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Internet of Things(IOT):Research Challenges and Upcoming Applications

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Abstract— *We're entering a new era of computing technology that many are calling the Internet of Things (IoT). Machine to machine, machine to infrastructure, machine to environment, the Internet of Everything, the Internet of Intelligent Things, intelligent systems—we can call it whateverwe want, but it's happening, and its potential is huge. We see the IoT as billions of smart, connected "things" or a sort of ("universal global neural network" in the cloud) that will encompass every aspect of our lives, and its foundation is the intelligence that embedded processing provides. The IoT is comprised of smart machines interacting and communicating with other machines, objects, environments and infrastructures. As a result, huge volumes of data are being generated, and that data is being processed into useful actions that can "command and control" things to make our lives much easier and safer—and to reduce our impact on the environment. The creativity of this new era is boundless, with amazing potential to improve our lives. This paper presents the recent development of IoT technologiesanddiscusses future applicationsandresearchchallenges.*

Keywords—*InternetofThings;IoTapplications;IoTchallenges; future technologies; smart cities; smart environment;smartagriculture; smartliving*

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I. INTRODUCTION

The Internet can be explained as the communicationnetworkwhich connects individuals to information while The Internet of Things (IoT) is an interconnected system of distinctively addressable physical items with various degrees of processing, sensing, and actuation capabilities that share the capability to interoperate and communicate through the Internet as their joint platform. Thus, the main objective of the Internet of Things is to make it possible for objects to be connected with other objects or individuals, at any time or anywhere using any network, path or service. The Internet of Things (IoT) is gradually being regarded as the subsequent phase in the Internet evolution. IoT will make it possible for ordinary devices to be linked to the internet in order to achieve countless disparate goals. Currently, an estimated number of only 0.6% of devices that can be part of IoT has been connected so far. However, by the year 2025, it is likely that over 75 billion devices will have an internet connection.

As the internet continues to upgrade, it has become more than a simple network of computers, but rather a network of various devices, while IoT serves as a network of various "connected"devices or network of networks, as shown in Fig. 1. Nowadays, devices like smartphones, vehicles, industrial systems, cameras, toys, buildings, home appliances, industrial systems and countless others can all share information over the Internet. Regardless of their sizes andfunctions, these devices can accomplish smart reorganizations, tracing, positioning, control, real-time monitoring and process control. In the past years, there has been an important propagation of Internet capable devices. Even though its most significant commercial effect has been observed in the consumer electronics field; like particularly the revolution of smartphones and the interest in wearable devices (watches, headsets, etc.), connecting people has become merely a fragment of a bigger movement towards the association of the digital and physical worlds.

With all this in mind, the Internet of Things (IoT) is expected to continue expanding its reach as pertains the number of devices and functions, which it can run. This is evident from the ambiguity in the expression of "Things" which makes it difficult to outline the ever-growing limits of the IoT. While commercial success continues to materialize, the IoT constantly offers a virtually limitless supply of opportunities, not just in businesses but also in research. Accordingly, the understudy addresses the various potential areas for application of IoT domains and the research challenges that are associated with these applications.

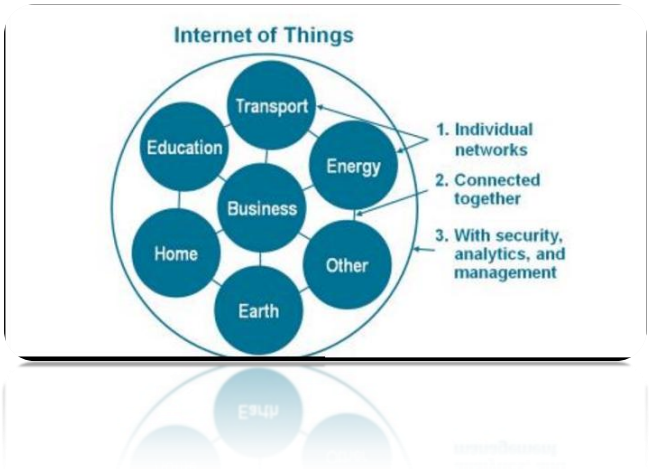


Fig. 1. IoT can be viewed as a Network of Networks [3].

