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A Brief Study of IoT vs Computing Domain: Features, Challenges and Limitation

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***Abstract*— There are a lot of machines linked to the internet these days and increasing day by day. These devices help a lot in the daily life of humans. IoT can connect multiple devices, with a wide range of features. Objects, which we may call nodes, can communicate through the internet, using data communication protocols and using Radio Frequency Identification (RFID). IoT integrates with multiple devices. Multiple devices are those that are not only material but also digital. Therefore, IoT integrates interaction with social features. IoT applications has potential to hear, communicate, collaborate, and interact with other objects. IoT applications require scalability and tolerance. This paper starts with the basic discussion of IoT and then their relationship with different technologies, such as Big Data, Block Chain, Machine Learning, Edge Computing, Fog Computing and how much it's helpful in IoT-based applications. We did comparative analysis of their features in different domains listed above and list down protocols, challenges and limitations of these technologies. A lot of work done previously on these domains separately, but we are summarizing the whole work in our research paper to clearly define the relationship between IoT, and these domains listed above. This paper provides intuition into the IoT, IoT's relationship with other computing domain. We also list down the features, protocols, challenges, and limitations of these emerging technologies.**

***Index Terms*—Emerging Technologies, Computing Domain, Big Data and Block Chain**

I. INTRODUCTION

INTERNET of Things (IoT) defines a network of objects or objects embedded with sensors, software, and other technologies for the purpose of connecting and sharing data with other devices and systems over the Internet". 7 billons IoT devices connected to internet todays, this number is growing day by day Researchers said it will increase by 22 billion by 2025 [1]. Everyday objects like household object, kitchen gadgets, smart automobile, wearable fitness and trackers, healthcare application are connected to the internet via embedded devices. People, processes, and things can communicate with each other seamlessly. Tangible objects share and collects data with minimum human involvement. The proliferation of network protocols has made easy to connect "devices" to clouds to transfer data efficiently. An IoT system have physical devices, network connectivity, data processing, application user interface. IoT architecture have 5 layer such as perception, network, middleware, application and business layer [1]**.** Lowest layer in IoT architecture is Perception layer. Recognition of the data from the nature is the purpose of this layer. Components of perception layer is as follows sensors, RFID tags, bar code labels, GPS and camera. Network layer is next layer gettering data from the perception layer and sends it to the Internet for computation is the purpose of network layer. Middleware layer received data from network layer. Middleware layer manages service and data storage. It then transfers the output to the next application layer. Application layer this is topmost layer. Main purpose of this layer is to deliver different applications to users. According to the needs of the user, the application layer shows data in the form of smart home, vehicle tracking, smart transportation, smart city, smart health, smart farming, and many other types of applications. Business layer is about making money through the service provider [2]**.**

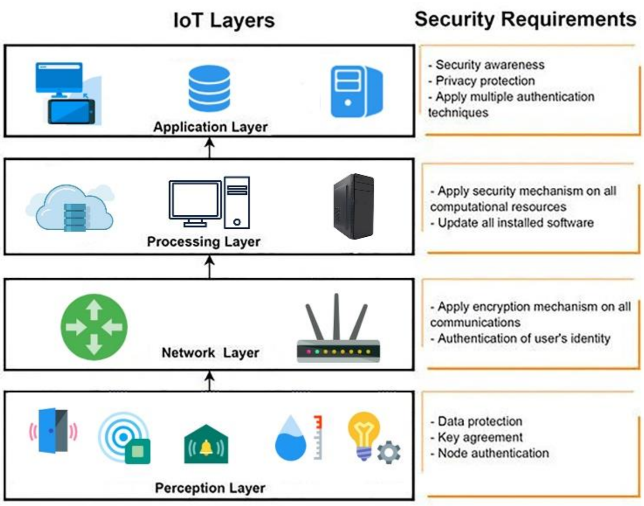

Fig. 1. IoT Layers

A. Distributed Computing

Declining hardware costs and advances network technology have open interest in the use of large compatible and distributed computing systems. Distributed computing is described as "A distributed computer is a model in which parts of a software system are shared between multiple computers. Although the components are spread across multiple computers, they operate as a single system" [3]**.** Distributed computing made the working of complex problems and complex systems easy. Currently several hundred computers are connected to form a distributed computer system. For maximum system efficiency all work must be distributed between nodes in the network. A distributed system can be classified as a group of multiple independent nodes having multiple features, terminologies, Performance parameter, Advantages and disadvantages. Following terminologies used in distributing computing, Job, Granularity, Node, Task, Topology, Overheads, Bandwidth and Latency [4]**.** In the literature review, we discussed this technology in detail under the flag of IoT.

