Internet of (Moving) Things: Paradigms and Opportunities

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Abstract

The Internet of Things (IoT) is an emerging connectivity paradigm that impacts every imaginable industry. Since the IoT is applied in numerous sectors, for instance, e-health, e-learning, smart cities, virtual conferences, industrial field, the technology aims at influencing our ways of communication and how we operate in each sector. IoT is one of the innovations of significant interest in the world especially during crucial cases such as coronavirus outbreak (COVID-19). It is said that the technology will profoundly affect the behaviours of potential users and numerous aspects of daily activities. This paper aims at evaluating the IoT, and at developing a broad comprehension of the technology as well as examine it from a mobility point of view.

Keywords: Internet of Things, Internet of moving things, paradigms, architecture, design, security, applications, opportunities, COVID-19.

1 Introduction

According to Palattella et al. [23], Internet of Things (IoT) aims at revolutionizing the way people live and work through different approaches with new services, involving numerous interactions among several heterogeneous

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devices. On the other hand, the primary purpose of IoT is to offer an information technology infrastructure for enabling the exchange of "things" reliably and securely [10]. Moreover, the internet connection among devices has significantly increased while the cost of internet services access has dropped dramatically. For instance, most devices such as battery-free devices are being built with Wi-Fi connection abilities [7]. However, the definition of IoT is not yet well established as this technology's use spreads in numerous fields and backgrounds.

According to Atzori et al. [1], IoT is defined as "*Novel paradigm that is rapidly gaining the ground of modern wireless telecommunications*". Numerous technologies are existing including sensors, mobile phones, actuators, radio-frequency identification tags which can be utilised and manipulated by unique addressing schemes to make the devices achieve common goals by the interaction and cooperation with each other. Kumar et al. [16], defined IoT as a system which creates associations between different digital machines, computational devices, and mechanical devices that are equipped with unique capabilities of sending and receiving data through interconnected networks without necessarily interacting with humans or machines.

IoT is revolutionising the world and people through the creation of new and intelligent devices which are applied in numerous fields and sectors. However, since the technology is applied in many areas, the exact architecture design or model is not yet well established. The designers and developers need to observe specific considerations such as reliability, interoperability, flexibility, scalability and open layered without the bias of any platform or programming language. Designers should develop the IoT operating systems in compliance with the various standards of internet protocols such as HTTPs, IPSec and others as one of the strategies to IoT implementation. Additionally, the future of IoT is expected to be witnessed through several implementations, and people and things will be connected, and business will be transformed significantly. The conventional ways of handling most activities will change due to automation of devices.

2 IoT Elements

These refer to the components making the Internet of Things to offer ubiquitous computing services. These include the middleware such as the data analytic computing tools and on-demand storage, hardware consisting of embedded communication tools, actuators, and sensors, and presentation which comprise of the interpretation and visualisation tools accessible from specific platforms. Some of the technologies making up these three components are; firstly, RFID (radio frequency identification) which is a critical technology used in designing wireless data communication tools such as microchips [4]. This technology does not use any battery power instead they depend on the reader's interrogation signals for communicating and automatic identification of anything. Thus, it is suitable for use in fields such as access control applications and transportation to replace the traditional registration stickers and tickets. Secondly, the wireless sensor networks (WSN) which are a significant technological advancement that provides low-cost and efficient devices used for empowering remote sense applications. Moreover, WSN helps in gathering, allying, processing and presenting useful information from different sources and it is more powerful than RFID technology. The WSN is made up of the middleware, secure data aggregation, communication stack, and hardware. Thirdly, addressing schemes which enable technical experts to control the devices via the internet remotely. The addressing schemes should be designed to be reliable, persistent, unique and scalable.

3 IoT Architecture Technology

Since IoT enables things and people to connect from anyplace, with anything and anytime, the technology addresses some feature such as content, convergence, connectivity, communication, computing and collections [9]. The design of IoT must consider the following heterogeneous things and critical requirements that is scalability, interoperability, modularity and extensibility. This will provide a wide field for both the developers and providers and user with the advantages of thriving in the competitive market while using the applications. Moreover, while things are interacting with each other and any other objects, they generate events automatically which records why a particular event occurred and the location. This information is critical for IoT designers and developers as they will predict when a specific event will happen and the possible causes thus the develop precautions necessary to counter the future events. Vermesan et al. [28], recommend that IoT standards should be designed to support unambiguous communication of events more semantic information which does not require the deeper prescription of how the events were generated. Moreover, the heterogeneity and decentralisation of things should be open, flexible, layered, event-driven and scalable architectural standard without bias to any specific OS, programming language or information system with effective utilisation of the available network.

