An Overview of Internet of Things: Architecture, Applications and Challenges

Aakanksha Jha[1], Archana Rohilla, Praveen Kumari[2,3]

[1]Student, [2,3]Assistant Professor Department Of CSE, DPGITM, Gurugram,

aakankshajha14@gmail.com

Abstract: **The Internet of Things is a nuanced technology that has the potential to change the world. The Internet of Things is a technology that enables communication among physical objects and with their surroundings. Each physical object in the network can be identified uniquely. This technology is powered by its structural architecture whose layers provide different functionalities and collectively form the IoT systems. This paper discusses the various protocols that have been deployed to provide secure transmission of data. The IoT is capable of automating systems thereby making it desirablefortheusers.Ithasbeenemployedinvarioussectorstoenhanceperformance,reduceerrorsandreducehuman intervention. Its application in many sectors like healthcare, agriculture, transportation, and retail has also been discussed. Though these sectors are using this technology, it has not been fully adopted. This is due to the issues of scalability, interoperability, and also the risks associated with security. These challenges and issues have also been summarized in the paper along with a few combattingstrategies.**

Keywords—IoT, MQTT, COAP, Service Management, Database Provisioning, Smart Cities, Smart Farming, SSL, DTLS, MEGAN.

I. INTRODUCTION

In this era of nuancedtechnologyandever-increasingdemand foremergingtechnologies,theInternetofThingshasemerged asamultidisciplinaryandmultifacetedtechnologyinthemass market. The Internet of Things enables an interconnected network system of edge devices, each with its capability of sensing, processing, and capacity of transmitting data, to communicate without any human intervention. The physical edge devices comprise computing, digital, and electrical components with embedded sensors and actuatorsfacilitating communication over the Internet. The individually addressable devices can be any physical entity that can be identified using Unique Identifiers which is a pattern givento uniquely identify a single entity or a group of entities within a specific context[1].

TheessenceoftheInternetofThingswasfirstfeltwhenlocal programmers in London used to connect to a refrigerator appliancethroughtheInternettocheckttheavailabilityofcold drinks [2]. The term was finally coined by Kevin Ashton in 1999[2].

II. RESEARCHMETHODOLOGY

A literature review can be conducted in many different ways with various strategies, standards, and guidelines. This literature review has been used as a methodological tool to comprehend and consolidate the theory in the area of the InternetofThings.Themainaimofthisliteraturereviewisto summarize the knowledge from prior research. Thisliterature review offers an overview of the topic and summarizes the various aspects of the topic. This literature review was conducted in a systematic manner. To begin withrelevant literature on the topic of the review was gathered from publications based on the subject. Most of the material is selected from google Scholar. In order to gain better insights on the topic websites pertinent to the topic are also sampled [1].Then a qualitative analysis is done to develop a thorough understanding of the topic and provide a review. Finally, some pitfalls are highlighted and relevant solutions for the same are discussed [2].

III. INTERNET OF THINGSARCHITECTURE

Thestructureandprovisionforthephysicalcomponents,their functional organization, their operational principles, protocols,andprinciplesandproceduresaredeployedthrough a common framework. Different researchers have proposed different architecture schemas, with overlappingtechnologies in model layers[3].This framework is not defined, and modifications are made according to different use cases. The basic architecture of IoT can be interpreted as a group of five horizontal layers that have their functionalities and purpose and collectively form the IoT ecosystem. The five functional blocks of IoT architecture are elaborated under[4].

3.1 PERCEPTIONLAYER

This is the bottommost layer of the architecture and is made up of physical devices. All the end devices are present at different locations along with sensors from the perception layer. The function of this layer is to gather the information given to the applications in the form of signals[5]. The sensors present in the device collect information from environmental parameters such as temperature, humidity, the concentration

of particulate matter, etc. [6]. It then processes the data and theinformationaboutthesephysicalparametersareconverted into electrical signals. Thus, this layer is known as the perceptionlayerasitperceivesthedatasent from the physical world[7].This layer is also known as the sensing layer. Thedata emitted by this layer is in the form of digital signals and act as a feed to the subsequent layer of the architecture.

• The working involves the conversion of analog signals received from the real world to machine-interpretable digital signals and vice-versa when analog signals are converted to digital signals[8-10].

• Along with sensors edge devices are alsoembedded with electronic devices, actuators, or indicators that produce motion as output from signal inputs. The working is reversed when digital signals are converted to produce motion by the end devices in the realworld[11].

Thereisnostandardforthesizeofcomponentspresentinthis layer and the devices can be of various sizes ranging from small units such as sensors to complex systems such as an automobile[12].

3.2. NETWORK LAYER

This is the second layer of the IoT architecture and is responsible for the transmission of data among the devices and to the internet. As IoT has a multitude of edge devices, enormous amounts of heterogeneous data are received from heterogeneous devices[13]. This data has heterogeneous formats. So, firstly this data is cleaned by removing noises. Then this clean data is used to deduce relationships to uncover patterns present in the target dataset. This deduced pattern is used to extractmeaningfulandvaluabledatafromgroupsofdatasets. Theobtainedmeaningfuldataareclubbedtogetherandcanbe utilized as per the requirement[14]. As IoT systems are vast networks of interconnected devices that interact with each other and their surroundings, many security threats and risks areposedtothem.Apartfromfacilitatingcommunication,the networklayeralsorendersadditionalsecurityfeaturestocater toanysuchsecurityattacks.Accordingtotherecentresearch, the network layer is the most developed layer by far of the complete IoT architecture as it is capable of advancing the relevant information for relevantprocedures[15-19].