B. Cloud Computing

The remotely providing computing services to end users refers to the idea of cloud. Cloud Computing is a distributed computer-based model where users provided with computer services and resources when user need them. The key feature of the clouds is Universal access[5]**.** With the increasing IoT devices that producing a big data, its major challenge for IoT devices to perform a task which required more power and bandwidth with precision. VSN and CCTV are examples of cloud computing. As multimedia consumes a lot of processing power, storage space, and editing resources, it will be extremely important to effectively manage and enable cloud-based service management [1]**.**

C. Fog Computing

IoT and Cloud computing integration is not easy, many challenges involves. Data center performed unnecessary communication. Data should pre-processed before sending to the cloud via Smart Gateway, which is compatible with Fog [6]**.** Cisco defines "Fog Computing a model that expand cloud computing and utilities to the edge of the network. Similar to cloud, fog also provides data computation, data storage, and application services to end-users" [7]. With the invention of low cost computer hardware such as sensors and smartphones, the researcher felt that computation should be done by nearby devices, which can reduce cost for data offloading at the cloud and provides a privacy and security data solution for users [5]**.** Smart Gateway perform well in this scenario. Smart Gateway has to handle various IoT features. Smart Gateway performs a many tasks, such as data collection, data pre-processing, upload only the required data to the cloud, data processing in a more efficient way and provide security of data, Gateway-based communications can be divided into two types: single-hop and multi-hop [6]**.**

D. Edge Computing

The Edge computing enhances IoT transferring data from the cloud to the nearest device location [8]**.** Edge computing application perform actions locally before connecting to the cloud, reducing network problems, security, and privacy issues. Edge computing can be easily integrated with other wireless networks such as vehicle ad-hoc networks (VANETs), intelligent transport systems (ITSs) and mobile ad-hoc networks (MANETs) to reduce network-related issues of computers. Combining with edge computing, these network applications make decisions very quickly. For example, in transportation systems, storage devices such as smartphones when developed by edge computing can quickly predict critical events and make decisions that can prevent accidents, in the field of health care edge computing enabled ambulance services that can make decisions automatically without cloud dependence. In the areas of e-commerce, edge computing can improve UX by providing a customize system, navigation and browsing [9].

E. Big Data

Tremendous growth of IoT has created challenges in big data. From past research, it is said that both technologies have a two-way connection. First connection, IoT produced large amount of data, and second connection is big data analysis of the process and service development. IoT is an online gadget that combines the integration of various gadgets with some smart information sharing connection. IoT gadgets are become the largest data provider for Big Data, as this includes variability, variability, randomness among others. IoT and Big data integration has the potential to address problems of data capturing, data analysis, data processing, data management and data storage etc. [10]. Traditionally, big data includes four dimensions, known as 4V's, Volume, Variety, Velocity and Veracity [11]. Some researcher mark issues of Big Data as 3Vs' by eliminating Veracity, or by adding Value and Validity. Mention in research [12] considered 5Vs'.

F. BlockChain

The IoT system offers a few advantages, the current centralized architecture presents many problems including security, a single point of failure, transparency, privacy, and data integrity. These challenges are an obstacle in the way of future development of IoT applications. Moving the IoT to one of the widely distributed ledger technologies may be the right choice to solve these problems. Among the most common and popular types of ledger technology distributed is blockchain [13] [14]. Blockchain is a technology that provides security in transactions between IoT devices. Supply decentralization, and shared ledger for the storage of processed and authenticated blocks in the IoT network. Blocks are connected to each other, and each block has its own previous block address [15]. Each block used hash function to link the current block to the previous block. This creates block chains, that's why it is called a blockchain [14]. In literature review we discussed this technology in detail under the flag of IoT.

G. Machine Learning

Machine learning is a methods with maximum appropriate result through getting to know or train records set. Machine learning presents embedded intelligence to IoT devices & infer the know-how from tool generated facts. Emerging technology in latest years and important advancements to internet protocols and computing structures, has made communication between different devices much easier [16]. Machine Learning takes all this guide labor out of the equation and 'trains' algorithms so that it can learn and evolve. But in preference to feeding AI with vast amounts of code, we're feeding it huge amounts of information. Machine learning is one of the techniques with the most optimal result through learning or training data set. Various machine learning algorithms like supervised, unsupervised, and reinforcement algorithms. Machine learning provides embedded intelligence to IoT devices & infers the knowledge from device-generated data. For example, Machine learning Techniques also used by Facebook Application to identify & detect vital facial features of a video subject in real-time because they have a huge amount of data to figure out, their ML platform has an easier time evolving to developing needs [17]. Machine learning technology allows businesses to respond faster to emails from clients, detect clouds in a satellite image, and finding 'habitable' planets in deep space. ML techniques and algorithms can be used in IoT based applications such as fraud detection, malware detection and speech recognition and provide intelligent services.

The rest of the paper is organized as follows: the Problem Statement is presented in section II. The Literature Review is presented in section III. The section IV provides the Propose Work. Finally, the conclusion and future directions are discussed in section V.

II. LITERATURE REVIEW

A. *IoT and Distributed computing:*

Distributed computing referred to study of distributed models of systems where the computation task is divided between several network devices, and these devices communicate between themselves through a message passing interface. The first known distributed system was present in 1970s which was known as local area network (LAN) that interconnected multiple computers for making applications to communicate with each other for developing a collective solution. In this section, we give a brief description of the distributed computing timeline to highlight the idea about how the computing paradigm has gradually evolved to today's different computing concepts, based on the requirements from the end users**.** Fig shows the timeline view of the evolution of distributed computing [5].