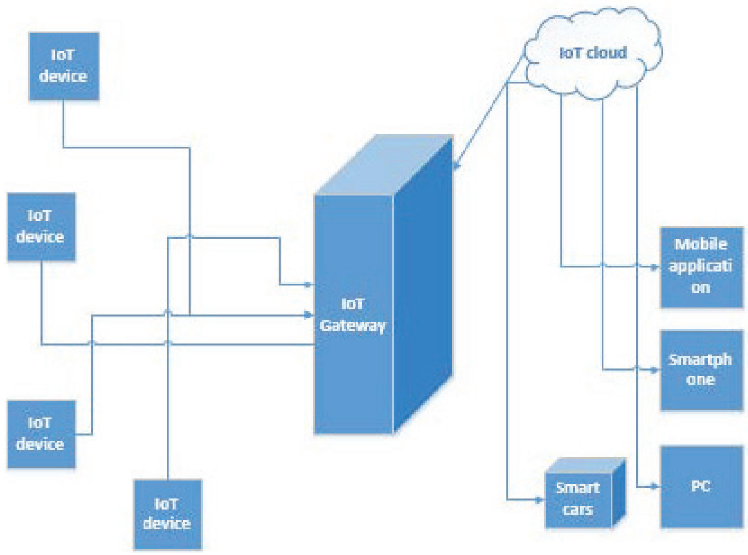

Figure 1 IoT Architecture design.

Some of the precautions taken in the architectural design of IoT is being aware that IoT does not rely on one permanent network connectivity but they primarily rely on the surrounding intelligence thus it is recommended to use a digital counterpart to monitor the status of the things consequently ensuring efficient update of entities and states to serve their major purpose. For example, in cases where things do not have permanent connectivity such as in interior aircraft cabin, the design should consider functionalities of information synchronisation in either, and effective caching is necessary. Additionally, it essential for the model to offer distributed capabilities of the things to manage specific data that they should share with other objects and things, including authorisation techniques. Below is an architectural design of IoT technology (Figure 1).

The IoT architecture comprises four major building blocks which include the sensor devices, the IoT gateway, mobile application and smart software and the cloud server. The IoT devices contain various sensors for collecting information from different sources such as the human body, environment/weather conditions, location, and communication. The gateway is also a framework that devices interact with. The gateway plays a vital role in this infrastructure by acting as a carrier between the World Wide Web (external internet) and the internal network of the nodes of sensors. It also

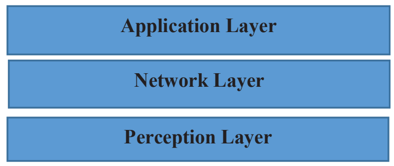

Figure 2 IoT layers.

allows the machine to machine communication since it is within the device domain. The smartphones and smart cars contain smart software applications used in monitoring and controlling end user devices. They are designed with a simple and user-friendly interface where they logically present data information collected from the various interactions in the form of graphs and other representations. Lastly, the cloud server securely stores and process information transmitted from the communication framework. Smart devices then utilize this information that performs intelligent functions.

According to Sethi and Sarangi [26], IoT architecture is comprised of three layers (Figure 2) including the application layer, perception layer and the network layer. The perception layer contains sensing devices to perceive and gather information from the surrounding. The network layer is used to create connection with other smart devices and the application layer is designed to provide users with application specific services.

4 Strategies Towards IoT Implementation

According to Weber [10], four significant concerns need to be addressed, these include; firstly, resilience to attacks which directs that at any instance, the systems must avoid any single point failures and only allow node failures through some adjustments. Secondly, access control where the providers of information should avail ways of data control for every information they provide [3]. Thirdly, data authentication, this is a very crucial and fundamental factor that must be observed at all levels every bit of information retrieved must be authenticated. Beside the successful encryption of data in devices, there still exist chances of the device being hacked such as the temperature sensor of smart homes which even if the information coming to them is encrypted, the ability to authenticate the source of information is not available which renders it risky to transmit fake data which is created by malicious attackers within the network. Lastly, client privacy where the inference of information using the lookup system should be challenging and only the information provided has the capabilities of inferring data associated with specific individuals [10]. IoT hardware must also be well monitored and developed to suit all the security requirements as it serves as the first insight to realising the IoT procedures and protocols since most of the devices require very low energy.

Additionally, since the fulfilment of all the security and privacy requirements is complicated, some privacy and security enhancing technologies are implemented to achieve these crucial goals. For example, the virtual and private networks which improve the integrity and raises the confidence levels for groups closely related and sharing information. The transport latency is another technology designed and dedicated to enhancing integrity and confidentiality in IoT. Other technologies include the private information retrieval systems which conceal information to be only accessible to interested parties. Although this technology is impractical due to global accessibility issues, union routing which operates by mixing internet traffic emerging from various sources and protects the data with union routers public keys while information is being transmitted and lastly the domain name system security extensions (DNSSEC) which promise of data integrity and confidentiality through its public-key cryptography model which confirms origin authenticity which is the right source of information delivered. According to Xu et al. [30], the operating systems of IoT should also consider the standard internet services and protocols including the IPSec (Internet Protocol security), SSH (Secure Shell), SFTP (Secure File Transfer Protocol), HTTPS (Hyper Text Transfer Protocol Secure), TLS (Transport Layer Security) and SNMP (Simple Network Management Protocol). This entails the equipment of the devices with automatic fall back and secure bootloader to detect and report any side-channel or physical attacks.