3.2.1 Securedtransmission

Theintegrityofdataismaintainedbypassingthedatathrough either secure hardware or firmware channels. It is the main processing unit of the IoT architecture[20]. The sharing of data can be instrumented through various technologies like wireless, wired, Radio Frequency Identification, Bluetooth, and Near Field Communication [21]. Many hardware channels use conventional protocols MQTT and COAP. In Message Queue Telemetry Support the end devices are clients that produce data. This data is published to an address in a common server known as a broker which is responsible for categorizing the data into topics[22]. The clients can subscribe to multiple such topics and receive every message published on these topics [23]. Another common protocol is COAP which is based on a client-server model. The end devices are clients that can send the request to a server and in return receive responses[24].

3.2.2 Low Power Wide Area Network

The edge devices consist of sensors of various sizes. Some sensors are small and consume less power to function. They can be harnessed with Wide Area Network and be used for communication between devices with a low power range[25-35].This can cover distances with I in the range of 50 km and transmit 10 to 1000 bits per second.

3.3 MIDDLEWARELAYER

This is the third layer of the architecture and lies between the network layer and the application layer. It is a software interface that utilizes the technologies of other layers and plays a very crucial role in the system's functionality[36]. The purpose of this layer is to process the data coming from the network layer and evince only the data that is required by the developers for the application development process. It works on the data to enhance interoperability[37]. The Interoperability of IoT can be understood as the ability of components to work together for the exchange of information[38].

After receiving the information, the data is abstracted and compared with the results achieved from ubiquitous computing. These comparisons are used for decision-making and stored in databases for further utilization[39]. Another significant task of this layer is to grant access control to devices by authenticating users.

• Service Management: This involves all theexercises including processing received data, making decisions evaluating the data with previously obtained results, and delivery of the requested services across the network[40].

• Database Provisioning: Multitudes of IoT systems generate varying amounts of data. In this case, a single static database will not be feasible in such a situation. There is a need for a flexible database whose capacity is extensible and scalable[41]. Intelligent devices generate data along with connectivity requirements. To cater to the challenges and serve these demands popular databases DBMS and NoSQL areused.Databaseprovisioningisbestachievedbydeploying a database provisioning setup with all services on a common platform[42]. Morpheus Virtual Alliance is a single platform that unifies the necessary tools like DBMS and enables cloud services of multiple clouds[43].

• InformationProcessing:Thisreferstothetranslation of sensory data, yielded from edge devices into machine-interpretable or human interpretable dataform[44-46].

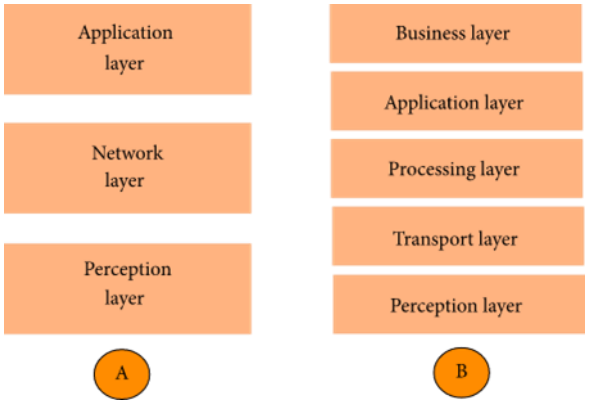
3.4 APPLICATIONLAYER

This is the fourth layer of the architecture which takes the processed information from the middleware layer and analyzes this to provide insights. This layer constitutes software based on different technologies, with varying complexities and functions[47-50]. A basic example includes mobile apps that can interact with home appliances.

3.5 BUSINESSLAYER

This layer is present on top of the application layer. Themain purpose of this layer is to analyze gathered insights and generate models from them. These models help in data-enabled decision-making. Such models are needed for the growth of the business[51]. As this is the end layer it receives the data from the application layer on which statistical algorithms

have been applied. These statistics are used to createpictorial representations of data in the form of models. These models dictate the further action plan of thebusiness.
The models answer four questions namely who, what, how, andwhy,andonthebasisoftheanswersreceiveditgenerates models that are of great value to anybusiness[52-56].



IV. APPLICATIONS OF THE INTERNET OF THINGS

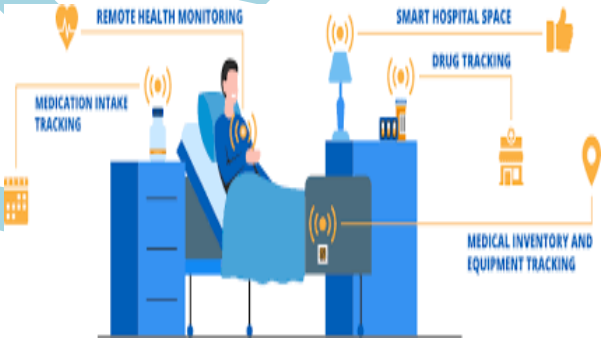
When the word Iot is mentioned majorly the first picture created in our mind is of an automatic industry with automatic, machines doing the work without any human intervention.Well,thissurelyisausecaseandsubpartofIoT called Industrial IoT, but not the whole of IoT[57]. IoT has significantly entered into our daily lives over the last two decades, with its presence in almost all sectors of living. The increasing amount of population and their technology-driven choices are contributing to the growth of IoT applications. Arising from the discipline of innovation, smart devices are turningintoassets.AccordingtoOracle,currently,thereexist 10billionconnectedIoTdevices,andthisnumberisexpected togrowto35billionIoTdevicesbytheendofthisyear.Truly IoT is one of the rapidly growing industries[58-60].

4.1 SMARTCITIES

A smart city is an area where the Extensive usage of radio frequency identification and sensors will be required to build smart cities. The top use case of IoT includes Remote Asset Monitoring Adoption [61]. In this, there is a real-time and continuous monitoring of assets and the reports are generated against the manual MS EXCEL reports. In India, some major cities like Delhi, Jaipur, and Pune are going through drastic changes with the mission to get transformed into smart cities. These cities will offer lucrative facilities like smart water-supply networks, smart libraries, and other community services. This will be made possible by collecting data from citizens, processing it, and then gathering insights from it to make decisions[62]. Such applications will offer significant breakthroughsintermsofsavingmoneyandenergy.Notonly this,manyotherserviceslikeparkingmeters,sewagesystems, and streetlights can be made intelligent with thecollaborative useofIoTandAI.Allthesewillbeinterlinkedandconnected to the internet to facilitate communication and monitoring [63-65].