II. POTENTIAL APPLICATION DOMAINS OFIOT

A.*SmartCities*

The IoT plays a crucial role in improvingthe smartness of cities and improving the general infrastructure.Some of IoT application areas in developing smart cities include;intelligent transportation systems, smart building, trafficcongestion, waste management, smart lighting, smartparking,andurbanmaps.Thismayincludedifferentfunctionalities such as; monitoring available parking spaceswithinthecity,monitoringvibrationsaswellasmaterialconditions of bridges and buildings, putting in place soundmonitoringdevicesinsensitivepartsofcities,aswellasmonitoring the levels of pedestrians and vehicles. ArtificialIntelligence(AI)enabledIoTcanbeeffectivetomonitor,controlandreducetrafficcongestionsinSmartCities, Moreover IoT allows installation of intelligent and weatheradaptivestreetlighting,detectionwasteandwastecontainersbykeepingtabsoftrashcollectionschedules.Intelligenthighwayscanprovidewarningmessagesandimportant information, such as access to diversions dependingontheclimaticconditionsorunexpectedoccurrencesinvolvingtrafficjamsandaccidents.

Application of IoT to achieve smart cities would requireusing radio frequency identification and sensors. Some of thealreadydevelopedapplicationsinthisareaaretheAwarehomeand the Smart Santander functionalities. In the United States,some major cities like Boston have plans on how to implementthe Internet of Things in most of their systems ranging fromtheirparkingmeters,streetlights,sprinklersystems,andsewagegratesareallscheduledtobeinterlinkedandconnectedto the internet. Such applications will offer significant breakthroughsintermsofsavingmoneyandenergy.

A. Healthcare

Most healthcare systems in many countries are inefficient,slow and inevitably prone to many types of errors and problems .This can easily be changedsince the healthcare sector relies on numerous activities anddevicesthatcanbeautomatedandupgradedthroughtechnology. Additional technology that can facilitate variousoperationslikereportsharingtomultipleindividualsandlocations,recordkeepinganddispensingmedicationswouldgoallongwayinupgradingthehealthcaresector.

A lot of benefits that IoT application offers in the health-care sector is most categorized into tracking of patients, staff,and objects, identifying, as well as authenticating, individuals,andtheautomaticgatheringofdataandsensing.Hospitalworkflow can be significantly update once patients flow istracked. Additionally, authentication and identification reduceincidents that may be dangerous to patients, record maintenanceand fewer cases of mismatching infants. In addition, automaticdata collection and transmission is vital in process automation,reduction of form processing timelines, automated procedureauditing as well as medical inventory management. Sensordevices allow functions centered on patients, particularly, indiagnosingconditionsandavailingreal-timeinformationaboutpatientshealthindicators.

Application domains in this sector include; being able tomonitorapatient'scompliancewithprescriptions,telemedicinesolutions,andalertsforpatients'well-being.Thereby,sensorscan be applied to outpatient and inpatient patients, dental Bluetooth devices and toothbrushes that can give information after they have being used and patient's surveillance.

OtherelementsofIoTinthiscapacityinclude;RFID,Bluetooth,andWi-Fiamong others. These will greatly enhance measurement andmonitoring techniques of critical functions like blood pressure,temperature, heart rate, blood glucose, cholesterol levels, andmanyothers

The applications of Internet of Things (IoT) and Internet ofEverything(IoE)arefurtherbeingextendedthroughthematerialization of the Internet of Nano-things (IoNT). Thenotion of IoNT, as the name implies, is being engineered byintegratingNano-sensorsindiverseobjects(things)usingNanonetworks.Medicalapplication,asshowninFig.2,isoneofthemajor focuses of IoNT implementations. Application of IoNTin human body, for treatment purposes,etc.. Thus, IoNT will enablenew medical data to be collected, leading to new discoveriesandbetterdiagnostics.

