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

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Abstract: ***With the Internet of Things (IoT) gradually evolving as the subsequent phase of the evolution of the Internet, it becomes crucial to recognize the various potential domains for application of IoT, and the research challenges that are associated with these applications. Ranging from smart cities, to health care, smart agriculture, logistics and retail, to even smart living and smart environments IoT is expected to infiltrate into virtually all aspects of daily life. Even though the current IoT enabling technologies have greatly improved in the recent years, there are still numerous problems that require attention. Since the IoT concept ensues from heterogeneous technologies, many research challenges are bound to arise. The fact that IoT is so expansive and affects practically all areas of our lives, makes it a significant research topic for studies in various related fields such as information technology and computer science. Thus, IoT is paving the way for new dimensions of research to be carried out. This paper presents the recent development of IoT technologies and discusses future applications and research challenges.***

I. INTRODUCTION

The Internet can be described as the communication network that connects individuals to information while The Internet of Things (IoT) is an interconnected system of distinctively address able 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, 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 2020, it is likely that over 50 billion devices will have an internet connection.

As the internet continues to evolve, 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 a 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; i.e. 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.

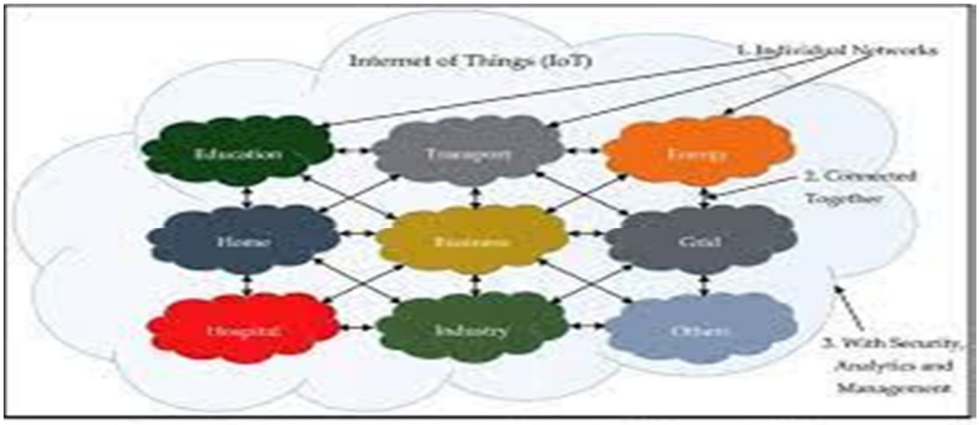

Fig. 1. IoT can be viewed as a Network of Networks [3].

II. POTENTIAL APPLICATION DOMAINS OF IOT

Potential applications of the internet of Things are not only numerous but also quite diverse as they permeate into virtually all aspects of daily life of individuals, institutions, and society. According to , the applications of IoT cover broad areas including manufacturing or the industrial sector, health sector, agriculture, smart cities, security and emergencies among many others.

A. Smart Cities

According to , the IoT plays a crucial role in improving the smartness of cities and enhancing general infrastructure. Some of IoT application areas in creating smart cities include; intelligent transportation systems , smart building, traffic congestion , waste management , smart lighting, smart parking, and urban maps. This may include different functionalities such as; monitoring available parking spaces within the city, monitoring vibrations as well as material conditions of bridges and buildings, putting in place sound monitoring devices in sensitive parts of cities, as well as monitoring the levels of pedestrians and vehicles. Artificial Intelligence (AI) enabled IoT can be utilized to monitor, control and reduce traffic congestions in Smart Cities . Moreover, IoT allows installation of intelligent and weather adaptive street lighting and detection waste and waste containers by keeping tabs of trash collection schedules. Intelligent highways can provide warning messages and important information, such as access to diversions depending on the climatic conditions or unexpected occurrences like traffic jams and accidents.