4.2 HEALTHCARE

The healthcare systems have evolved and advanced greatlyin terms of medicines and medical procedures, however, many underdeveloped countries have inept healthcare systems falling short in their accuracy and precision. This creates ineffectual healthcare systems. Healthcare devices can be developed with IoT to alleviate the situation[66]. Wearable devices like wristbands can be used by patients to monitor their blood sugar levels, blood pressure, heart rate, and oxygen levels. these can also keep a track of medicine schedules and act as reminders for patients without the need for attendants. Wearable devices can be used by physicians also for monitoring patients' conditions and record keeping. In recent times, the pandemic made us realize the importance of oxygen[67]. With the help of IoT, we can track the real-time location and availability of the selife-saving oxygen cylinders. Not only this availability of many other types of equipment can be tracked in real-time without any hassle [68]. Additionally, these advanced systems provide better authentication and identification of parents to avoid any mismatch incidents. Automated data collection from medical inventory will instrument will help in providing ease for purchase on time. If these operations are conducted smoothly and on time then the overall workflow of the hospital is enhanced, contributing to the hospital's profit[69-70]. These technologies and automated machines can greatly improve the plight of healthcare systems across the world.



4.3 AGRICULTURE

India's 60% population is dependent upon agriculture for their livelihood [71]. Not just India, many countries have the agriculture sector as the major contributing sector to their economy. Keeping, the facts and figures about economy and GDP aside, agriculture is the most important sector as it produces our fuels, without which our lives would come to an end. Thus, agricultural practices should be very efficient.
However, most of the agricultural practices, especially the farming methods used are primitive[72]. With the help of IoT,we can use smart farming methods that will provide a promising solution to the sector. Smart farming methods combine farming and IoT technology by using sensors.
Manual methods are used to regulate climatic conditions. Automation off arms will help regulate the climatic conditions inside the farm, this will enhance the production and quality of crops[73-76].

Sensors embedded in the harvesting devices can monitor information about the type of soil, and its moisture content and provide better field management [77].
Biofortification is the production of crops with desired amountsofnutrition,IoTcanhelpbetterregulatethenutrients in the crops with real-time monitoring. IoT assists in better electricity and water management thereby reducing the costs. Smart farming methods encourage organic crops as very few pesticides and fertilizers are used[78-80].

4.4 RETAIL ANDLOGISTICS

There are numerous advantages provided by IoT in the retail field.Usually,retailshopsareovercrowdedbycustomerswho arerunningindifferentsectionstofindtheirdesiredproducts. IoT systems can provide information about products, their availability, and their location [81]. Sensors can be installed in the production factories and organizations that will gauge any change in the levels of gases and moisture. Alert signals wouldbeimmediatelysenttothemonitoringdevicesoralarm bells can be rung through actuators.. Automatic surveillance of the machinery will detect any damages or failure, and accordingly schedule repair routines without any delay [82]. Various business processes like inventory management, product procurement, material requirement planning,ordermanagement,andbillingcanbecarriedoutby IoT [83].

V CHALLENGES OF THE INTERNET OF THINGS

Inthismodernworldofadvancedtechnology,theimportance of interconnecting networks is of utmost importance which brings smart devices together. We have become heavily dependent on devices for our chores .Not only this working of regulatory bodies in many countries is instrumented by IoT technologies. For instance, a few days back speaking about the importance of the interconnecting network, the NV Ramana struck a common ground on the immediate need for the creation of national and state-level bodies to seek out the backlog of cases pending over in the courts since a long time in the subordinate courts, which has eroded the people's faith in the judiciary and has posed a great challenge[84-85]. The strengthening of IoT infrastructure and connectivity everywhere on a priority basis will help in this. However, as IoT systems are dense networks of systems that communicate with each other risks are inevitable. Theserisks pose many challenges to the IoT system[86]. Despite all the comfort provided by these systems, which have successfully developed confidence in the users, these challenges instill hesitance[87].

5.1 SECURITY

Ensuring security is the utmost concern of any system. A dense system of IoT requires extremely efficient security measuresasahugeamountofuserdataisatstake.Atthenode level, security measures including authentication, and authorizationarerequiredtokeepthedatasafeandintact.IoT users have come from different skill backgrounds, so their acquaintance with technologies used in IoT is an unfair expectation[88]. To bridge this gap further research on cryptographic security services should be conducted that will devise services operable on resource-constrained IoT devices .Proficient security protocols should be deployed at every communication layer to confer security. Secure Socket Layer (SSL) and Datagram Transport Layer Security (DTLS) are cryptographic protocols that are implemented between the transport and application layers to provide security [89, 90]. Mostly, the IoT systems are wireless, thereby making them even more prone to threats.

5.2 INTEROPERABILITY

Interoperability of any system refers to its capacity for communicationwithothercomponentsofthesystem.TheIoT technology is heavily dependent on data sharing, thus IoT developersmuststrivetoimprovetheinteroperabilityofthese systems. Myriads of heterogeneous edge devices and technologiesmakeupthesystem,duetothisthedifferentdata produced may not be compatible with each other, thereby raising interoperability issues[91]. To combat this issue researchers have provided a set of solutions collectively known as interoperability handling approaches. These approaches include adapters. Adapters or gateways are designs that perform the conversion of protocols from sending device to receiving device and vice-versa [92].This facilitates interoperability. By far the best strategy to encourage interoperability is MEGAN which stands for Multipurpose EnerGy-efficient Adaptable low-cost sensor Node a new sensor that has the ability to interface 32 different sensors and actuators. Its reliability is evident from its capacity to operate under different operating conditions[93-96].

