. C. W. Lin "Applications of wireless sensor networks and internet of things frameworks in the industry revolution 4.0: A systematic literature review", *Sensors*, Vol. 22, No. 6, pp. 2087, 2022. https://doi.org/10.3390/s22062087

[67] T. R. Mohan, J. P. Roselyn, R.A. Uthra, D. Devaraj, and K. Umachandran. "Intelligent

machine learning based total productive maintenance approach for achieving zero downtime in industrial machinery", *Computers & Industrial Engineering*, Vol. 157, pp. 107267, 2021. https://doi.org/10.1016/j.cie.2021.107267

[68] F. Y. Abdelmajied "Industry 4.0 and its implications: Concept, opportunities, and future directions", *Supply Chain-Recent Advances and New Perspectives in the Industry 4.0 Era*, 2022. http://dx.doi.org/10.5772/intechopen.102520

[69] R. Malik "Retail and internet of things: a digital transformation", *Advancing Smarter and More Secure Industrial Applications Using AI, IoT, and Blockchain Technology*, pp. 251-260, 2022. http://dx.doi.org/10.4018/978-1-7998-8367-8.ch014

[70] N. Rane "Enhancing customer loyalty through Artificial Intelligence (AI), Internet of Things (IoT), and Big Data technologies: improving customer satisfaction, engagement, relationship, and experience", *Internet of Things (IoT), and Big Data Technologies: Improving Customer Satisfaction, Engagement, Relationship, and Experience*, 2023. http://dx.doi.org/10.2139/ssrn.4616051

[71] A. Haleem and M. Javid et al "Artificial intelligence (AI) applications for marketing: A literature-Based study", *International Journal of intelligent networks*, Vol. 3, pp. 119-132, 2022. https://doi.org/10.1016/j.ijin.2022.08.005

[72] S. K. Rathor and D. Saxena "Energy management system for smart grid: An overview and key issues", *International Journal of Energy Research*, Vol. 44, No. 6, PP. 4067-4109, 2023. http://dx.doi.org/10.1002/er.4883

[73] T. Ahmad and D. Zhang "Using the internet of things in smart energy systems and networks", *Sustainable Cities and Society*, Vol. 68, pp.102783, 2021. https://doi.org/10.1016/j.scs.2021.102783

[74] N. H. Motlagh, M. Mohammadrezaei, J. Hunt and B. Zakeri "Internet of Things (IoT) and the energy sector", *Energies*, Vol. 13, No. 2, pp. 494, 2020. https://doi.org/10.3390/en13020494

[75] H. Yar, Imran, A. Z. Khan, M. Sajjad, and Z. Kastrati, "Towards smart home automation using IoT- enabled edge-computing paradigm", *Sensors*, Vol. 21, No. 14, pp. 4932, 2021 https://doi.org/10.3390/s21144932

[76] G. Bedi, R. Singh et al "Review of internet of things (IOT) in electric power and energy systems", *IEEE Internet of things Journal,* Vol. 5, No. 2, pp. 847-870, 2018. https://doi.org/10.1109/JIOT.2018.2802704

[77] M. Sayeduzzaman, T. Hasan, A. A. Nasser, and A. Negi "An Internet of Things-Integrated Home Automation with Smart Security System", *Automated Secure Computing for Next-Generation Systems*, pp. 243-273, 2024. https://doi.org/10.1002/9781394213948.ch13

[78] P. Dutta, T. M. Choi, S. Somani, and R. Butala "Blockchain technology in supply chain operations: Applications, challenges and research opportunities", *Transportation research part E: Logistics and transportation review*, Vol. 142, pp. 102067, 2020. https://doi.org/10.1016/j.tre.2020.102067

[79] I. Mistry, S. Tanwar, S. Tyagi, & N. Kumar, "Blockchain for 5G-enabled IoT for industrial automation: A systematic review, solutions, and challenges. *Mechanical systems and signal processing*, Vol. 135, art. no. 106382, 2020.

[80] R. W. Ahmad, K. Salah, R. Jayaraman, I. Yaqoob, S. Ellahham and M. Omar "The role of blockchain technology in telehealth and telemedicine", *International Journal of medical informatics*, Vol. 148, art. no. 104399, 2021. https://doi.org/10.1016/j.ijmedinf.2021.104399

[81] A.Karale "The challenges of IoT addressing security, ethics, privacy, and laws", *Internet of Things*, Vol. 15, art. no. 100420, 2021. https://doi.org/10.1016/j.iot.2021.100420

[82] S. Sicari, A. Rizzardi, L. A. Grieco, and A. Coen-Porisini "Security, privacy and trust in Internet of Things: The road ahead", *Computer networks*, Vol. 76, pp. 146-164, 2015. https://doi.org/10.1016/j.comnet.2014.11.008

[83] Y. Mehmood, F. Ahmad, I. Yaqoob, A. Adnane, M. Imran, and S. Guizani "Internet-of-things-based smart cities: Recent advances and

challenges", *IEEE Communications Magazine*, Vol. 55, No.9, pp. 16-24, 2017. https://doi.org/10.1109/MCOM.2017.1600514

[84] P. R. Kothamali "AI- powdered quality Assurance Revolutionizing automation frameworks for cloud applications", *Advanced computing systems,* Vol. 5, No. 3, pp. 1-25, 2025. https://doi.org/10.69987/JACS.2025.50301

[85] E. Borgia "The Internet of Things vision: Key features, applications and open issues", *Computer Communications*, Vol. 54, pp. 1-31, 2014. https://doi.org/10.1016/j.comcom.2014.09.008

[86] S. Bansal and D. Kuma "IoT ecosystem: A survey on devices, gateways, operating systems, middleware and communication", *International Journal of Wireless Information Networks*, Vol. 27, No. 3, pp. 340-364, 2020. https://doi.org/10.1007/s10776-020-00483-7

[87] B. Diène, J. J Rodrigues, O. Diallo, E. H. M. Ndoye, and V. V. Korotaev "Data management techniques for Internet of Things", *Mechanical Systems and Signal Processing*, Vol. 138, art. no. 106564, 2020. https://doi.org/10.1016/j.ymssp.2019.106564

[88] H. Allioui, and Y. Mourdi "Exploring the full potentials of IoT for better financial growth and stability: A comprehensive survey", *Sensors*, Vol. 23, No. 19, art. no. 8015, 2023. https://doi.org/10.3390/s23198015

[89] S. Zeadally, F. K Shaikh, A. Talpur, and Q. Z. Sheng "Design architectures for energy harvesting in the Internet of Things", *Renewable and Sustainable Energy Reviews*, Vol. 128, art. no. 109901, 2020. https://doi.org/10.1016/j.rser.2020.109901

[90] S. Nižetić, P. Šolić, et al "Internet of Things (IoT): Opportunities, issues and challenges towards a smart and sustainable future", *Journal of cleaner production*, Vol. 274, art. no. 122877, 2020. https://doi.org/10.1016/j.jclepro.2020.122877

[91] L. A. Tawalbeh, F. Muheidat, M. Tawalbeh, and M. Quwaider "IoT Privacy and security: Challenges and solutions", *Applied Sciences*, Vol. 10, No. 12, art. no. 4102, 2020. https://doi.org/10.3390/app10124102

[92] I. Brass, and J. H. Sowell "Adaptive governance for the Internet of Things: Coping with emerging security risks", *Regulation & Governance*, Vol. 15, No. 4, pp. 1092-1110, 2021. https://doi.org/10.1111/rego.12343

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