

Overcoming the Challenges of IoT Integration: Future Applications in Industrial Automation and Smart Systems

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Abstract -Recognizing the different possible domains for IoT applications and the research problems connected with these applications is essential as the Internet of Things (IoT) gradually develops as the next stage of the Internet's evolution. Almost every element of daily life is anticipated to be impacted by IoT, from smart cities to health care, smart agriculture, logistics, and retail to even smart surroundings and smart living. Although recent years have seen significant advancements in IoT enabling technology, several issues still need to be addressed. Numerous research hurdles are inevitable because the Internet of Things concept is based on diverse technologies. The Internet of Things' vast reach and impact on almost every aspect of our life makes. Because IoT is so widespread and impacts almost every aspect of our life, it is a major research issue for studies in a number of related domains, including computer science and information technology. The Internet of Things is therefore opening up new avenues for research. The latest advancements in IoT technology are presented in this paper along with potential uses and research issues.

Key Words: Internet of Things; IoT applications; IoT difficulties; future technologies; smart cities, smart environment, smart agriculture, and smart lifestyle

1.INTRODUCTION

The Internet is a communication network that connects people to information, whereas the Internet of Things (IoT) is an interconnected system of uniquely addressable physical items with varying degrees of processing, sensing, and actuation capabilities that can interoperate and communicate using the Internet as a common platform [1]. Thus, the major goal of the Internet of Things is to enable items to communicate with other objects and persons at any time and from any location via any network, path, or service. The Internet of Things (IoT) is increasingly being viewed as the next

step in the evolution of the Internet. The Internet of Things will enable everyday objects to be linked to the internet in order to achieve a wide range of goals. Currently, just 0.6% of IoT-capable devices have been connected [2]. However, by 2020, it is expected that over 50 billion devices would have internet access.

The internet has evolved from a simple network of computers to a network of many devices, and as Fig. 1 illustrates, the Internet of Things functions as a network of many "connected" devices, or a network of networks [3]. These days, information can be shared via the Internet by phones, cars, industrial systems, cameras, toys, buildings, home appliances, and a myriad of other gadgets. Notwithstanding their dimensions and These gadgets are capable of intelligent reorganizations, process control, real-time monitoring, tracing, and placement.

The number of gadgets that can connect to the Internet has increased significantly in recent years. Although the consumer electronics industry has seen its most notable commercial impact, notably the rise of smartphones and interest in wearable technology (watches, headsets, etc.), connecting people has become only one aspect of a larger trend towards the merging of the digital and physical worlds.

The Internet of Things (IoT) is anticipated to keep growing in terms of the number of devices and functions it can support in light of all of this. It is challenging to delineate the constantly expanding boundaries of the Internet of Things due of the ambiguity in the term "Things" [4]. Even if commercial success is still being achieved, the Internet of Things is always opening up a seemingly endless number of possibilities for both study and business. Therefore, the course discusses the different possible applications of IoT domains as well as the research issues related to these applications.

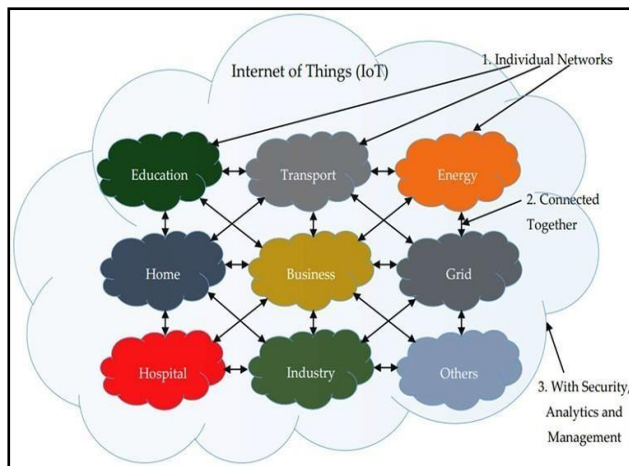


Figure 1: The Internet of Things can be thought of as a network of networks [3].

II. IOT'S POSSIBLE APPLICATION DOMAINS

Because they are present in almost every facet of people's, organizations', and society's everyday lives, the internet of things has a wide range of potential uses. [5] claims that the Internet of Things has applications in a wide range of fields, such as smart cities, manufacturing or the industrial sector, health, agriculture, security, and emergencies, among many others.

1. Smart Cities

According to [6], the Internet of Things is essential for boosting general infrastructure and making cities smarter. Smart buildings, intelligent transportation systems [7], waste management [9], traffic congestion [7, 8], smart parking, smart lighting, and urban maps are a few of the IoT application areas used to create smart cities. This could involve a variety of features, like keeping an eye on the number of parking spots available in the city, keeping an eye on the vibrations and structural integrity of bridges and buildings, installing sound monitoring equipment in sensitive areas of cities, and keeping an eye on the numbers of cars and pedestrians. Smart Cities can use IoT enabled by artificial intelligence (AI) to monitor, manage, and lessen traffic congestion [6]. By monitoring garbage collection schedules, IoT also makes it possible to deploy intelligent and weather-adaptive street lighting and detect waste and waste containers. Warning signs and critical information, such access to detours based on weather patterns or unforeseen events like traffic bottlenecks and accidents, can be sent via intelligent roadways.