5 Securing the IoT System

The main aim of IoT is the transformation of the way humans live in the modern world by using intelligence devices that can perform various chores and tasks [33]. The model involves the interconnection of several devices, objects, humans and services that continually communicate. IoT also involves the information sharing exchange process to achieve major objectives that involve economic benefits and unprecedented conveniences [34]. The typical security goals for any system or technology include confidentiality, integrity and availability, which are applicable to the IoT system. However, there are multiple limitations and numerous restrictions for IoT systems, which include its ubiquitous and heterogeneous nature, the resources of power and computing and the components or the devices involved. However, there are specific protocols designed to enhance Internet communication with the IoT devices, such as Institute of Electrical and Electronics Engineers (IEEE) 802.15.4, IPv6 over Low-power Wireless Personal Area Networks (6LoWPAN), Constrained RESTful Environments, IPv6 and Constrained Application Protocol (CoAP), which were designed by various standardisation bodies including IEEE and the Internet Engineering Task Force [32, 34].

Moreover, the current security features suggest two security challenges that include challenges to security and technology. The technology challenges result from the heterogeneous and ubiquitous nature of the IoT devices, whereas the security challenges are associated with specific functional principles that are required to achieve proper security within the network [33]. In addition, the technology challenges are categorised into concerns related to energy, technology, distribution and scalability whereas the matters pertaining to security challenges include end-to-end security, confidentiality, integrity and authentication.

However, the security requirements or the IoT principles are classified into availability, non-repudiation, confidentiality and authentication, which must be assured by the various protocols applied in the different IoT architecture layers. Confidentiality ensures that data is available only to the authorised users such as humans, internal and external objects and machines within and outside the network. It also involves information exchange management and data management between the various nodes [33]. Integrity involves ensuring that data is sent from the right sender, and the data is not compromised by any intentional or unintentional interference during transmission. Availability ensures that all IoT users can access information anytime and from anywhere using all the reachable devices. Authentication involves a clear identification and authorisation of other objects although authentication is restricted by the nature of IoT.

The IoT architecture (Figure 3) contains different layers that are classified according to the functions and the devices in the network. These include the sensing layer (or the perception layer), the network and the application layers [33]. All the layers are vulnerable to attacks and threats. Firstly, the sensing layer encounters three security threats including weaknesses in the efficiency of the wireless technologies that are likely to be compromised by the disturbing waves and the interception of the sensor nodes by either the attackers or the owner; this raises concerns regarding other possible vulnerabilities of the device hardware components being attacked. The network

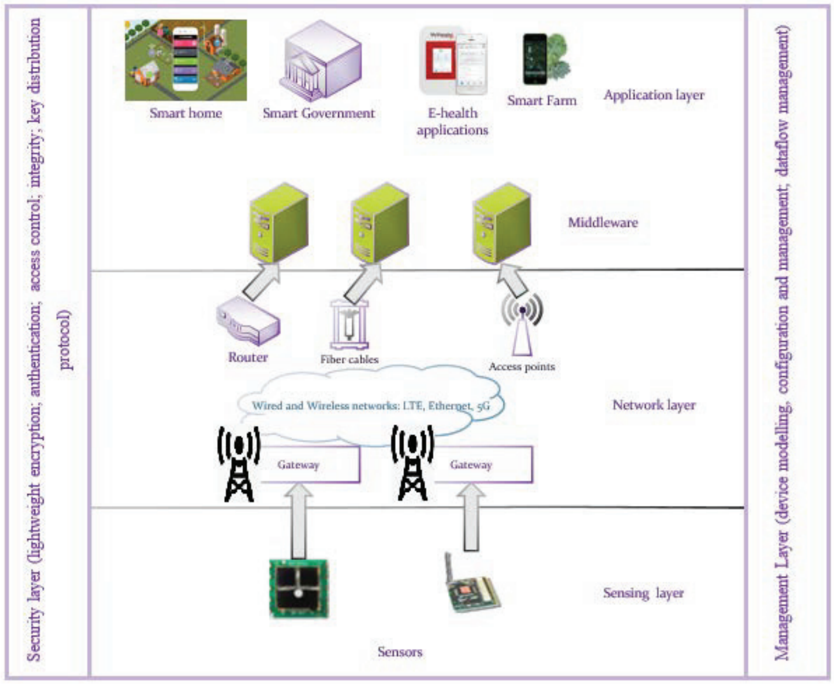

Figure 3 IoT architecture.

topology inference in this layer consists of radio-frequency identification, and the sensors increase the number of possible attacks. Secondly, the network layer is susceptible to attacks such as denial-of-service (DoS), and this layer has compatibility problems in machine-to-machine communication [33]. The architecture of Internet Protocol Security (IPsec) implements the encryption and authentication protocols in this layer [34]. Lastly, the application layer faces the challenges of identity authentication and data privacy because of the indiscriminate development of the IoT applications.