5.3 SCALABILITY

The scalability of any system refers to its capacity to deliver the same efficiency with changes in the size of the system. So basically, an IoT system should be able to deliver the same performance with the addition of equipment's and services. Currently, there are more than 13 billion active IoT systems across the world. This number is expected to have an explosive growth of 30.9 billion devices by the end of 2025[97]. As IoT is rapidly growing, the scalability of IoT systems is an important concern.

•Automated Bootstrapping: To initiate the working of any new device upon its addition to the system, the device must be bootstrapped, registered with the server, and configured for security. These processes are generally conducted through a manual operator. However, manual operation will not be practical in the future. Thus, devices

should be equipped with bootloaders and security keys to enabletheautomaticset-upofthedeviceinanylocation[98-101].

• Adopt Multiple Data Storage Technologies: Whenit comes to technology selection, best-suited technology must be used to build different portions of IoT like user interface, data stream processing, and data for batch processing. All of this would require different database technology for their optimal function therefore the type of data should dictate the choice of database technology[102].

5.4 LEGAL ANDREGULATORY

Sharing of data across the internet has certain vices such as it collects biometric data of individuals and based thereon, the reputation is maligned. The Right to Reputation of an individual cannot be sacrificed and crucified at the alteration of the Right of Freedom of Speech and Expression of another[103]. Observations and false allegations have the propensity to cause irreparable harm to one reputation.
Generally, it is seen that as the data is shared from one end to another it moves across areas of different jurisdictions [104]. Legally it encroaches upon civil rights, personal liberty and privacy, and data detention beyond its jurisdiction, which is highly discriminatory.

VI CONCLUSION

The adoption of the Internet of Things is a boon to humanity. It is a revolutionary embarkment that will help in creating a better future. In this paper, the architecture of the IoT, its multidisciplinary applications, and the challenges faced by it have been discussed in a comprehensive manner. Several architectural schemas have been proposed by different researchers, here the 5-layer architecture has been discussed that can be mapped onto the 3-layer architecture[105-110]. IoT technology has been able to per meate almost all sector so four livelihoods. The positive impact on four of the main sectors including smart cities, healthcare, agriculture, and retail have been discussed. Along with the benefits of IoT, this technology faces certain challenges that need to be looked upon by the IoT developers[111-120]. Certain novel strategies have been discussed whose adoption can ease the degree of challenges.

VII REFERENCES

[1] Identifiers in Internet of Things (IoT). (2018). ALLIANCE FOR INTERNET OFTHINGSINNOVATION.
[2] Foote, K. D. (2022, January 14). A Brief History ofthe Internet ofThings.
[3] Saxena, S. (2020, 0 0). 5 Layer Architecture of Internetof Things.
[4] AltexSoft. (2020, August 12). IoT Architecture: the Pathway from Physical Signals to BusinessDecisions. Altexsoft. https://www.altexsoft.com/
[5] Bilal,Muhammad.(2017).AReviewofInternetofThings Architecture, Technologies and Analysis Smartphone-based Attacks Against 3Dprinters.
[6] ThinkPalm.(2021,January8).ANINTRODUCTIONTO IOT ARCHITECTURE AND ITS BENEFITS FOR ENTERPRISES!ThinkPalm.
[7] Jaffey, T. (n.d.). MQTT and CoAP, IoT Protocols. ECLIPSE FOUNDATION. Retrieved May 12, 2022, from https://www.eclipse.org
[8] Srinivasa, A H, & Siddaraju. (2019). A Comprehensive Study Of Architecture, Protocols And Enabling Applications In Internet Of Things (Iot)**.**
[9] Oracle India. (n.d.). What is IoT? Oracle India. Retrieved May 12, 2022,from
[10] Wegner, P. (2021, October 13). The top 10 IoT Use Cases. IOT ANALYTICS. [11]Karjagi, R., & Jindal, M. (2022, 0 0). What can IoT do for healthcare? Wipro.
[12]Kant, A. (2019, March 19). India needs farm revolution to attain 9-10% GDP growth: Amitabh Kant. THE ECONOMICTIMES.
[13]Rahman, A., & Hussein, H. (2019). Internet of Things (IOT): Research Challenges and Future Applications.
[14]Sachin Kumar, Tyagi, P., & Zymbler, M. (n.d.). Internet of Things is a revolutionary approach for future technology enhancement: a review. SpringerOpen. Retrieved May 12, 2022,
[15]Dierks T, Allen C. The TLS protocol version 1.0, IETF RFC, 2246; 1999.
[16]S. Misra, S. K. Roy, A. Roy, M. S. Obaidat and A. Jha, "MEGAN: Multipurpose Energy-Efficient, Adaptable, and Low-Cost Wireless Sensor Node for the Internet of Things," in IEEE Systems Journal. doi: 10.1109/JSYST.2019.2920099
[17]Atiquzzaman, Mohammed & Noura, Mahda & Gaedke, Martin. (2018). Interoperability in Internet of Things: Taxonomies and Open Challenges. Mobile Networks and Applications. 10.1007/s11036-018-1089-9.
[18] Sinha, S. (2021, September 22). State of IoT 2021: NumberofconnectedIoTdevicesgrowing9%to12.3billion globally, cellular IoT now surpassing 2 billion. IOT ANALYTICS.
[19] Dalal, S., Seth, B., Radulescu, M., Secara, C., & Tolea, C. (2022). Predicting Fraud in Financial Payment Services through Optimized Hyper-Parameter-Tuned XGBoost Model. Mathematics, 10(24), 4679.
[20] Dalal, S., Onyema, E. M., & Malik, A. (2022). Hybrid XGBoost model with hyperparameter tuning for prediction of liver disease with better accuracy. World Journal of Gastroenterology, 28(46), 6551-6563.
[21] Edeh, M. O., Dalal, S., Obagbuwa, I. C., Prasad, B. V. V., Ninoria, S. Z., Wajid, M. A., & Adesina, A. O. (2022). Bootstrapping random forest and CHAID for prediction of white spot disease among shrimp farmers. Scientific Reports, 12(1), 1-12.
[22] Zaki, J., Nayyar, A., Dalal, S., & Ali, Z. H. (2022). House price prediction using hedonic pricing model and machine learning techniques. Concurrency and Computation: Practice and Experience, 34(27), e7342.
[23] Dalal, S., Onyema, E., Romero, C., Ndufeiya-Kumasi, L., Maryann, D., Nnedimkpa, A. & Bhatia, T. (2022). Machine learning-based forecasting of potability of drinking water through adaptive boosting model. Open Chemistry, 20(1), 816-828. https://doi.org/10.1515/chem-2022-0187
[24] Onyema, E. M., Dalal, S., Romero, C. A. T., Seth, B., Young, P., & Wajid, M. A. (2022). Design of Intrusion