B. Healthcare

Most healthcare systems in many countries are inefficient, slow and inevitably prone to error. This can easily be changed since the healthcare sector relies on numerous activities and devices that can be automated and enhanced through technology. Additional technology that can facilitate various operations like report sharing to multiple individuals and locations, record keeping and dispensing medications would go a long way in changing the healthcare sector .

A lot of benefits that IoT application offers in the healthcare sector is most categorized into tracking of patients, staff, and objects, identifying, as well as authenticating, individuals, and the automatic gathering of data and sensing. Hospital workflow can be significantly improved once patients flow is tracked. Additionally, authentication and identification reduce incidents that may be harmful to patients, record maintenance and fewer cases of mismatching infants. In addition, automatic data collection and transmission is vital in process automation, reduction of form processing timelines, automated procedure auditing as well as medical inventory management. Sensor devices allow functions centered on patients, particularly, in diagnosing conditions and availing real-time information about patients' health indicators

C. Smart Agriculture and Water Management

According to , the IoT has the capacity to strengthen and enhance the agriculture sector through examining soil moisture and in the case of vineyards, monitoring the trunk diameter. IoT would allow to control and preserve the quantity of vitamins found in agricultural products, and regulate microclimate conditions in order to make the most of the production of vegetables and fruits and their quality. Furthermore, studying weather conditions allows forecasting of ice information, drought, wind changes, rain or snow, thus controlling temperature and humidity levels to prevent fungus as well as other microbial contaminants

When it comes to cattle, IoT can assist in identifying animals that graze in open locations, detecting detrimental gases from animal excrements in farms, as well as controlling growth conditions in offspring to enhance chances of health and survival and so on. Moreover, through IoT application in agriculture, a lot of wastage and spoilage can be avoided through proper monitoring techniques and management of the entire agriculture field. It also leads to better electricity and water control.

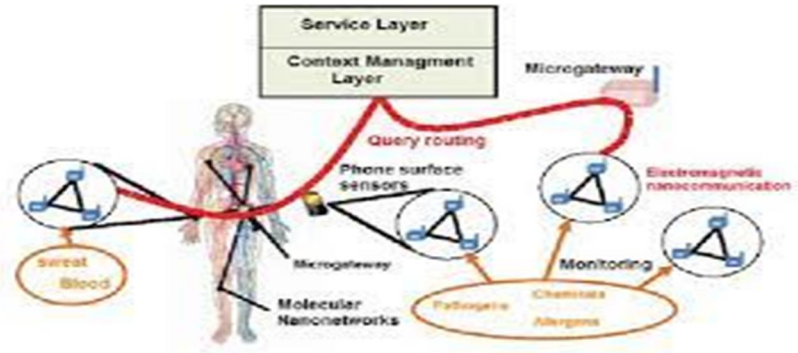

Fig. 2. The Internet of Nano-Things

D. Retail and Logistics

Executing the IoT in Supply Chain or retail Management has many benefits. Some include; observing storage conditions throughout the supply chain, product tracking to enable trace ability purposes, payment processing depending on the location or activity period in public transport, theme parks, gyms, and others. Inside the retail premises, IoT can be applied to various applications such as direction in the shop based on a preselected list, fast payment processes like automatically checking out with the aid of biometrics, detecting potential allergen products and controlling the rotation of products on shelves and warehouses in order to automate restocking procedures

The IoT elements mostly used in this setting include; wireless sensor networks and radio frequency identification. In retail, there is a current use of SAP (Systems Applications and Products), while in logistics numerous examples include quality consignment conditions, item location, detecting storage incompatibility issues, fleet tracking among others. In the industry domain, IoT helps in detecting levels of gas and leakages within the industry and its environs, keeping track of toxic gases as well as the oxygen levels within the confines of chemical plants to ensure the safety of goods and workers and observing levels of oil, gases and water in cisterns and storage tanks. Application of IoT also assists in maintenance and repair because systems can be put in place to predict equipment malfunctions and at the same automatically schedule periodic maintenance services before there is a failure in the equipment. This can be achieved through the installation of sensors inside equipment or machinery to monitor their functionality and occasionally send reports.