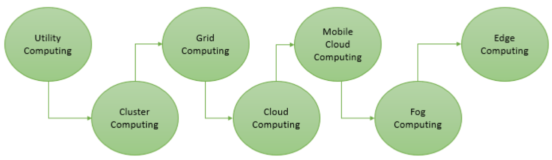

Fig. 2. Evolution of Computing

According to [3], In standard distribution 3-layer model was used for user processing, business processing and database processing. Client-side processing was done on PC at user location, business processing was performed remotely, and database processing and website processing was done on another computer that provides centralized access to many business processes, typically, this type of distributed computer used a client-server communication model. According to research [16], Client-Server was the simplest model of distributed computing in the early days. The network was divided among the presentation layer and application layer. This kind of architecture has been widely used in the several applications such as ERP, billing and inventory applications**.** According to [17], Smart Home, Wearables, Connected Cars, Industrial Internet, Smart Cities IoT in agriculture Smart Retail, IoT in Poultry and Farming, IoT in Healthcare, Energy Engagement are examples of distributed computing with under the flag of IoT**.** According to [18] , Sensors and actuators was collecting a large amount of data from which we could be used to get information by extracting the different patterns. We got large amount of data from these devices which cannot be handled in a centralized way and that must be combined with distributed computing so that information transmitted is reduced by dividing the load among devices.

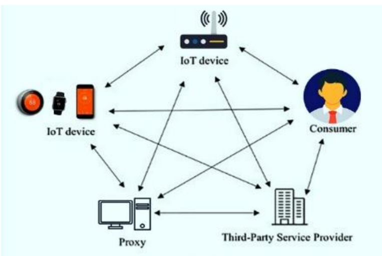

Fig. 3. Relationship between IoT and Distributed Computing

B. *IoT and Cloud Computing:*

Cloud integration with IoT called as Cloud of Things. Cloud computing is used for processing data under distributed environment. Data is not considered to build knowledge, also useful for user operations. This calls for additional processing, which is not possible at the end of IoT because of low value and light-weight device, additional processing is possible with cloud. There are many clouds platforms available such Google Cloud Platform, Digital-Ocean, Microsoft Azure, IBM Bluemix, Amazon Web Services, ,and Alibaba etc. Thanks to advanced networks, such as 3G, 4G, LTE, LTE Advanced, WiBro, etc., more communication will be possible [1]**.** With CoT, resources provide gave access to entire area where the services can be easily accessible. This helps generate more revenue through services [6]. Cloud computing paradigm used the concept of service-oriented architecture (SOA) in order to break user problem into different services and work towards these services in order to solve the problem. Cloud platform can be used as SaaS, laaS and PaaS [5].

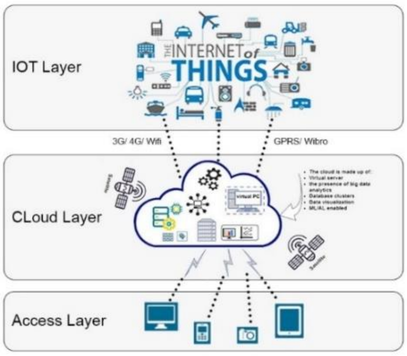

Fig. 4. Relationship between IoT and Cloud

C. *IoT and Fog Computing:*

Cloud computing had other problems such as high latency, mobility, and location installation. But on the other hand, IoT applications required low latency, mobility, and real-time analysis, as well as location installation. So, we need a co-process that could deal with these problems. This controversy had led to the birth of a new paradigm known as Fog Computing which was introduced by CISCO. Undoubtedly, cloud computing is an excellent solution to this issue but these data centers was still distributed globally and was limited. Some IoT-based applications do not tolerate delays, some applications require calculation using their own system and some may generate a very large amount of data that could cause significant network load [19]**.** Fog Computing brings computation close to device. Fog is layer between edge and cloud. Fog Computing platform gives accounting, communication and storage facilities among IoT nodes and traditional cloud. As compared to cloud, Fog computing is focused on applications which are integrated wide distribution of data. Similarly, temporary storage, pre-processing, data security and privacy, and other such functions performed more easily and effectively in the presence of a smart network or Fog, which is available in conjunction with Smart Gateway [6].

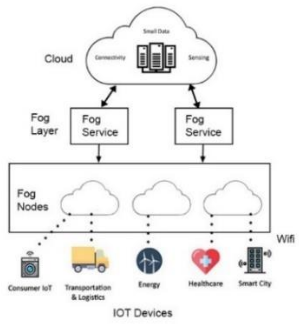

Fig. 5. Relationship between IoT and Fog Computing

D. *IoT and Edge Computing:*

Different Computing models was used wisely to give better systems to user with the help of IoT. In this emerging computing era, cloud computing used to examine and keep data. But now a day user wants low latency, use can compromise on cost but can't compromise on time that's why Edge computing is introduce which modified technology that enables many inventions. Edge computing will do the following tasks [8].

- Management of data collections in IoT devices.
- Provide high security to data from sensor to gateway.
- Data Analysis at the edge.