6 The Future of IoT

According to Sheth [27], IoT momentum and market implementations have grown quickly as shown the conference reports of the 2016 consumer electronics show which was covered at the 2016 world economic forum and the numerous materials writers about intelligent systems and applications powered by IoT. The technology has attracted a huge number of vendors including large and start-up companies. The evolution of IoT involves sensing, expansion of control and increased imagination where numerous applications have been developed to solve specific problems and to enhance reliability such as the replacement of power meters with simple solutions that save time while recording the readings. Moreover, more tools are needed to design new IoT architecture and all aspects of this technology need to be updated including security systems, network models and management systems. Some experts make predictions of IoT, including the platform will increase things and connectivity costs to be cheaper, the industry will significantly change with emergence of new business and enterprise models, there will be more about "things" as they will be significant information carriers and if well utilized well and the information transformed as insight, it will positively change most businesses and valuable in cases requiring tracking [8], there will also be the trading of mobile dollars for IoT thus revenue to be generated is expected to rise, most cities will be smart, technology about IoT will result in new conflicts arising from the developers launching new and sophisticated devices.

7 Internet of (Moving) Things

The Internet of things' vision offers several opportunities for companies, industries, and users to exploit its application for their benefit [13]. Some of the most productive sectors have and are adopting this technology as a way of equipping themselves with the latest intelligence techniques to improve performance, productivity and security. The impacts of adopting this technology into the mobility sector are widely felt especially in smart cities and even the upcoming cities. The concept of embedding wireless network connectivity, technology and sensors among the majority of the traditional non-smart objects has made the 'smart city' idea to be achievable. Most devices such as moving vehicles are being turned into mobile hotspots thus people walking, inside the vehicles, are all connected with this new technology. Examples of cities companies and cities currently dedicating their time and investments to make IoT of moving things possible is Veniam which is a Portugal-based start-up company and new organizations in most US cities are taking this approach.

The primary goal of this implementation is to make lowest-cost and most reliable wireless identifiable systems with increased functionalities [14]. Additionally, with this technology in place, people will be connected wherever they are at any place and anywhere since moving objects such as buses

Table 1 Differences between IoT and Big Data

IoT	Big Data
Project time is the most valuable entity in any project.	Data is allowed to rest a bit before being used to perform any kind of analysis.
Information is collected and analysed in real-time and decision making needs to be real-time.	Data collected is in a simple format and raw thus needs to be organized and managed to be usable.
There immense sheer velocity in IoT projects.	Big data projects work at a tolerable velocity.
Handles machine-generated data from numerous sensors for supporting real-time use cases.	Handles human-generated data for supporting long-term duration use cases.
Involves all devices able to connect to internet.	No all devices used in big data can access the internet connection.

and cars are equipped with live networks. However, is in its early stages of development and research as indicated by the scarcity of literature materials documenting and exploring IoT in moving things. The aim of this section is to examine, explore and document internet of things in moving objects with the focus of recommending new models and designs of the technology in the current world and contribute to new literature materials about the topic.

The new technology in moving objects is designed with a platform that collects and gather data which helps in keeping track and effectively managing traffic flow thus it can detect alternate and shortcut routes which saves time and money. Traffic jams are a problem that most cities encounter and having a technology that will detect and determine when a traffic jam might or a specific route that it is has occurred, even the people who wish to traffic at a later time could change their schedule to avoid traffic. Together with the Big Data technology which mines data from numerous sources including the social media, smart cities will be a reality [15]. However, Big Data and IoT differ in some features, and the two technologies' adoption is different as shown in Table 1.

Additionally, sensors can be installed at various checkpoints to measure the speed of traffic by determining accurate data. Also, global positioning system (GPS) technology in buses can help the bus owners locate the specific locations of the bus thus supporting efficient management. Effective and appropriate decision making is what every person, group or organization wants to maintain better performance while improving productivity. Currently, most of the successful businesses are data-driven with the significant target of utilizing the organized filtered data to collect intelligence of future adjustments. Thus, IoT in moving things is a dream achieved through its impact in the most market. For example, the Veniam start-up company which launched wireless technology in its buses and cars reported its Wi-Fi connects to almost 73% of the bus riders in the region which has motivated them into new ventures such as opening a new centre in Singapore. The company has also received great support from other investors such as Orange and Verizon to support the connection of over 260,000 active clients.

Moreover, most this technology's enthusiasts state that the quality of life in smart cities, the economy and the future of mobility relies on the people's capabilities of making the best out of the available infrastructure. Vehicles are the ideal points of mobile sensors and wireless hotspots in any street due to their availability everywhere with strong batteries which are repetitively recharged. Hence, the implementation of wireless architecture systems will not negatively impact the transport sector and wireless infrastructure which requires little power to supply internet connections across a wide area network or transmit data across the wireless medium [16]. The Figure 4 shows a structural model of network connection across the moving objects.