C. Smart Agricultureand WaterManagement

The IoT has the ability to strengthenandenhancetheagriculturesectorthroughexaminingsoilmoisture and in the case of vineyards, monitoring the trunkdiameter. IoT would allow to control and preserve the quantityofvitaminsfoundinagriculturalproducts,andregulatemicroclimateconditionsinordertomakethemostofthepr oductionofvegetablesandfruitsandtheirquality.Furthermore,studyingweatherconditionsallowsforecastingofice information, drought, wind changes, rain or snow, thuscontrolling temperature and humidity levels to prevent fungusaswellasothermicrobialcontaminants.

Whenitcomestocattle,IoTcanassistinidentifyinganimalsthatgrazeinopenlocations,detectingdetrimentalgases from animal excrements in farms, as well as controllinggrowth conditions in offspring to enhance chances of healthand survival and so on. Moreover, through IoT application inagriculture,wastageandspoilagecanbeavoidedthrough proper monitoring techniques and management of theentire agriculture field. It also leads to better electricity andwatercontrol.

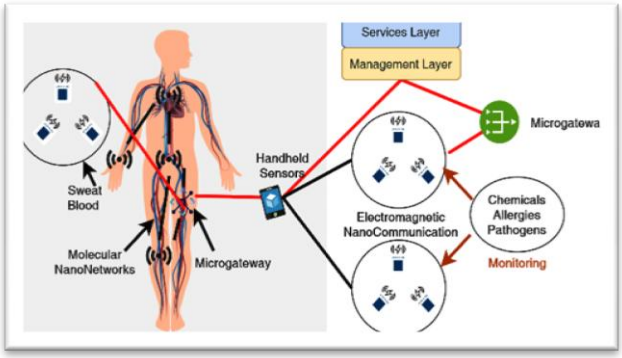


Fig. 2. The Internet of Nano-Things

In water management, the role of IoTincludes studying water suitability in seas and rivers for bothdrinking and agriculture use, detecting pressure variations inpipes, and liquid presence outside tanks as well as monitoringlevels of water variation in dams, rivers and reservoirs. TheseIoTapplicationsutilizeWirelesssensornetworks.ExamplesofexistingIoTapplicationsinthisdomaininclude;SI SVIA,GBROOS,andSEMAT.

D. RetailandLogistics

Executing the IoT in Supply Chain or retail ManagementhasmanyAdvantages.Someinclude;observingstorageconditionsthroughout the supply chain, product tracking to enable traceabilitypurposes,paymentprocessingdependingonthelocationor activity period in public transport, theme parks, gyms, andothers. Inside the retail premises, IoT can be applied to variousapplicationssuchasdirectionintheshopbasedonapreselectedlist,fastpaymentprocesseslikeautomaticallyche cking out with the aid of biometrics etc..

TheIoTelementsmostlyusedinthissettinginclude;wireless sensor networks and radio frequency identification. Inretail, there is a current use of SAP (Systems Applications andProducts),whileinlogisticsnumerousexamplesincludequalityconsignmentconditions,itemlocation,detectingsto rage incompatibility issues, fleet tracking among others. Inthe industry domain, IoT helps in detecting levels of gas andleakages within the industry and its environs, keeping track oftoxic gases as well as the oxygen levels within the confines ofchemical plants to ensure the safety of goods and workers andobserving levels of oil, gases and water in cisterns and storagetanks.ApplicationofIoTalsoassistsinmaintenanceandrepairbecausesystemscanbeputinplacetopredictequip mentmalfunctions and at the same automatically schedule periodicmaintenanceservicesbeforethereisafailureintheequipment.This can be achieved through the installation of sensors insideequipmentormachinerytomonitortheirfunctionalityandoccasionallysendreports.