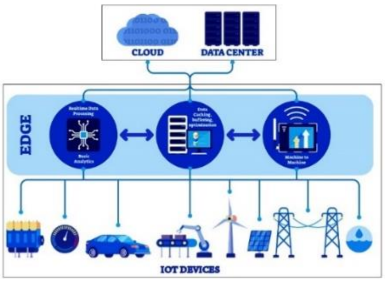

Fig. 6. Relationship between Edge Computing and IoT

According to recent research, following technologies are shifting IoT towards the edge computing AI & ML architectures, 5G & 6G networks, Cloud technologies, Hardware & Sensors, Cybersecurity, and Tactile Internet [20].

1) AI & ML architectures:

By the growth of AI software platforms and hardware platforms and the availability of large data sets to test and use AI combined with growing computing power makes AI the key to a few real IoT real-life situations. However, this flexibility has so far been the basis of the network, while the current growth of AI and hardware platforms increases AI support on the edge.

2) 5G & 6G networks:

Low-cost, reliable and awesome internet connection is an essential requirement in a IoT environments. This requirement is even more important with the increase in computing on the edge which will further contribute to increasing the load on the edge of the network. With the increasing network load on the edge, to avoid increasing the power consumption of network resources on the edge, in addition, it is expected that the continuous implementation of portable infrastructure will include connectivity and computer infrastructure, thus opening up new ways to deliver and manage IoT infrastructure.

3) Cloud technologies:

While a growing transition to the edge will reduce the acceptance of traditional cloud providers, the role of cloud technology will still be key to providing a reliable and independent IoT infrastructure from cloud to edge (or edges). Indigenous cloud approaches have proven to be effective in distributed environments and have enabled the role and automation of IoT services in cloud development. The emergence of this technology will be the key to allowing IoT to grow on the edge and in all the many infrastructure providers.

4) Hardware and sensors:

Edge computing apparently depends on the flexibility of the hardware. Edge nodes are requested to drive AI and machine learning activities that would only be possible in cloud infrastructure, while addressing other barriers such as capacity. The increasing number of sensors used will also contribute to IoT stability, thus requiring - not only energy-saving sensors - but also those associated with bio.

5) Cybersecurity:

From centralized to distributed infrastructure paradigm increases security management complexity and increases the potential infrastructure attacks. It is expected that security and privacy technologies will evolve to accommodate shared use and increase their resilience to new attack methods that may jeopardize the edges.

6) Tactile Internet:

Some of the improvements listed above associated with a reduction in the cost of AR / MR devices acts as a catalyst for the immediate adoption of the affected internet. IoT will soon be integrated with AR / MR to allow novel applications and business models that completely transcend time and space constraints. The COVID19 epidemic is another factor in this process, as it has led to the explosion of market demand for services involving remote monitoring and support [20].

E. *IoT and Big Data:*

Traditionally, big data includes four dimensions, known as 4V's, Volume, Variety, Velocity and Veracity [11]. Mention in research [12] considered 5Vs'. Whereas some research in [21] , [22] , [23] considered 10Vs' as Big Data issues. Other methods of data processing are pre-processing and the creation of Meta data. Data pre-processing helps to reduce data volume. IoT sensors use built-in resources to perform pre-processing before sent for further working. Meta data used to store data and their necessary attributes for future processing. Considering the diversity of data, it took a huge number of resources to process data. Relational database is used to store data traditionally and commercially. IoT data features made data management based on traditional relationships impossible. Use of a traditional data for the processing of IoT data may cause the query to slow down and may cause delays in responses. We have normally two types of storage format Structured and Unstructured data storage. NoSQL and MongoDB are significant in IoT evolution. NoSQL and MongoDB ideal for use in big data and in specially for IoT device data [11]. Using Data Visualization method such as maps, charts, plots, diagrams, line or bar graphs, and matrices large data generated by IoT devices represented in a visual way and can be a very powerful way to highlight any conflict in a data set. Several tools such as Plotly, Sisense, Tableau, Microsoft Azure and Power BI, Kibana and Grafana was used for visualization of data [11]. Mining technology made possible to keep large amounts of data generated directly or indirectly by users and then analyze it to generate useful new information. Reference of below figure [24].

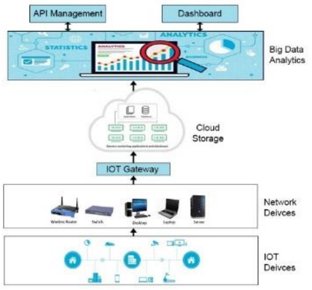

Fig. 7. Relationship between IoT and Big Data

F. IoT and BlockChain:

The integration of Blockchain and IoT could be summarized as follows security, identification, reliability, decentralized framework, autonomous, and scalability. IOTA, IOTIFY, iExec, Xage, and SONM are used developed IoT application using Blockchain [15]. Investigations identified the access control as the main responsible for the security breach. Therefore, the adoption of improper access control systems can result in significant privacy and economic damage to individuals and businesses. In [25] researcher presents a complete access control solution involves three components authorization, authentication, and auditing. Blockchain as technology, has the ability to provide a service layer that makes it easy to integrate with IoT infrastructure. Blockchain technology and its features can be used throughout the digital world, strengthening hundreds of industries by eliminating connectors and reducing costs. Blockchain as a service that can be used by various IoT devices and applications. This is called Blockchain as a service (BaaS). Typically, BaaS focuses on capturing controlling, creating, deploying many aspects of blockchain technology such as consistency, corruption protection and smart contracts [14].