The significant role of transportation in the modern life clearly showed the need for advancements in the transport sector. The technology can be utilized to determine the fuel efficiency, location and the relationship of vehicles and businesses belonging to the same industry or people where

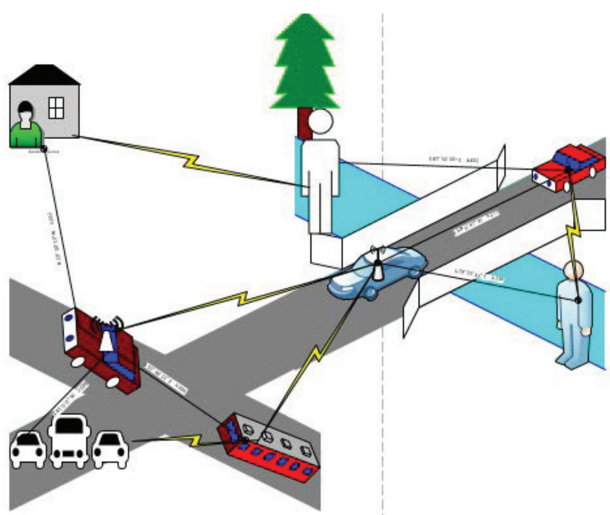

Figure 4 Internet of moving things connections.

the data gathered by using the system can be utilized in tracking various environments to develop and full picture of the client base and needs. The business owners such as manufacturers will then utilize this data to create products making suitable and making sense of human life. On the other hand, intelligence systems such as some traffic light detection systems can help in regulating car speed which in turn coordinates traffic lights to save fuel and time. Some drivers are careless, while some drink and drive which contributes to increased chances of causing accidents and some drivers are careful in driving. If a case of an accident is reported by a certain vehicle, the insurance companies can determine the careless and careful driver through real-time monitoring systems thus they should offer insurance discounts [17] according to information collected.

IoT in moving things has led to increased trends of autonomous vehicles which have transformed design and marketing of cars followed with the change from the exterior to interior emphasis to offer opportunities for consumers and passengers to co-construct individual experiences by personalised interaction features [18]. Various researchers and experts suggest that in the next two to five years, most self-driving cars will reach level five which promises of full autonomy. Autonomous, in this case, means that the vehicles have designed with all the necessary functionality and monitoring the roadway conditions as well as safety-critical features for an entire road trip. Moreover, level five is the most perfect while level four is limited to specific functions such as covering all driving scenarios due to the operational design domain feature limitations. Additionally, level five's autonomy is expected to perform at the same levels as a human driver expert. Thus, people can sit in their cars, relax while they enjoy a cool driving experience. It is also expected that autonomous vehicles will change the relationship between vehicles and people, passenger culture and ownership models where domestic flights and rail transport will experience challenges due to the new technology in than road transport. The building of autonomous cars also must consider sensitive features which enables them to safely sense everything while driving.

Internet of moving things (IoMT) technology has the capabilities of visualizing, mapping, monitoring, analysing and gaining historical and real-time insights from the data collected by the objects connected to the network. This critical information requires specialized IoMT software systems and the DB4IoT database engine to be controlled and managed according to specific requirements of the technology. The DB4IoT provides the IoMT analytical tools which save money and time for traffic planners, public transit and government agencies and other interested parties through its continuous transformation from the interactive maps, charts to graphs, and dashboards of the web [19].

The establishment of the internet of moving by Veniam Company, it is seen to be a significant contribution to smart city technology well as a roadmap to the smart city future. According to Collier [6], the ways to establishing this technology involve the following simple steps. Firstly, 'create connectivity, collect data'. With the availability of Wi-Fi network, it satisfies the needs of the people by connecting them to the internet. The demands for a reliable internet connectivity and access to digital information is increasing due to the rise of various demands across each sector. Wi-Fi technology brings an added capacity to the growing 4G (fourth generation) wireless networks into the 5G (fifth generation). Moreover, 5G cellular systems with reliable, cost-efficient, ubiquitous and scalable connection technology is also considered as revolutionary to the global IoT emergence [28]. While people are connected in the smart cities, the technology can be used for collecting data from the devices which can be shared to optimization of city operations. Government agencies and companies gather valuable information which is presented to city leaders and managers to help them in making critical and informed decisions for city planning and operation services. Later, some objects will be transformed into communication hubs by providing Wi-Fi in the city such as introducing 'smart communications infrastructure and applications'. Example of other companies offering similar services is the Sync.City and Totem. The next step is 'get moving'. According to Collier [6], the Veniam promises that the traditional challenges of people moving around for finding strong internet connections to satisfy their needs will be solved through proving new network which will follow the users anywhere. Vehicle-to-Vehicle (V2V) technology will address this problem effectively where moving objects will be equipped with network infrastructure with simple transition features which enables a user to stay connected even if they change from one connection to another. Also, the V2V technology is beneficial for road transport by being able to transmit base safety information about issues such as possible crashes among different vehicles [19]. Lastly, 'order the hardware, software and cloud combo'. Data is a valuable element in realizing the main objectives of IoMT, thus transformation of this technology into a "vehicle-to-cloud" platform must be equipped with sophisticated tools for effective functionality. Security systems, monitoring and analytical systems should be well configured for easy integration with these systems which maintains and reliable and efficient communication. Additionally, the technology is efficient, safe and secure to transport products without human intervention if the levels of autonomy are reached. Currently, cars are equipped with all the necessary luxuries such as connectivity, communication and any comfort one may need.