E. SmartLiving

Inthisdomain,IoTcanbeappliedinremotecontroldevices whereby one can remotely switch appliances on andoff hence preventing accidents as well as saving energy.Other smart home appliances include refrigerators fitted withLCD (Liquid Crystal Display) screens, enabling one to knowwhat is available inside, what has over stayed and is almostexpiringaswellaswhatneedstoberestocked.Thisinformation can also be linked to a smartphone applicationenabling one to access it when outside the house and thereforebuy what is needed. Likely, washing machines can allowone to remotely monitor laundry. In addition, a wide range ofkitchen devices can be interfaced through a smartphone, hencemaking it possible to adjust temperature, like in the case of anoven. Some ovens which have a self-cleaning feature can beeasily monitored as well. In terms of safety, IoTcan be applied through alarm systems and cameras can beinstalledtomonitoranddetectwindowordooropeningshencepreventingintruders.The paper entitled, "Using IoT and Smart Monitoring Devices to Optimize the Efficiency of Large-Scale Distributed Solar Farms," by Shapsough et al. presents a novel architecture that utilizes Internet of Things (IoT) technologies for real-time monitoring of large-scale distributed solar farms.

F. *SmartEnvironment*

The environment has a vital role within all aspects of life,from people to animals, birds and also plants,while are all affectedby an unhealthy environment in one way or another. Therehave been numerous efforts to create a healthy environment intermsofeliminatingpollutionandreducingwastageofresources,buttheexistenceofindustries,aswellastransportationswastescoupledwithrecklessandharmfulhuman actions are common elements which consistentlydamagetheenvironment.Consequently,theenvironmentrequires smart and innovative ways to help in monitoring andmanaging wastes, which provide a significant amount of datathatforcesgovernmentstoputinplacesystemsthatwillprotecttheenvironment.

SmartenvironmentstrategiesintegrationwithIoTtechnologyshouldbecreatedforsensing,trackingandassessment of objects on the environment that offer potentialbenefits in achieving a sustainable life and a green world. TheIoT technology allows observing and managing of air qualitythrough data collection from remote sensors across cities andproviding round the clock geographic coverage to accomplishbetterwaysofmanagingtrafficjamsinmajorcities.Also,IoTtechnologycanbeappliedinmeasuringpollution levels in water and consequently enlighten decisionsonwaterusage.Inwastemanagement,whichconsistsofvarious types of waste, like chemicals and pollutants beingdetrimental to the environment and to people, animals, andplantsaswell,IoTcanalsobeapplied.Thiscanbeachievedbyenvironmental protection in means of controlling industrialpollution through instantaneous monitoring and managementsystemscombinedwithsupervisioninadditiontodecisionmakingnetworks.Thisservestolessenwaste.

Inweatherforecasting,IoTcanbeusedtodeliverasignificant accuracy and high resolution for monitoring theweather by information sharing and data exchange. ThroughIoT technology, weather systems can collect information suchas barometric pressure, humidity, temperature, light, motionand other information, from vehicles in motion and transmittheinformationwirelesslytoweatherstations.Theinformationis attained by installing sensors on the vehicles and even onbuildings after which it is stored and analyzed to assist inweatherforecasting.Radiationisalsoathreattotheenvironment, humans and animal health as well as agriculturalproductivity.IoTsensornetworkscancontrolradiationthroughconstant monitoring of its levels.

III. RESEARCHCHALLENGES

For all the above potential applications of IoT, there has tobe proper feasibility into the different domains to ascertain thesuccess of some applications and their functionality. As withanyotherformoftechnologyorinnovation,IoThasitschallenges and implications that must be sorted out to enablemassadoption.EventhoughthecurrentIoTenablingtechnologies have greatly improved in the recent years, therearestillnumerousproblemsthatrequireattention,hencepaving the way for new dimensions of research to be carriedout.SincetheIoTconceptensuesfromheterogeneoustechnologiesthatareusedinsensing,collecting,action,processing, inferring, transmitting, notifying, managing, andstoring of data, a lot of research challenges are bound to arise.Theseresearchchallengesthatrequireattentionhaveconsequentlyspanneddifferentresearchareas.