Detection System based on Cyborg intelligence for security of Cloud Network Traffic of Smart Cities. Journal of Cloud Computing, 11(1), 1-20.
[25] Dalal, S., Onyema, E. M., Kumar, P., Maryann, D. C., Roselyn, A. O., & Obichili, M. I. (2022). A Hybrid machine learning model for timely prediction of breast cancer. International Journal of Modeling, Simulation, and Scientific Computing, 2023, 1-21.
[26] Dalal, S., Seth, B., Jaglan, V., Malik, M., Dahiya, N., Rani, U., ... & Hu, Y. C. (2022). An adaptive traffic routing approach toward load balancing and congestion control in Cloud–MANET ad hoc networks. Soft Computing, 26(11), 5377-5388.
[27] Edeh, M. O., Dalal, S., Dhaou, I. B., Agubosim, C. C., Umoke, C. C., Richard-Nnabu, N. E., & Dahiya, N. (2022). Artificial Intelligence-Based Ensemble Learning Model for Prediction of Hepatitis C Disease. Frontiers in Public Health, 847.
[28] Seth, B., Dalal, S., Jaglan, V., Le, D. N., Mohan, S., & Srivastava, G. (2022). Integrating encryption techniques for secure data storage in the cloud. Transactions on Emerging Telecommunications Technologies, 33(4), e4108.
[29] Malik, M., Nandal, R., Dalal, S., Maan, U., & Le, D. N. An efficient driver behavioral pattern analysis based on fuzzy logical feature selection and classification in big data analysis. Journal of Intelligent & Fuzzy Systems, 43(3), 3283-3292.
[30] Malik, M., Nandal, R., Dalal, S., Jalglan, V., & Le, D. N. (2022). Deriving driver behavioral pattern analysis and performance using neural network approaches. Intelligent Automation & Soft Computing, 32(1), 87-99.
[31] Shetty, S., & Dalal, S. (2022, December). Bi-Directional Long Short-Term Memory Neural Networks for Music Composition. In 2022 Fourth International Conference on Emerging Research in Electronics, Computer Science and Technology (ICERECT) (pp. 1-6). IEEE.
[32] Onyema, E. M., Shukla, P. K., Dalal, S., Mathur, M. N., Zakariah, M., & Tiwari, B. (2021). Enhancement of patient facial recognition through deep learning algorithm: ConvNet. Journal of Healthcare Engineering, 2021.
[33] Dalal, S., & Khalaf, O. I. (2021). Prediction of occupation stress by implementing convolutional neural network techniques. Journal of Cases on Information Technology (JCIT), 23(3), 27-42.
[34] Dalal, S., Jaglan, V., & Le, D.-N. (Eds.). (2021). Green Internet of Things for Smart Cities: Concepts, Implications, and Challenges (1st ed.). CRC Press. https://doi.org/10.1201/9781003032397.
[35] Dahiya, N., Dalal, S., & Jaglan, V. (2021). 8 Mobility in Green Management IoT. Green Internet of Things for Smart Cities: Concepts, Implications, and Challenges, 125.
[36] Dahiya, N., Dalal, S., & Jaglan, V. (2021). 7 Efficient Green Solution. Green Internet of Things for Smart Cities: Concepts, Implications, and Challenges, 113.
[37] Seth, B., Dalal, S., & Dahiya, N. (2021). 4 Practical Implications. Green Internet of Things for Smart Cities: Concepts, Implications, and Challenges, 61.
[38] Malik, M., Nandal, R., Dalal, S., Jalglan, V., & Le, D. N. (2021). Driving pattern profiling and classification using deep learning. Intelligent Automation & Soft Computing, 28(3), 887-906.
[39] Jindal, U., Dalal, S., Rajesh, G., Sama, N. U., Jhanjhi, N. Z., & Humayun, M. (2021). An integrated approach on verification of signatures using multiple classifiers (SVM and Decision Tree): A multi-classification approach.
[40] Seth, B., Dalal, S., Le, D. N., Jaglan, V., Dahiya, N., Agrawal, A., ... & Verma, K. D. (2021). Secure Cloud Data Storage System Using Hybrid Paillier–Blowfish Algorithm. Computers, Materials & Continua, 67(1), 779-798.
[41] Vijarania, M., Dahiya, N., Dalal, S., & Jaglan, V. (2021). WSN Based Efficient Multi-Metric Routing for IoT Networks. In Green Internet of Things for Smart Cities (pp. 249-262). CRC Press.
[42] Goel, M., Hayat, A., Husain, A., & Dalal, S. (2021). Green-IoT (G-IoT) Architectures and Their Applications in the Smart City. In Green Internet of Things for Smart Cities (pp. 47-59). CRC Press.
[43] Chawla, N., & Dalal, S. (2021). Edge AI with Wearable IoT: A Review on Leveraging Edge Intelligence in Wearables for Smart Healthcare. Green Internet of Things for Smart Cities, 205-231.
[44] Dahiya, N., Dalal, S., & Jaglan, V. (2021). Efficient Green Solution for a Balanced Energy Consumption and Delay in the IoT-Fog-Cloud Computing. In Green Internet of Things for Smart Cities (pp. 113-123). CRC Press.
[45] Dahiya, N., Dalal, S., & Jaglan, V. (2021). Mobility Management in Green IoT. In Green Internet of Things for Smart Cities (pp. 125-134). CRC Press.
[46] Seth, B., Dalal, S., & Dahiya, N. (2021). Practical Implications of Green Internet of Things (G-IoT) for Smart Cities. In Green Internet of Things for Smart Cities (pp. 61-81). CRC Press.
[47] Dalal, S., Agrawal, A., Dahiya, N., & Verma, J. (2020, July). Software Process Improvement Assessment for Cloud Application Based on Fuzzy Analytical Hierarchy Process Method. In International Conference on Computational Science and Its Applications (pp. 989-1001). Springer, Cham.
[48] Seth, B., Dalal, S., Jaglan, V., Le, D. N., Mohan, S., & Srivastava, G. (2020). Integrating encryption techniques for secure data storage in the cloud. Transactions on Emerging Telecommunications Technologies.
[49] Hooda, M., & Shravankumar Bachu, P. (2020). Artificial Intelligence Technique for Detecting Bone Irregularity Using Fastai. In International Conference on Industrial Engineering and Operations Management Dubai, UAE (pp. 2392-2399).
[50] Arora, S., & Dalal, S. (2019). An optimized cloud architecture for integrity verification. Journal of Computational and Theoretical Nanoscience, 16(12), 5067-5072.
[51] Arora, S., & Dalal, S. (2019). Trust Evaluation Factors in Cloud Computing with Open Stack. Journal of Computational and Theoretical Nanoscience, 16(12), 5073-5077.
[52] Shakti Arora, S. (2019). DDoS Attacks Simulation in Cloud Computing Environment. International Journal of Innovative Technology and Exploring Engineering, 9(1), 414-417.
[53] Shakti Arora, S. (2019). Integrity Verification