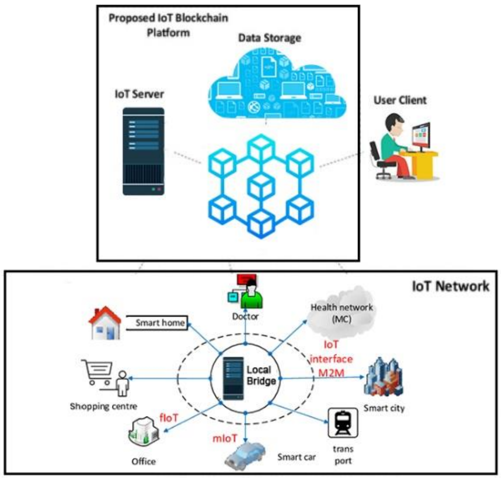

Fig. 8. Relationship between BlockChain and IoT

G. IoT and Machine Learning:

The IoT is merging into day life swiftly, as a unique era of the past few years. The motive of Internet of Things (IoT) is to save energy, time, and money. The information or data which are retrieved from IoT devices passed through a decision support system after processing to make experience out of it. With the help of machine learning, computer systems carry out tasks inclusive of predictions, clustering, classification, sample reputation, and many others. Machine Learning algorithms grouped into four classes: Supervised learning algorithms used to deal with problems like regression such as estimating life experience and weather forecasting, based on prevailing market price predicting house price etc. Unsupervised Learning: Unsupervised learning algorithms used to deal with problems involving data preparation & visualization, clustering problems, features of hidden structures. It also has applications in genetics such as clustering DNA pattern, recommendation systems, customer segmentation, or business strategies. Reinforcement Learning: Reinforcement learning algorithm used to deal with problems like scenario-based learning policies, controller optimization. For example, it has application in automatic parking system [17] Machine Learning Techniques using data which are stored on cloud servers for advanced analysis & sharing among other devices. Some Important applications are categorized into; Smart Homes; This include traditional home appliances like fridges, washing machines, invertors, smart doors, which are now developed smart and collaborate to each other as a authorized user by the internet. fitness-care help: new gadgets were evolved to enhance an affected person's properly-being. Plasters with wireless sensors can display a wound's kingdom and document the information to the doctor without the want for their physical presence. clever Transportation: using sensors embedded to the motors, or cellular gadgets and devices set up in the town, it is feasible to offer optimized route guidelines, clean parking reservations, monetary street lighting fixtures, telematics for a public way of transportation, a twist of fate prevention, and independent using Environmental situations tracking: wireless sensors allotted in the city make the appropriate infrastructure for a wide form of environmental conditions monitoring. Barometers, humidity sensors, or ultrasonic wind sensors can help to create advanced weather stations [28]. Machine Learning algorithms used for these purposes like KNN, Decision making, classification based, PCAs, Regression, K means etc. It allows to lessen computational values; improved computing electricity and integration of numerous technological breakthroughs have made this feasible [17].

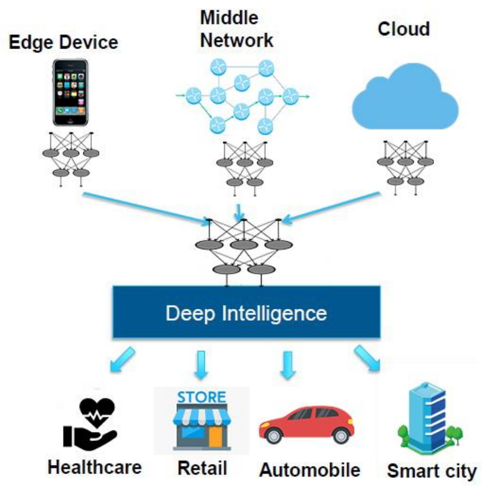

Fig. 9. Relationship between Machin Learning and IoT

III. OUR ANYLYSIS AND WORKING

In this section, we present the our propose work. Along with that, we also talk about the scope of the presented work. We listed the features of each technology discussed in paper, their challenges, and their limitations after doing little survey of different research paper, websites and conference papers etc.