A. PrivacyandSecurity

It is a fact that IoT has become a vital element asregards the future of the internet with its increased usage, itnecessitates a need to adequately address security and trustfunctions.ResearchersareawareoftheweaknesseswhichpresentlyexistinmanyIoTdevices.Furthermore,thefoun

dationofIoTislaidontheexistingwirelesssensornetworks (WSN), IoT thus architecturally inherits the sameprivacy and security issues via WSN possesses. Variousattacks and weaknesses on IoT systems prove that there isindeed a need for wide ranging security updates which willprotectdataandsystemsfromendtoend.Manyattacksgenerallyexploitweaknessesinspecificdevicestherebygaining access into their systems and consequently makingsecure devices weak. This security gap furthermotivatescomprehensivesecuritysolutionsthatconsistofresearch that is efficient in applied cryptography for data andsystem security, non-cryptographic security techniques as wellas frameworks that assist developers to come up with safesystemsondevicesthatareheterogeneous.
ThereisaneedformoreresearchtobeconductedoncryptographicsecurityservicesthathavethecapabilitytooperateonresourceconstrainedIoTdevices.Thiswouldenable different skilled users to securely use and deploy IoTsystems regardless of the inadequate user interfaces that areavailablewithalmostallIoTdevices.Inadditiontotheprotection and security aspects of the IoT, additional areas likeconfidentialityincommunication,trustworthiness,andauthenticity of communication parties, and message integrity,andsupplementarysafety,requirementsshouldalsobeincorporated. These may include features like being able toprevent communication of various parties. As an example, inbusiness transactions, smart objects must be prevented fromfacilitating competitors' access to confidential information inthedevicesandthususingthisinformationmaliciously.

B.Processing, AnalysisandManagementofData
Theprocedureforprocessing,analysisanddatamanagementistremendouslychallengingbecauseoftheheterogeneousnatureofIoT,andthelargescaleofdatacollected, particularly in this era of Big Data. Currently, most systems utilize centralized systems in offloading data and carrying out computationally intensive tasks on an international cloud platform..

Nevertheless, there is a constant concern aboutconventionalcloudarchitecturesnotbeingeffectiveintermsoftransferring the massive volumes of data that are produced and consumedbyIoTenableddevicesandbeablefurthersupporttheaccompanyingcomputationalloadandsimultaneously meet timing constraints. Most systems are therefore relying on current solutions such as mobile cloudcomputing and fog computing which are both based on edgeprocessing,tomitigatethischallenge.

Data analysis and its context not only plays a crucial role in the success of IoT, it also poses major challenges. Once data has been collected it has to be used intelligently in order to achieve smart IoT functions. Accordingly, the development of machine learning methods and artificial intelligence algorithms, resultant from neural works, genetic algorithms, evolutionary algorithms, and many other artificial intelligence systems are essential in achieving automated decision making.

C. *Monitoring and Sensing*
Even if technologies concerned with monitoring and sensing have made tremendous progress, they are constantly evolving particularly focusing on the energy efficiency and form aspect. Sensors and tags are normally expected to be active constantly in order to obtain instantaneous data, this aspect makes it essential for energy efficiency especially in lifetime extension. Simultaneously, new advances in nanotechnology or biotechnology and miniaturization have allowed the development of actuators and sensors at the Nano- scale.