Mechanisms Adopted in Cloud Environment. International Journal of Engineering and Advanced Technology (IJEAT), 8, 1713-1717.
[54] Sudha, B., Dalal, S., & Srinivasan, K. (2019). Early Detection of Glaucoma Disease in Retinal Fundus Images Using Spatial FCM with Level Set Segmentation. International Journal of Engineering and Advanced Technology (IJEAT), 8(5C), 1342-1349.
[55] Sikri, A., Dalal, S., Singh, N. P., & Le, D. N. (2019). Mapping of e-Wallets With Features. Cyber Security in Parallel and Distributed Computing: Concepts, Techniques, Applications and Case Studies, 245-261.
[56] Seth, B., Dalal, S., & Kumar, R. (2019). Hybrid homomorphic encryption scheme for secure cloud data storage. In Recent Advances in Computational Intelligence (pp. 71-92). Springer, Cham.
[57] Seth, B., Dalal, S., & Kumar, R. (2019). Securing bioinformatics cloud for big data: Budding buzzword or a glance of the future. In Recent advances in computational intelligence (pp. 121-147). Springer, Cham.
[58] Jindal, U., & Dalal, S. (2019). A hybrid approach to authentication of signature using DTSVM. In Emerging Trends in Expert Applications and Security (pp. 327-335). Springer, Singapore.
[59] Le, D. N., Seth, B., & Dalal, S. (2018). A hybrid approach of secret sharing with fragmentation and encryption in cloud environment for securing outsourced medical database: a revolutionary approach. Journal of Cyber Security and Mobility, 7(4), 379-408.
[60] Sikri, A., Dalal, S., Singh, N. P., & Dahiya, N. (2018). Data Mining and its Various Concepts. Kalpa Publications in Engineering, 2, 95-102.
[61] Sameer Nagpal, S. (2018). Analysis of LrMu Power Algorithm in the Cloud Computing Environment using CloudSim Toolkit. International Journal of Research in Electronics and Computer Engineering (IJRECE), 6(3), 1175-1177.
[62] Nagpal, S., Dahiya, N., & Dalal, S. (2018). Comparative Analysis of the Power Consumption Techniques in the Cloud Computing Environment. Journal Homepage: http://www. ijmra.us, 8(8), 1.
[63] Kumar, N., Dalal, S., & Dahiya, N. (2018). Approach of Lion Optimization Algorithm for Efficient Load Balancing in Cloud Computing. Journal Homepage: http://www. ijmra.us, 8(8), 1.
[64] Sameer Nagpal, S. (2018). Comparison of Task Scheduling in Cloud Computing Using various Optimization Algorithms. Journal of Computational Information Systems, 14(4), 43-57.
[65] Arora, S., & Dalal, S. (2018). Hybrid algorithm designed for handling remote integrity check mechanism over dynamic cloud environment. International Journal of Engineering & Technology, 7(2.4), 161-164.
[66] Kukreja, S., & Dalal, S. (2018). Modified drosophila optimization algorithm for managing re-sources in cloud environment. International Journal of Engineering & Technology, 7(2.4), 165-169.
[67] Jindal, U., Dalal, S., & Dahiya, N. (2018). A combine approach of preprocessing in integrated signature verification (ISV). International Journal of Engineering & Technology, 7(1.2), 155-159.
[68] Nagpal, S., Dahiya, N., & Dalal, S. (2018). Comparison of Task Scheduling in Cloud Computing Using various Optimization Algorithms. Journal of Computational Information Systems ISSN, 1553-9105.
[69] Jindal, U., Dalal, S., & Dahiya, N. (2018). A combine approach of preprocessing in integrated signature verification (ISV). International Journal of Engineering & Technology, 7(1.2), 155-159
[70] Shakti Arora, S. (2018). Resolving problem of Trust context in Cloud Computing. International Journal of Engineering Research in Computer Science and Engineering (IJERCSE), 5(1), 138-142.
[71] Dalal, S., Dahiya, N., & Jaglan, V. (2018). Efficient tuning of COCOMO model cost drivers through generalized reduced gradient (GRG) nonlinear optimization with best-fit analysis. In Progress in Advanced Computing and Intelligent Engineering (pp. 347-354). Springer, Singapore
[72] Seth, B., & Dalal, S. (2018). Analytical assessment of security mechanisms of cloud environment. In Progress in Advanced Computing and Intelligent Engineering (pp. 211-220). Springer, Singapore.
[73] Kukreja, S., & Dalal, S. (2018). Performance analysis of cloud resource provisioning algorithms. In Progress in Advanced Computing and Intelligent Engineering (pp. 593-602). Springer, Singapore.
[74] Rani, U., Dalal, S., & Kumar, J. (2018). Optimizing performance of fuzzy decision support system with multiple parameter dependency for cloud provider evaluation. Int. J. Eng. Technol, 7(1.2), 61-65.
[75] Dahiya, N., Dalal, S., & Khatri, S. (2017). An Enhanced Bat Algorithm for Data Clustering Problems. International Journal of Advanced Research in Computer Science, 8(3).
[76] Dahiya, N., Dalal, S., & Khatri, S. (2017). Data clustering and its Application to numerical function optimization algorithm. International Journal of Advanced Research in Computer Science, 8(1).
[77] Arora, S., & Dalal, S. (2017). Adaptive Model For Integrity Verification In Cloud Computing System. International Journal of Advanced Research in Computer Science, 8(1), 233-236.
[78] Neeraj Dahiya, S. (2017). Numerical Function Optimization: Model, Procedure And Uses. International Journal of Engineering Science and Technology (IJEST), 9(4), 266-270.
[79] Dahiya, N., Dalal, S., & Khatri, S. (2016). Refinement with Image clustering using Self-Organizing Map and Numerical Function Optimization. International Journal of Computer Science and Information Security, 14(11), 909.
[80] Neeraj Dahiya, S. (2016). A Review on Numerical function optimization Algorithm and its Applications to Data Clustering & Classification. International Journal of Recent Research Aspects, 3(3), 115-121.
[81] Arora, S., & Dalal, S. (2016). Novel Approach of Integrity Verification in Dynamic Cloud Environment. International Journal of Computer Science and Information Security, 14(8), 207.
[82] Dalal, S., & Kukreja, S. (2016). Genetic Algorithm based Novel approach for Load Balancing problem in Cloud environment. International Journal of computer science and information security, 14(7), 88.
[83] Arora, S., & Dalal, S. (2016). Study of Integrity Based