TABLE I. FEATURES OF IOT AND DIFFERENT DOMAIN

Features	**Features of different technologies under the flag of IoT**							
	IoT	***DC***	***CC***	***FC***	***EC***	***BD***	***BC***	***ML***
Security and Privacy	✓	✓	✓	✓	✓	✓	✓	
Power Consumption	✓							
Device Connectivity	✓							
Data sensing	✓							
Intelligence Capabilities	✓	✓	✓	✓	✓		✓	
Dynamic System	✓	✓	✓	✓	✓			
Large Scale Network/Sensor	✓	✓	✓	✓			✓	
Data Analysis	✓	✓	✓	✓	✓		✓	✓
Unique Identity	✓	✓					✓	
Autonomous Decision/System	✓		✓	✓	✓		✓	✓
Heterogeneity	✓	✓	✓	✓				
Resource sharing		✓	✓					
Concurrency		✓						
Openness		✓						
Fault Tolerance		✓	✓					
Scalability		✓	✓					
Transparency		✓	✓	✓	✓		✓	
Performance	✓	✓	✓	✓	✓	✓	✓	
Easy Maintenance			✓					
On Demand Service			✓					
Economical			✓					
Availability			✓					
Edge Location				✓	✓			
Geographical Distribution		✓	✓	✓	✓			
Interoperability		✓	✓	✓	✓	✓		
Real-time interactions				✓	✓	✓		✓
Mobility Support				✓	✓			
Low Latency				✓	✓			
Proximity				✓	✓			
Location Awareness				✓	✓			
Data structure						✓		
Real-time collection						✓		
Real-time analysis						✓		✓
Real-time Prediction						✓		✓
Immutability								
Decentralized Technology							✓	
Distributed Ledgers							✓	
Enhanced Security							✓	
Anonymity							✓	
Cost Reduction							✓	
Automatically Data Visualization Ability							✓	✓

TABLE II. CHALLENGES OF IOT AND DIFFERENT DOMAI

Challenges	Challenges of different technologies under the flag of IoT							
	IoT	***DC***	***CC***	***FC***	***EC***	***BD***	***BC***	***ML***
Compatibility	✓							
Interoperability	✓	✓					✓	
Limited Bandwidth	✓							
Quality of Service	✓	✓	✓	✓	✓	✓	✓	✓
Big Data	✓							
Scalability	✓	✓	✓			✓	✓	
Design Challenges	✓	✓	✓	✓	✓	✓	✓	
Synchronization		✓						
Resource Identification		✓						
Portability			✓					✓
Reliability			✓	✓	✓	✓		✓
Cost			✓					✓
Lack of resources			✓					
Management of Resources			✓	✓	✓	✓		
Downtime			✓					
Placement of Fog Servers				✓				
Delay in Computing			✓	✓				
Data Management			✓	✓	✓	✓		
Computation	✓	✓	✓	✓	✓	✓		
Constantly Changing and Updating						✓		
Lack of Understanding						✓	✓	
Storage						✓	✓	
Rules and Regulation							✓	
Discovery and Integration							✓	
Under fitting & over fitting of training data								✓

TABLE III. LIMITATION OF IOT AND DIFFERENT DOMAI

Limitations	Limitation of different technologies under the flag of IoT							
	IoT	***DC***	***CC***	***FC***	***EC***	***BD***	***BC***	***ML***
Low Computing Resources	✓							
Low Energy Resources	✓							
Limited Storage Capacity	✓							
Absence of a global clock		✓						
Absence of shared memory		✓						
Network Congestion			✓					
Network Connection/ Offline cloud			✓					
Energy Consumption				✓				
Network Management				✓				
Data Governance				✓				
Limited data control					✓			
Limited Capabilities					✓			
Biased fundamental User Data						✓		
Inaccessible User Data						✓		
Immutable							✓	
Key Management							✓	
High Energy Consumption							✓	
Scalability								✓
Computational Complexity								✓
Not Efficient on semantic and syntactic diversified data								✓

IV. Conclusion and Future Direction

The Internet of Things is gaining importance day by day. There are a lot of applications working with a collaboration of internet of Things and technologies mentioned in the paper. IoT will bring automation to everything around us. Integration of the Internet of Things with other computing domain blockchain leads to the evolution of many applications. In this paper, we described the emerging technologies and the relationship between different technologies and the Internet of Things. We listed the features, challenges, and limitations of these emerging technologies. challenge and limitation of all technologies. There are many features, challenges, and limitations listed after surveying many research papers and websites.

REFREENCES

[1] A. K. •. E. Shakshuki, "Cloud of Things: Integration of IoT with Cloud Computing," in *Robots and Sensor Clouds*, Springer.

[2] [Online]. Available: https://www.oracle.com/internet-of-things/what-is-iot/.

[3] "techtarget," [Online]. Available: https://whatis.techtarget.com/definition/distributed-computing .

[4] R. Z. K. Md. Firoj Ali, "Distributed Computing: An Overview," *Int. J. Advanced Networking and Applications.*

[5] H. G. S. C. S. K. G. hubha Brata Nath, "A Survey of Fog Computing and Communication Current Researches and Future," *IEEE,* 2018.

[6] E.-N. H. Mohammad Aazam, "Fog Computing and Smart Gateway Based Communication for Cloud of Things," *International Conference on Future Internet of Things and Cloud,* 2014.

[7] [Online]. Available: https://blogs.cisco.com/perspectives/iot-from-cloud-to-fog-computing .

[8] M. R. K. Soumyalatha Naveen, "Key Technologies and challenges in IoT Edge Computing," *IEEE,* 2019.