Fig. 3. Top Sensors in IoT

D. Blockchain of Things: Fusion of Blockchainand Internet of Things

Similar to IoT, blockchain technologies have also gained tremendous popularity since its introduction in 2018. Even though blockchain was first implemented as an underlying technology of Bitcoin cryptocurrency, it is now being used in multifaceted nonmonetary applications. Miraz argues that both IoT and Blockchain can strengthen each other, in a reciprocal manner, by eliminating their respective inherent architectural limitations. The underlying technology of IoT is WSN. Therefore, analogous to WSN, IoT also suffers from security and privacy issues. On the contrary, the main reasons for blockchain's implementation trend in non- monetary applications is due to its inbuilt security, immutability, trust and transparency. These attributes are powered by blockchain's consensus approach and utilization of Distributed Ledger Technologies (DLTs) which require extensive dependency on participating nodes. Therefore, the fusion of these two technologies Blockchain and Internet of Things (IoT) conceives a new notion i.e. the Blockchain of Things (BCoT) where blockchain strengthens IoT by providing extra layer of security while the "things" of IoT can serve as participating nodes for blockchain ecosystems. Thus, blockchain enabled IoT ecosystems will provide enhanced or improved overall security as well as benefits from each other.

E. Interoperability

Traditionally as regards the internet, interoperability has always been and continues to be a basic fundamental value because the initial prerequisite in Internet connectivity necessitates that "connected" systems have the ability to "speak a similar language" in terms of encodings and protocols. Currently, various industries use a variety of standards in supporting their applications. Due to the large quantities and types of data, as well as heterogeneous devices, using standard interfaces in such diverse entities is very important and even more significant for applications which support cross organizational, in addition to a wide range of system limitations. Therefore, the IoT systems are meant towards being designed to handle even higher degrees of interoperability.

IV. CONCLUSION

The IoT can best be described as a CAS (Complex Adaptive System) that will continue to evolve hence requiring new and innovative forms of software engineering, systems engineering, project management, as well as numerous other disciplines to develop it further and manage it the coming years. The application areas of IoT are quite diverse to enable it to serve different users, who in turn have different needs. The technology serves three categories of users, individuals, the society or communities and institutions. As discussed in the application section of this paper, the IoT has without a doubt a massive capability to be a tremendously transformative force, which will, and to some extent does already, positively impact millions of lives worldwide.

Different governments around the world have shown an interest in the IoT concept by providing more funding in the field that is meant to facilitate further research.

The number of different technologies required to supportthe deployment and further growth of the IoT places a premium on interoperability, and has resulted in widespread efforts to develop standards and technical specifications that support seamless communication between IoT devices and components..

UL is committed to the continued development and widedeployment of technologies in support of theIoTecosystem. UL senior technical experts serve in key leadershippositions in many of the current standards developmentefforts,including the OIC, the Thread Group, theNFCForum,andtheAirFuelAlliance. UL is also just oneof the twoNFCForum-authorizedtestinglaboratories in North America, and is an exclusive testing partner for one of the Thread Group's announced certification program.

Ulhasextensive or advanced experience in IoT technologies, and canconducttestingatlocations throughout North America, the European Union and Asia.

REFERENCES

[1]. M. H. Miraz, M. Ali, P. S. Excell, and R. Picking, "A Review on Internet of Things (IoT), Internet of Everything (IoE) and Internet of Nano Things (IoNT)", in 2015 Internet Technologies and Applications (ITA), pp. 219– 224, Sep. 2015, DOI: 10.1109/ITechA.2015.7317398.

[2]. P. J. Ryan and R. B. Watson, "Research Challenges for the Internet of Things: What Role Can OR Play?," Systems, vol. 5, no. 1, pp. 1–34, 2017.