Algorithm in Decentralized Cloud Computing Environment. International Journal of Institutional & Industrial Research, 1(1), 15-17.
[84] Vishakha, S. D. (2016). Performance Analysis of Cloud Load Balancing Algorithms. International Journal of Institutional and Industrial Research, 1(01), 1-5.
[85] Dalal, S., & Jindal, U. (2016, March). Performance of integrated signature verification approach. In 2016 3rd International Conference on Computing for Sustainable Global Development (INDIACom) (pp. 3369-3373). IEEE.
[86] Dahiya, N., Dalal, S., & Tanwar, G. (2016, March). Refining of image using self-organizing map with clustering. In AIP Conference Proceedings (Vol. 1715, No. 1, p. 020064). AIP Publishing LLC.
[87] Dahiya, N., Dalal, S., & Khatri, S. (2016). A Review on Numerical function optimization Algorithm and its Applications to Data Clustering & Classification. International Journal of Recent Research Aspects, 3(3), 111-115.
[88] Arora, S., & Dalal, S. (2016). Enhanced Privacy Preserving Access Control in the Cloud. International Journal of Recent Research Aspects, 3(4), 66-70.
[89] Dahiya, N., Dalal, S., Khatri, S., & Kumar, Y. (2016). Cat Swarm Optimization: Applications And Experimental Illustrations To Data Clustering. International Journal of Control Theory and Applications, 9(41), 759-765.
[90] Rani, U., & Dalal, S. (2016). Neural Network Applications in Design Process of Decision Support System. International Journal of Recent Research Aspects, 4(2), 40-44.
[91] Seth, B., & Dalal, S. (2016). Designing Hybrid Security Architecture in Multi Cloud System. International Journal of Control Theory and Applications, 9(41), 767-776.
[92] Seth, B., & Dalal, S. (2016). Analysis of cryptographic approaches. International Journal of Recent Research Aspect, 3(1), 21-24.
[93] Jindal, U., & Dalal, S. (2016). Survey on Signature verification and recognition using SIFT and its variant. International Journal of Recent Research Aspects, 3(3), 26-29.
[94] Sharma, P., & Dalal, S. (2014). Reviewing MANET Network Security Threats. identity, 25-30.
[95] Sharma, D., Dalal, S., & Sharma, K. K. (2014). Evaluating Heuristic based Load Balancing Algorithm through Ant Colony Optimization. environment, 5-9.
[96] Sharma, D., Sharma, K., & Dalal, S. (2014). Optimized load balancing in grid computing using tentative ant colony algorithm. International Journal of Recent Research Aspects, 1(1), 35-39.
[97] Jindal, K., Dalal, S., & Sharma, K. K. (2014, February). Analyzing spoofing attacks in wireless networks. In 2014 Fourth International Conference on Advanced Computing & Communication Technologies (pp. 398-402). IEEE.
[98] Dalal, Surjeet & Srinivasan, S, Approach of multi agent system in controlling bullwhip effect of supply chain management system using case based reasoning, Department of Computer Science, Suresh Gyan Vihar University, 20/01/2014, http://hdl.handle.net/10603/36464
[99] Sharma, S., & Dalal, S. (2014). Recognition and identification schemes for the development of Eigen feature extraction based iris recognition system. International Journal of Recent Research Aspects ISSN, 2349-7688.
[100] Sharma, P., Sharma, K., & Dalal, S. (2014). Preventing Sybil Attack in MANET using Super nodes approach. International Journal of Recent Research Aspects, 1(1), 30-34.
[101] Simi Gupta, D., & Dalal, S. (2014). Efficient broker scheduling in Cloud Computing. International Journal of Recent Research Aspects, 1(2), 74-77.
[102] Sharma, S., & Dalal, S. (2014). Feature Recognition from Histogram and Eigen Algorithm in Digital Image Processing.
[103] Gupta, S., Sharma, K. K., & Dalal, S. (2014). Multi objective parameters for real time scheduling in cloud computing.
[104] Mittal, A., & Dalal, S. (2014). Implying p-Cure algorithm in case retrieval stage of the case-based reasoning. International Journal of Recent Research Aspects, 3(3), 91-98.
[105] Mittal, A., Sharma, K. K., & Dalal, S. (2014). Approach of BPEL in supply chain activities for managing bullwhip effect of SCM system. Int. J. Res. Asp. Eng. Manag, 1(2), 26-30.
[106] Sharma, P., & Dalal, S. (2014). Shortest Path Algorithms Technique for Nearly Acyclic Graphs. International Journal of Recent Research Aspects, 3(3), 36-39.
[107] Dalal, S., Jaglan, V., & Sharma, K. K. (2014). Designing architecture of demand forecasting tool using multi-agent system. International Journal of Advanced Research in Engineering and Applied Sciences, 3(1), 11-20.
[108] Sheikh, M., Sharma, K., & Dalal, S. (2014). Efficient method for WiMAX soft handover in VOIP and IPTV. International Journal of Research Aspects of Engineering & Management, 1(2), 5-48.
[109] Kumar, S., & Dalal, S. (2014). Optimizing Intrusion Detection System using Genetic Algorithm. International Journal of Research Aspects of Engineering and Management ISSN, 2348-6627.
[110] Mittal, A., Sharma, K. K., & Dalal, S. (2014). Applying clustering algorithm in case retrieval phase of the case-based reasoning. International Journal of Research Aspects of Engineering and Management, 1(2), 14-16.
[111] Dalal, S., Jaglan, V., & Sharma, K. K. (2014). Integrating Multi-case-base-reasoning with Distributed case-based reasoning. International Journal of Advanced Research in IT and Engineering ISSN, 2278-6244.
[112] Saini, A., Sharma, K. K., & Dalal, S. (2014). A survey on outlier detection in WSN. International Journal of Research Aspects of Engineering and Management ISSN, 2348-6627.
[113] Sharma, P., Sharma, D. K., & Dalal, S. (2014). Preventing Sybil Attack In MANET Using Super Node Using Approach. International Journal of Recent Research Aspects, ISSN, 2349-7688.
[114] Chahar, P., & Dalal, S. (2013). Deadlock resolution techniques: an overview. International Journal of Scientific and Research Publications, 3(7), 1-5.
[115] Dalal, Surjeet, Keshav Jindal, and Monika Nirwal.