Self-driving vehicles such as the Google cars are a proved implementation of the technology where the cars are designed with critical features considerations. They cause accidents rarely since they can collect information from the surrounding to determine when to stop and when to move after it was tested and succeeded in a road test travel measured in miles [4]. Moreover, Bonnefon et al. [4] reported that the benefits of autonomous vehicles are increasing through the changes in traffic efficiency, mitigation of road and traffic accidents by almost 90% and reduction of pollution. This is beneficial in various perspectives of older people regaining access the world although previously they have been limitations chances of travelling long distances, they were confined to senior care centres and homes only which increases stress. This technology has also helped some people to gain freedom such as the handicapped people who were restricted to traveling with the caregivers. The existence of systems able to track records of driving has reduced people's worries as they can monitor where their loved ones have been dropped such as children to and from school by these autonomous vehicles. However, self-driven cars are not 100% effective in carping all road accidents thus it calls for new approaches to regulating the cars, particularly where the harm is inevitable. Although user acceptance and user experience continues to vary due to varied reasons, the technology is believed to advance further with new features and models.

The continuously changing landscape of technology requires dynamic systems which are cost-effective, environmentally friendly and making urban life more effective. The IoMT is one of the sectors which requires close and careful monitoring or the infrastructure to accommodate necessary features as recommended by the various sectors involving the national environment management authority. If in the cases where these systems will accelerate the rates of environmental pollution which affects critical sectors such as agriculture and people with diseases, there is no value of adopting the technology.

8 Application and Examples of IoT

The Internet of Things technology applications has significantly increased with the current implementations covering critical sections in organizations and the public sector such as research, medical practices, transport and simulation of crucial experiments. Due to its advantages of involving simple

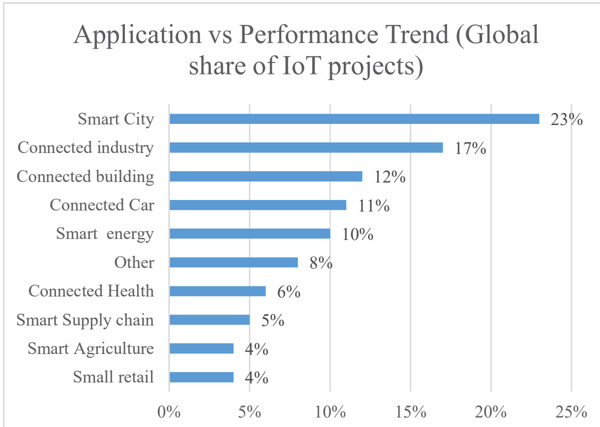

Figure 5 Global share of IoT projects application vs performance trend [31].

hardware devices such as smartphones, wearable devices, and home machine, and other devices, researchers and technology enthusiasts believe that its application will spread in usage like the internet. IoT in the application is aimed at improving scalability, interoperability, improving customer value, providing strategies to new market entry and competitive analysis. The application examples of IoT operates differently including the real-time operations and those applications requiring reliability and high availability where the technology is playing a vital role in functions such as for cause isolation, anomaly and fault detection, automated corrective action and monitoring and control functions. This section aims at identifying and discussing IoT examples and applications and the utilization of this technology in the various fields.

There are various IoT applications. Furthermore, the trend to create these applications is expected to increase more rapidly due to the wide fields of applications, the technology's great impact and recent recorded projects underway focusing on IoT implementations. Figure 5 shows a global share of IoT projects for 2018 [31].

The following are some of the paradigms that are widely using the technology:

8.1 Unmanned Aerial Vehicles (drones)

The adoption of these important devices (unmanned aerial vehicles (UAVs)) is one of the areas which has received significant concern in the recent past, where they are being used as flying wireless communication platform. Also, the devices are capable of improving the coverage of devices on the ground and can be used for enhancing connectivity as wireless relays. Additionally, this technology is also used as a mobile area base station for providing enhanced reliability by boosting the wireless networks capacity and for providing reliable download and upload communications supporting ground users. This is because the UAVs can be adjusted in terms of the mobility and altitude which can help in establishing good connections under low transmission powers and moving near to the potential users on the ground. The technology also improves shadowing and blockage of signals through making them work on high altitudes which establish LOS (line-of-sight) links of communication effectively. Thus, they can provide solutions which are efficient to energy challenges and cost-effective solutions for data collection from the ground mobile users using simple and limited terrestrial infrastructure across broad geographical areas [22].