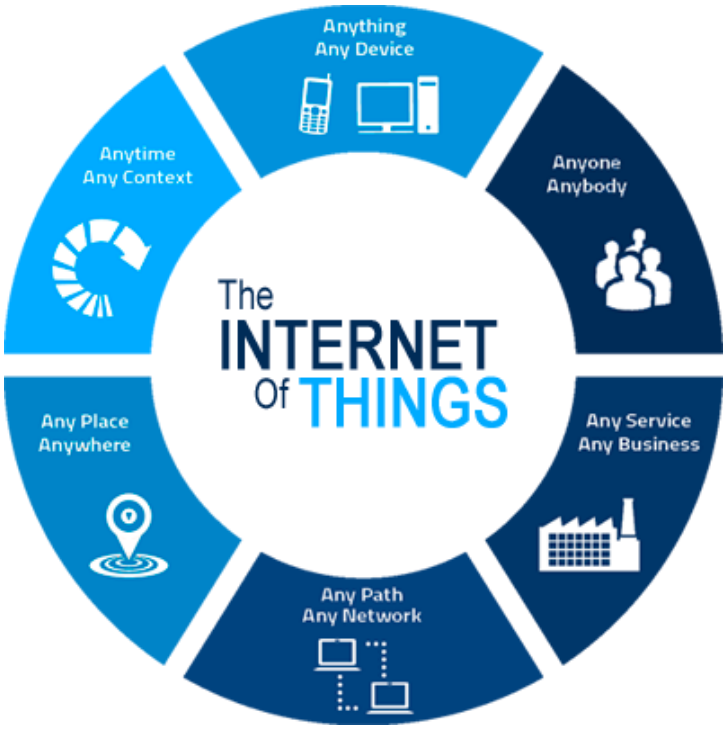
[3]. M. Miraz, M. Ali, P. Excell, and R. Picking, "Internet of Nano-Things, Things and Everything: Future Growth Trends", Future Internet, vol. 10, no. 8, p. 68, 2018, DOI: 10.3390/fi10080068.

[4]. E. Borgia, D. G. Gomes, B. Lagesse, R. Lea, and D. Puccinelli, "Special issue on" Internet of Things: Research challenges and Solutions".," Computer Communications, vol. 89, no. 90, pp. 1–4, 2016.

[5]. K. K. Patel, S. M. Patel, et al., "Internet of things IOT: definition, characteristics, architecture, enabling technologies, application future challenges," International journal of engineering science and computing, vol. 6, no. 5, pp. 6122–6131, 2016.

[6]. S. V. Zanjal and G. R. Talmale, "Medicine reminder and monitoring system for secure health using IOT," Procedia Computer Sci-

ence, vol. 78, pp. 471–476, 2016.
[7]. R. Jain, "A Congestion Control System Based on VANET for Small Length Roads", Annals of Emerging Technologies in Computing (AETiC), vol. 2, no. 1, pp. 17–21, 2018, DOI: 10.33166/AETiC.2018.01.003.
[8]. S. Soomro, M. H. Miraz, A. Prasanth, M. Abdullah, "Artificial Intelligence Enabled IoT: Traffic Congestion Reduction in Smart Cities," IET 2018 Smart Cities Symposium, pp. 81–86, 2018, DOI: 10.1049/cp.2018.1381.
[9]. Mahmud, S. H., Assan, L. and Islam, R. 2018. "Potentials of Internet of Things (IoT) in Malaysian Construction Industry", Annals of Emerging Technologies in Computing (AETiC), Print ISSN: 2516-0281, Online ISSN: 2516-029X, pp. 44-52, Vol. 2, No. 1, International Association of Educatorsand Researchers (IAER), DOI: 10.33166/AETiC.2018.04.004.
[10]. Mano, Y., Faical B. S., Nakamura L., Gomes, P. G. Libralon, R. Meneguete, G. Filho, G. Giancristofaro, G. Pessin, B. Krishnamachari, and Jo Ueyama. 2015. Exploiting IoT technologies for enhancing Health Smart Homes through patient identification and emotion recognition. Computer Communications, 89.90, (178-190). DOI: 10.1016/j.comcom.2016.03.010.