E. Smart Living

In this domain, IoT can be applied in remote control devices whereby one can remotely switch appliances on and off hence preventing accidents as well as saving energy . Other smart home appliances include refrigerators fitted with LCD (Liquid Crystal Display) screens, enabling one to know what is available inside, what has over stayed and is almost expiring as well as what needs to be restocked. This information can also be linked to a smartphone application enabling one to access it when outside the house and therefore buy what is needed. Furthermore, washing machines can allow one to remotely monitor laundry. In addition, a wide range of kitchen devices can be interfaced through a smartphone, hence making it possible to adjust temperature, like in the case of an oven. Some ovens which have a self-cleaning feature can be easily monitored as well. In terms of safety in the home, IoT can be applied through alarm systems and cameras can be installed to monitor and detect window or door openings hence preventing intruders .

F. Smart Environment

The environment has a vital role within all aspects of life, from people, to animals, birds and also plants, are all affected by an unhealthy environment in one way or another. There have been numerous efforts to create a healthy environment in terms of eliminating pollution and reducing wastage of resources, but the existence of industries, as well as transportations wastes coupled with reckless and harmful human actions are common place elements which consistently damage the environment. Consequently, the environment requires smart and innovative ways to help in monitoring and managing waste, which provide a significant amount of data that forces governments to put in place systems that will protect the environment.

Smart environment strategies integration with IoT technology should be created for sensing, tracking and assessment of objects of the environment that offer potential benefits in achieving a sustainable life and a green world. The IoT technology allows observing and managing of air quality through data collection from remote sensors across cities and providing round the clock geographic coverage to accomplish better ways of managing traffic jams in major cities . IoT sensor networks can control radiation through constant monitoring of its levels, particularly around nuclear plant premises for detecting leakage and propagating deterrence

III. RESEARCH CHALLENGES

For all the above potential applications of IoT, there has to be proper feasibility into the different domains to ascertain the success of some applications and their functionality. As with any other form of technology or innovation, IoT has its challenges and implications that must be sorted out to enable mass adoption. Even though the current IoT enabling technologies have greatly improved in the recent years, there are still numerous problems that require attention, hence paving the way for new dimensions of research to be carried out. Since the IoT concept ensues from heterogeneous technologies that are used in sensing, collecting, action, processing, inferring, transmitting, notifying, managing, and storing of data, a lot of research challenges are bound to arise. These research challenges that require attention have consequently spanned different research areas

A. *Privacy and Security*

Owing to the fact that IoT has become a vital element as regards the future of the internet with its increased usage, it necessitates a need to adequately address security and trust functions. Researchers are aware of the weaknesses which presently exist in many IoT devices. Furthermore, the foundation of IoT is laid on the existing wireless sensor networks (WSN), IoT thus architecturally inherits the same privacy and security issues WSN possesses . Various attacks and weaknesses on IoT systems prove that there is indeed a need for wide ranging security designs which will protect data and systems from end to end. Many attacks generally exploit weaknesses in specific devices thereby gaining access into their systems and consequently making secure devices vulnerable . This security gap further motivates comprehensive security solutions that consist of research that is efficient in applied cryptography for data and system security, non-cryptographic security techniques as well as frameworks that assist developers to come up with safe systems on devices that are heterogeneous.

B. *Processing, Analysis and Management of Data*

The procedure for processing, analysis and data management is tremendously challenging because of the heterogeneous nature of IoT, and the large scale of data collected, 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 about conventional cloud architectures not being effective in terms of transferring the massive volumes of data that are produced and consumed by IoT enabled devices and to be able further support the accompanying computational load and simultaneously meet timing constraints . Most systems are therefore relying on current solutions such as mobile cloud computing and fog computing which are both based on edge processing, to mitigate this challenge.

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/biotechnology and miniaturization have allowed the development of actuators and sensors at the Nanoscale.