The drones comprise of small batteries which are limited thus they cover only short distances as the energy constraints could not allow them moving in long distances. However, the devices are used within their scope as they collect crucial information from other IoT devices and send it to the transmitter which is out of range thus playing the role of base stations or aggregators for major networks of IoT [24]. Users, developers, and researchers must address the critical issues of this essential devices to enable them to work more effectively for the intended purposes. According to Kirichek [15], drones can be used in the delivery of real-time data to remote servers. This application is a solution for the challenges facing the wireless body area networks which are used in the assessment of the human body and reducing the chances of more critical conditions arising and saving a life. Further analysis of the field data collected is necessary for the experts to establish ways of mitigating the continuous spread of the certain medical condition. The available technologies such as 3G technology and Wi-Fi requires large power consumption to perform the same purpose. The current applications of drones are expected to increase with high market potential in various fields such as pollution control, framing, rescue and predictable operations, and collisions avoidance because of their high mobility. According to Motlagh et al. [21], drones might be the key enablers of the IoT vision with their ubiquitous usability.

8.2 Connected Vehicles

IoT technology application in this area using connected wireless networks for communications is used in the maintenance of vehicles, enhancing safety and monitoring. On the other hand, some systems are implemented as travel and traffic information systems which helps in the control and road travel management. With close strong sensor networks, accidents are minimized since even the self-driving cars have the capabilities of detecting the environment surrounding and able to estimate the distance between the front and behind cars which directs them in decisions of when to move. Additionally, they are used in entertainment. Having connected vehicles helps the people in the buses enjoy various entertainment in their comfort zones since they can access the internet and other resources while traveling. Users can browse the internet using their own devices equipped with wireless network features.

8.3 Smart Grid

This application may not be deeply explored although the IoT technology is a crucial improvement in the sector for a between delivery of such as power control and delivery among electrical utilities. Some functionalities can be implemented using the technology to help in fault and incident recovery, and it is also applied in automated load shedding. This makes work easier for the electrical engineers and technicians in troubleshooting major electricity problems through informed decisions. It is difficult to find a solution over a vast electricity infrastructure, but with this improvement put into place, the sector will advance and by effectively addressing challenges such as delays and critical faults. It also improves the security of the power grids which are major targets for some hackers. The smart grids are equipped with critical infrastructure including the smart appliances, smart meters, actuator-cars, sensors and private/public infrastructure of communication which must be protected to ensure the main vision of IoT in this application is realized [3].

8.4 Healthcare

The healthcare sector is one of the key areas that have experienced the positive impact of IoT. This is evident particularly in the presence of the worldwide pandemic coronavirus disease of 2019 (COVID-19) [36]. The technology helps in the management of chronic disease conditions, telemedicine, and emergency medicine. Several wearables developed by companies such as Samsung, Apple, Misfit, and Jawbone can now be classified as fitness and health devices. The devices can monitor the sleep, temperature, blood pressure, heart rate and other metrics of health to enable us to stay healthy every day. Healthcare providers having specific devices can be easily notified of their patient's chronic condition by the communication and information sharing between the wearables and third-party apps (owned by physician). Additionally, applications such as HERO smart medication dispenser enables home treatment to be easier which helps in drug prescription even to the older adults. This application is paired with other devices to offer timely alerts to caregivers and family members about the drugs that have been skipped or to be taken and the quantity remaining in store to help in determining when to purchase more medicine and which ones. Doctors can process measurements required in monitoring some health conditions such as the ovulation state in women.

8.5 Emergency Response and Law Enforcement

IoT is applied in the coordination and organization of response plans, damage assessment performance, and helping in the achievement of situational awareness. These are critical areas where the technology is applied in real-time operations to improve accuracy and increase the efficiency of controlling the main areas of application. For example, response plans involve faster, accurate and reliable decision making to provide the right response to an emergency. The ability to gather information through communication of different devices, the systems used in the response plans are effective since they are data driven such as the cases of road traffic incidences where the associated agencies and people get information in real-time, and the system suggests some appropriate reactions that should be done to address issues at the incidences. Defining and monitoring for the adherence to the respective laws governing different activities is essential to ensure operations requiring immediate actions are well handled.

8.6 Logistics

Internet of Things technology is applied in the logistics sector to monitor goods in transit, tracking of information and offering automated services such as the distribution and stocking of goods. For example, the global supply chain marketing is gradually changing due to the technology implementation using deep learning algorithms, computer vision, ‘just walk out technologies’ and sensor fusion in companies such as Amazon which has significantly changed the models of marketing. Moreover, it is also used in managing the maintenance regimes for multi-modal transportation.

8.7 Construction

The construction projects and project management entail several aspects involving different people in the project development levels. The application of IoT Technology can be applied in tracking the project milestones and overall progress, capturing the various aspects as built at the site of construction. Also, this technology can be used in the coordination, tracking, and scheduling of material delivery. This is a simplification of the challenges facing construction project managers who might not consider all elements are contributing to the success of the project. Some stakeholders such as the main implementers (workers) may fail to deliver the anticipated deliverable within a specific period but having a device that is designed with automatic features can notify the stakeholder especially the top management about the progress according to the schedule. Additionally, some construction projects such as complex buildings may be located in places with limited space hence the delivery of materials by the suppliers at any given time might be inconvenient as the construction team might lack space for material storage. This calls for sophisticated and intelligent technology working with the just in time systems (JIT) to ensure convenient and continuous project implementations. On the other hand, the monitoring and maintaining of site experience can be possible with the technology.