[11]. V. Sundareswaran and M. S. null, "Survey on Smart Agriculture Using IoT," International Journal of Innovative Research in Engineering & Management (IJIREM), vol. 5, no. 2, pp. 62–66, 2018.
[12]. P. Tadejko, "Application of Internet of Things in logistics-current chal- lenges," Ekonomia i Zarz{a˛}dzanie, vol. 7, no. 4, pp. 54–64, 2015.
[13]. S. Rajguru, S. Kinhekar, and S. Pati, "Analysis of internet of things in a smart environment," International Journal of Enhanced Research in Man-agement and Computer Applications,vol. 4, no. 4, pp. 40–43, 2015.
[14]. H. U. Rehman, M. Asif, and M. Ahmad, "Future applications and research challenges of IOT," in 2017 International Conference on Informa-tion and Communication Technologies (ICICT), pp. 68–74, Dec 2017.
[15]. Z. Alansari, N. B. Anuar, A. Kamsin, M. R. Belgaum, J. Alshaer, S. Soomro, and M. H. Miraz, "Internet of Things: Infrastructure, Architecture, Security and Privacy", in 2018 International Conference on Com- puting, Electronics Communications Engineering (iCCECE), pp. 150– 155, Aug 2018, DOI: 10.1109/iCCECOME.2018.8658516.
[16]. J. A. Chaudhry, K. Saleem, P. S. Haskell-Dowland, and M. H. Miraz, "A Survey of Distributed Certificate Authorities in MANETs," Annals of Emerging Technologies in Computing (AETiC), vol. 2, no. 3, pp. 11– 18, 2018, DOI: 10.33166/AETiC.2018.03.002.
[17]. A. S. A. Daia, R. A. Ramadan, and M. B. Fayek, "Sensor Networks Attacks Classifications and Mitigation", Annals of Emerging Technologies in Computing (AETiC), vol. 2, no. 4, pp. 28–43, 2018, DOI: 10.33166/AETiC.2018.04.003.
[18]. Z. Alansari, N. B. Anuar, A. Kamsin, S. Soomro, M. R. Belgaum, M. H. Miraz, and J. Alshaer, "Challenges of Internet of Things and Big Data Integration", in Emerging Technologies in Computing (M. H. Miraz, P. Ex- cell, A. Ware, S. Soomro, and M. Ali, eds.), (Cham), pp. 47–55, Springer International Publishing, 2018, DOI: 10.1007/978-3-319- 95450-9_4.
[19]. J. Cooper and A. James, "Challenges for database management in the internet of things"IETE Technical Review,vol.26,no.5,pp.320–329,2009.
[20]. D. B. Ansari, A.-U. Rehman, and R. Ali, "Internet of Things (IoT) Proto- cols: A Brief Exploration of MQTT and CoAP," International Journal of Computer Applications, vol. 179, pp. 9–14, 03 2018.
[21]. M. H. Miraz and M. Ali, "Applications of Blockchain Technology beyond Cryptocurrency", Annals of Emerging Technologies in Computing (AETiC), vol. 2, no. 1, pp. 1–6, 2018, DOI: 10.33166/AETiC.2018.01.001.
[22]. Miraz, M.H., "Blockchain of Things (BCoT): The Fusion of Blockchain and IoT Technologies", Advanced Applications of Blockchain Technology, Studies in Big Data 60, 2019, DOI: 10.1007/978-981-13- 8775-3_7, https://doi.org/10.1007/978-981-13-8775-3_7.
[23]. Miraz, M. H. and Ali, M., 2018. Blockchain Enabled Enhanced IoT Ecosystem Security, Proceedings of the International Conference on Emerging Technologies in Computing 2018, London Metropolitan University, UK, Part of the Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering (LNICST), vol. 200, pp. 38-46, Online ISBN: 978-3-319-95450-9, Print ISBN: 978-3-319-95449-3, Series Print ISSN: 1867-8211, Series Online ISSN: 1867-822X, DOI:

10.1007/978-3-319-95450-9_3, Springer- Verlag, https://link.springer.com/chapter/10.1007/978-3-319-95450-9_3.
[24]. A. Mazayev, J. A. Martins, and N. Correia, "Interoperability in IoT Through the Semantic Profiling of Objects," IEEE Access, vol. 6, pp. 19379–19385, 2018.
[25]. R. Porkodi and V. Bhuvaneswari, "The Internet of Things (IoT) Applications and Communication Enabling Technology Standards: An Overview," in 2014 International Conference on Intelligent Computing Applications, pp. 324–329, March 2014.