[9] S. S. M. P. D. P. A. G. M. M. C. C.-T. L. I. F. Hesham El-Syed, "Edge of Things: The Big Picture on the Integration of Edge, IoT and the Cloud in a Distributed Computing Environment," *IEEE,* 2017.

[10] S.-S. M. A. A. K. B. M. S. Ruth Chweya, "IoT and Big Data Technologies: Opportunities and Challenges for Higher Learning," *International Journal of Recent Technology and Engineering* , 2020.

[11] M. T. Shivanjali Khare, "Big Data in IoT," *IEEE* , 2019.

[12] A. J. Ishwarappa, "A Brief Introduction on Big Data 5Vs Characteristics and Hadoop Technology," *International Conference on Computer, Communication,* 2015.

[13] H. K. J. F. Q. L. R. S. Bo Tang, "IoT Passport: A Blockchain-Based Trust Framework for Collaborative Internet-of-Things," *IEEE Access,* 2019.

[14] M. A. A. A. G. A. a. G. W. Hany F. Atlam, "A Review of Blockchain in Internet of Things and AI," 2020.

[15] T. Alam, "Blockchain and its Role in the Internet of Things (IoT)," *International Journal of Scientific Research in Computer Science, Engineering and Information Technology*, vol. 5, no. 1, 2019.

[16] [Online]. Available: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3548431 .

[17] "IoT and Machine Learning- A Technological Combination for Smart Application," *International Conference on Innovative Advancement in Engineering and Technology,* 2020.

[18] D. T. Patel, "Distributed Computing for Internet of Things (IoT)," 2019.

[19] [Online]. Available: https://www.analyticsvidhya.com/blog/2016/08/10-youtube-videos-explaining-the-real-world-applications-of-internet-of-things-iot/ .

[20] A. A. J. B. S. M. a. F. D. l. P. Javier Prieto, "IoT Approaches for Distributed Computing," *Hindawi,* 2018.

[21] J. S. H. M. H. A. T. M. A. Mansoor Ahmad Rasheed, "A Survey on Fog Computing in IoT," *VFAST Transactions on Software Engineering* , 2021.

[22] A. Heijnen, "IoT and Edge Computing: Opportunities for Europe," *Next Generation Internet of Things,* 2020.

[23] M. A. H. S. G. B. A. A. A. S. S. Nawsher Khan, "The 10 Vs, Issues and Challenges of Big Data," 2018.

[24] A. A. A. E.-A. ,. H. H. Ahmad M. Awaad, "A Survey on Big Data and IOT," *Solid State Technology,* 2020.

[25] A. S. M. M. M. G. S. J. H. A. F. Z. R. MARIEH TALEBKHAH, "IoT and Big Data Applications in Smart Cities: Recent Advances, Challenges, and Critical Issues," *IEEEACCESS,* 2021.

[26] F. N. A. G. A. K. I. A. T. H. A. S. A. I. Y. MOHSEN MARJANI, "Big IoT Data Analytics: Architecture, Opportunities, and Open Research Challenges," *IEEEACCESS,* 2017.

[27] A. R. A. G. L. C. E. D. B. Otto Julio Ahlert Pinno, "ControlChain: Blockchain as a Central Enabler for Access Control Authorizations in the IoT," *IEEE,* 2017.

[28] G. K. 1. S. K. a. D. K. Fotios Zantalis 1, "A Review of Machine Learning and IoT in," *MDPI,* 2019.

[29] [Online]. Available: https://www.i-scoop.eu/internet-of-things-iot/internet-of-things-what-definition/.

[30] [Online]. Available: https://www.educba.com/iot-features/.

[31] [Online]. Available: https://www.javatpoint.com/iot-features.

[32] [Online]. Available: https://www.javatpoint.com/iot-features.

[33] [Online]. Available: https://www.interviewbit.com/blog/features-of-iot/.

[34] [Online]. Available: https://www.geeksforgeeks.org/characteristics-of-internet-of-things/.

[35] [Online]. Available: http://www.csc.villanova.edu/~schragge/CSC8530/Intro.html.

[36] [Online]. Available: https://www.geeksforgeeks.org/features-of-distributed-operating-system/.

[37] [Online]. Available: https://data-flair.training/blogs/features-of-cloud-computing/.

[38] [Online]. Available: https://www.javatpoint.com/features-of-cloud-computing.

[39] [Online]. Available: https://www.jigsawacademy.com/blogs/cloud-computing/characteristics-of-cloud-computing/.

[40] [Online]. Available: https://www.techtarget.com/searchcloudcomputing/feature/7-key-characteristics-of-cloud-computing.

[41] [Online]. Available: https://techvidvan.com/tutorials/features-of-cloud-computing/.

[42] [Online]. Available: https://www.controleng.com/articles/five-characteristics-of-cloud-computing/.

[43] [Online]. Available: https://www.interviewbit.com/blog/characteristics-of-cloud-computing/.

[44] [Online]. Available: https://cloudtweaks.com/2012/09/key-features-of-cloud-computing/.