"Developing Flexible Decision Support Systems Using Case-Base Reasoning System." International Journal of Engineering and Management Research (IJEMR) 3.4 (2013): 13-17.

[116] Dalal, S., & Sharma, K. K. (2013). Simulating supply chain activities in multi-agent based supply chain management system with plasma simulator. International journal of Computer Science & Communication, 4(1), 80-85.

[117] Dalal, S., Tanwar, G., & Alhawat, N. (2013). Designing CBRBDI agent for implementing supply chain system. system, 3(1), 1288-1292.

[118] Dalal, S., & Athavale, V. (2012). Challenging Bullwhip Effect of Supply Chain Through Case Based Multi Agent System: A Review. International Journal of Advanced Research in Computer Science and Software Engineering, 2(12), 267-272.

[119] Dalal, S., Tanwar, G., & Jindal, K. (2012). Agent Oriented Programming In Trading System Automation. International Journal of Research in IT, Management and Engineering, 2(8), 51-59.

[120] Dalal, Surjeet, and Vijay Athavale. "Analysing Supply Chain Strategy Using Case-Based Reasoning." Journal of Supply Chain Management Systems 1.3 (2012).

[121] Jindal, K., Dalal, S., & Jaglan, V. (2012). Comparative Study On IEEE 802.11 Wireless Local Area Network Securities. International Journal of Advanced Research in Computer Science, 3(1).

[122] Jindal, K., Dalal, S., & Tanwar, G. (2012). Congestion Control Framework in Ad-Hoc Wireless using Neural Networks in QoS. International Journal of Research in Computer Engineering and Electronics, ISSN, 15-18.

[123] Dalal, S., Athavale, V., & Jindal, K. (2012). Designing Case-based reasoning applications with Colibri Studio. International Journal of Research in Computer Engineering and Electronics, 1(1), 15-18.

[124] Jaglan, V., Dalal, S., & Srinivasan, S. (2011). Improving performance of business intelligence through case based reasoning. International Journal of Engineering Science and Technology, 3(4), 2880-2886.

[125] Jaglan, V., Dalai, S., & Srinivasan, S. (2011). Enhancing security of agent-oriented techniques programs code using jar files. International Journal on Computer Science and Engineering, 3(4), 1627-1632.

[126] Dalal, S., Athavale, V., & Jindal, K. (2011). Case retrieval optimization of Case-based reasoning through Knowledge-intensive Similarity measures. Int. J. Comput. Appl, 34(3), 12-18.

[127] Surjeet Dalal, V., & Kumar, S. (2010). Designing of business tool using intelligent agent. In National Conference Advanced Computing & Communication tech ACCT (pp. 751-754).