8.8 Infrastructure Operation and Maintenance in Smart Cities

A smart city is a new focus in most developed and developing countries aimed at automating service delivery and improving the lifestyle in most sectors in the urban areas. According to Cocchia [5], various researchers define the smart city in different ways according to the understanding of the word "smart," including, ubiquitous city, intelligent city, knowledge city, digital city, sustainable city and others. Moreover, IoT together with other technologies such as cloud computing and Web 2.0 play a significant function in smart cities by helping the city to implement digital policies aimed at supporting e-service delivery to all citizens.

Additionally, the operation and maintenance of crucial entities in the smart cities. These include services and utilities. The services include street repair, waste management, parking systems, lighting, bridges and tunnels maintenance, civic buildings, recreational facilities and parks operation. The ability to connect varieties of devices and tools across the city and public places, this technology improves the experience of people while in the smart cities while using different services. Utilities controlled by this technology include gas, water, communications, and power. Any smart city must efficiently manage these utilities to achieve the principal objectives behind the emergence of the intelligent city ideology.

The other category of example applications which deliver significant value to a large population fraction and their requirements are much less stringent include: firstly, smart home where the IoT is applied in the management of everything including house utilities, essential systems within the home with modern residence features such as the security, heating, appliances, cooling, lighting, and environment conditions management systems. Example of applications thriving well in this area is the Singlecue. NEST thermostat that is viewed as an energy an energy server through its efficiency in helping house conditions control. Secondly, personal lifestyle and health where an individual can track the caloric intake, exercise, social interactions, individual habits, activities, notifications, and events. Thirdly, sports where this technology is utilized in training by recording the sequences of motions, performance recording, style and stance, the effectiveness of new skills and techniques and other valuable features to be measured in the sports sector.

8.9 Smart Farming

Agriculture is a critical area with a great significance in most nations. the emergence of IoT applications has a significant impact on determining the right seasons for growing specific crops and the weather conditions appropriate for each plant. IoT in smart farming is a novel approach which is aimed at improving productivity. Various devices such as remote-controlled vehicles operate on either manual or automatic modes to help in multiple agricultural activities such as cutting, spraying, and monitoring humidity, conditions of soil, temperature, and water supply [35]. The adoption of scientific techniques offers great hope for farmers for higher yields, as farming techniques improve in efficiency. The feasibility of smart farming demands for more advanced and reliable tools to effectively provide maximum outputs. Smart applications—accessed through a smartphone or a tablet connected to a wide area network—assess and determine humidity, temperature, and other weather conditions; hence, proper activities are done to improve the soil condition for better yields.

According to the next design of the smart farming scenario, a reliable sensing network is necessary to enable the farmer to smartly plan, control, and monitor the farm. Sensitive farming requirements include sensors measuring humidity, soil productivity, and pH as well as other characteristics. Each node plays a significant role in collecting, storing, and processing data to provide the farmer with effective results for predicting the focus in farming. Usually, all the devices transmit their information to a mobile application in a smartphone where the smart farmer can predict, monitor, and control the critical areas that will ensure high yields are produced. Although smart farming does not require complex computing capabilities and tools, the available computing tools must be equipped with functions of vision or target and the data analytical capabilities to improve results of data analysis in the smartphone application. Efficient communications are vital through a wireless network to enable reliable detection of the changing state of information in the farm.

People can learn about the amount of water usage required in the farms for outdoor agriculture. On the other hand, the IoT is applied in indoor agriculture for management and monitoring of micro-climate conditions such as light, temperature, soil quality and humidity which will help in maximizing productivity. An example of the current application developed for this purpose is blossom which is a smart watering system which utilizes data from real-time weather forecasts collection to help farmers create optimal schedules of watering. The application is mobile based software which is easy to install, set up and manage. Thus, even farmers in the remote areas can enjoy its benefits.

9 Conclusion

IoT is an important technology in the current world has it is aimed at solving major problems facing human file and improving the transport with new experiences. The connection of all the moving devices to share a common network has enhanced the collection of vital information which organizations and agencies utilize to improve their performance to meet customer needs as well as transforming from the traditional transport conventions. For examples of notable cases of IoMT best implementations noted is the Veniam company which introduced the technology and it has obtained numerous benefits as well as support from interested companies.

The applications and examples of IoT are widely spread with numerous implementations in the various domains. This is due to the realization of its benefits in each sector and its vision to automate service delivery using functionalities of collecting data from the environment and interaction with two or more devices for performing critical roles. Some of the major applications identified include the unmanned aerial vehicles used in information delivery and communications, connected vehicles, healthcare to monitor and control chronic conditions, construction, smart electricity grids, smart city infrastructure control and management among others. Undoubtedly, in the post-COVID-19 world, all the above applications would have an increased effect. However, developers need to improve in some few features not well decremented and some issues not yet addressed to make IoT applications a reality and effective in any field.

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