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 research 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. According to , this has become even more evident, as 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. A good example is the Chinese Government

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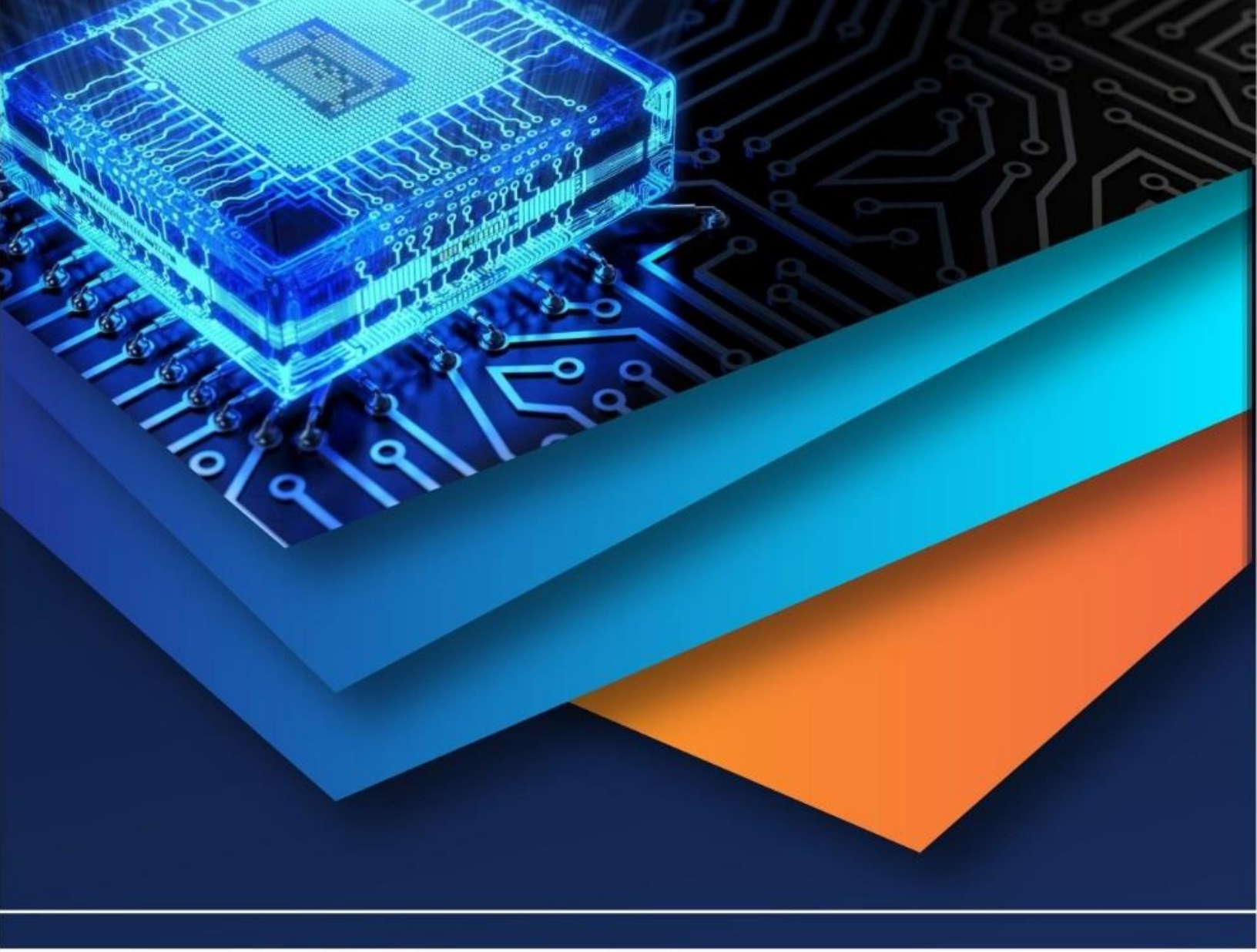

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