[45] S. S. R. Shabnam Kumari, "Fog Computing: Characteristics and Challenges," *International Journal of Emerging Trends & Technology in Computer Science (IJETTCS),* 2017.

[46] [Online]. Available: https://techstrain.com/fog-computing/.

[47] [Online]. Available: https://viso.ai/edge-ai/edge-computing-a-practical-overview/.

[48] [Online]. Available: https://www.simplilearn.com/what-is-edge-computing-article.

[49] [Online]. Available: https://www.techtarget.com/searchdatacenter/definition/edge-computing.

[50] D. K. Y. P. M. V. G. V. B. Prakash P, "Fog Computing: Issues, Challenges and Future Directions," *International Journal of Electrical and Computer Engineering,* 2017.

[51] [Online]. Available: https://nexusintegra.io/big-data-vs-iot/.

[52] [Online]. Available: https://mastechinfotrellis.com/blog/big-data-internet-things-iot.

[53] [Online]. Available: https://101blockchains.com/introduction-to-blockchain-features/.

[54] [Online]. Available: https://101blockchains.com/blockchain-adoption-challenges/.

[55] [Online]. Available: https://www.simplilearn.com/tutorials/blockchain-tutorial/what-is-blockchain.

[56] [Online]. Available: https://www.ibm.com/topics/blockchain-iot.

[57] E. G. I. S. M. Ali Tunc, "A Survey on IoT Smart Healthcare: Emerging Technologies, Applications, Challenges, and Future Trends," *arXivLabs* , 2021.

[58] M. K. Shubhangi K.Gawalia, "Energy Autonomy in IoT Technologies," *ScienceDirect,* 2018.

[59] A. G. Mahesh Kavre, "Internet of Things (IoT): A Survey," *IEEE,* 2019.

[60] P. T. M. Z. Sachin Kumar1, "Internet of Things is a revolutionary approach for future technology enhancement: a review," *Journal of BIg Data,* 2019.

[61] A. H. Hussein, "Internet of Things (IOT): Research Challenges and Future Applications," *(IJACSA) International Journal of Advanced Computer Science and Applications,,* 2019.

[62] A. P. A. S. Sanket Thakare, "The Internet of Things – Emerging Technologies, Challenges and Applications," *International Journal of Computer Applications,* 2016.

[63] [Online]. Available: https://www.iot-now.com/2020/06/03/103228-5-challenges-still-facing-the-internet-of-things/.

[64] [Online]. Available: https://www.geeksforgeeks.org/challenges-in-internet-of-things-iot/.

[65] [Online]. Available: https://www.geeksforgeeks.org/challenges-in-internet-of-things-iot/.

[66] [Online]. Available: https://www.ejbtutorial.com/distributed-systems/challenges-for-a-distributed-system.

[67] [Online]. Available: https://aws.amazon.com/builders-library/challenges-with-distributed-systems/

[68] A. K. T. Kamal Sheel Mishra, "Some Issues, Challenges and Problems of Distributed Software System," *(IJCSIT) International Journal of Computer Science and Information Technologies,* 2014.

[69] [Online]. Available: https://cem-basaranoglu.medium.com/the-biggest-challenges-in-distributed-systems-27520a58258c.

[70] [Online]. Available: https://www.geeksforgeeks.org/design-issues-of-distributed-system/.

[71] V. D. Manoj Chopra, "A Comparative study of cloud computing through IOT," *International journal of Engineering development and research- IJEDR,* 2019.

[72] L. SURYA, "SECURITY CHALLENGES AND STRATEGIES FOR THE IOT IN CLOUD," *SSRN Electronic Journal,* 2016.

[73] [Online]. Available: https://www.jigsawacademy.com/blogs/cloud-computing/challenges-of-cloud-computing/.

[74] [Online]. Available: https://www.datapine.com/blog/cloud-computing-risks-and-challenges/.

[75] [Online]. Available: https://www.techwell.com/techwell-insights/2017/10/6-major-challenges-cloud-computing.

[76] R. F. J. M. A. Fatima Haouari, "Fog Computing Potentials, Applications, and Challenges," *International conference on computer and applications,* 2018.

[77] [Online]. Available: https://www.techtarget.com/searchnetworking/answer/What-are-edge-computing-challenges-for-the-network.

[78] [Online]. Available: https://www.itproportal.com/features/five-edge-computing-challenges-enterprises-face-and-how-to-overcome-them/.

[79] [Online]. Available: https://www.greyb.com/edge-computing-challenges-and-their-solutions/.

[80] N. W. S. B. P. K. a. D. S. N. Blesson Varghese, "Challenges and Opportunities in Edge Computing," *IEEE,* 2016.

[81] [Online]. Available: https://www.xenonstack.com/insights/big-data-challenges.

[82] [Online]. Available: https://www.upgrad.com/blog/major-challenges-of-big-data/.

[83] [Online]. Available: https://www.techtarget.com/searchdatamanagement/tip/10-big-data-challenges-and-how-to-address-them.

[84] [Online]. Available: https://blog.hubspot.com/website/big-data-challenges.

[85] "On blockchain and its integration with IoT. Challenges and opportunities," *Future Generation Computer Systems* , 2018.