Using sensors and radio frequency identification would be necessary for the implementation of IoT to create smart cities. The Aware home and Smart Santander features are a couple of the apps that have previously been created in this field. Major American cities, such as Boston, have plans to integrate the Internet of Things into most of its systems. Sewer grates, sprinkler systems, parking meters, and streetlights are all expected to be connected to the internet and interconnected. Applications like these will provide major breakthroughs in energy and cost savings.

B. Medical Treatment

Many nations have slow, ineffective, and unavoidably error-prone healthcare systems. Given how many processes and tools the healthcare industry uses that may be automated and improved by technology, this is easily changeable. Additional technology that can help with tasks like record keeping, drug distribution, and exchanging reports with numerous people and places would significantly transform the healthcare industry [10].

Tracking patients, employees, and items, identifying and authenticating people, and automatically collecting data and sensing are just a few of the many advantages that IoT applications in the healthcare industry provide. Following patient flow tracking, hospital workflow can be greatly enhanced. Authentication and identification also lower the number of mismatched newborn cases, record maintenance, and occurrences that could endanger patients. Furthermore, automated data collection and transmission is essential for medical inventory management, automated procedure auditing, process automation, and reducing form processing durations. Sensor devices enable patient-centered functions, specifically in the diagnosis of conditions and the provision of real-time data on health indicators for patients [6].

In this field, application fields include telemedicine solutions, alerts for patients' health, and the ability to track a patient's adherence to medications. Consequently, sensors is applicable to both inpatient and outpatient patients, dental Bluetooth devices, toothbrushes that provide information after usage, and patient monitoring. Among other IoT components in this role are RFID, Bluetooth, and Wi-Fi. Measurement and monitoring methods for vital functions such as blood pressure, temperature, heart rate, blood glucose, cholesterol, and many more will be much improved by these.

By creating the Internet of Nano-things (IoNT), the Internet of Things (IoT) and Internet of Everything (IoE) are expanding their applications [3]. As the name suggests, the concept of IoNT is being developed by utilizing nano networks to integrate nano-sensors into various objects (things). One of the primary areas of attention for IoNT implementations is medical applications, as illustrated in Fig. 2. When IoNT is used in the human body for therapeutic purposes, it makes it easier to acquire data from in situ body areas that were

previously inaccessible through the use of medical devices with large sensors. IoNT will thus make it possible to gather new medical data, which will result in improved diagnostics and novel discoveries.

C. Smart Agriculture and Water Management

According to [11], 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.

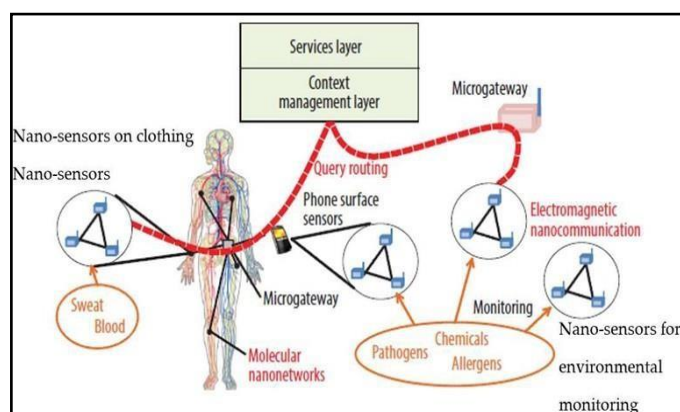


Fig. 2. The Internet of Nano-Things [3].

As [11] explain, in water management, the role of IoT includes studying water suitability in seas and rivers for both drinking and agriculture use, detecting pressure variations in pipes, and liquid presence outside tanks as well as monitoring levels of water variation in dams, rivers and reservoirs. These IoT applications utilize Wireless sensor networks. Examples of existing IoT applications in this domain include; SiSviA, GBROOS, and SEMAT.

A. 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 [12].

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.

B. Smart Living

C. 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 [1, 3]. 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 [3]. **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. Additionally, IoT technology can be applied in measuring pollution levels in water and consequently enlighten decisions on water usage. In waste management, which consists of various types of waste, like chemicals and pollutants being detrimental to the environment and to people, animals, and plants as well, IoT can also be applied. This can be achieved by environmental protection by means of controlling industrial pollution through instantaneous monitoring and management systems

combined with supervision in addition to decision making networks. This serves to lessen waste [13].

In weather forecasting, IoT can be used to deliver a significant accuracy and high resolution for monitoring the weather by information sharing and data exchange. Through IoT technology, weather systems can collect information such as barometric pressure, humidity, temperature, light, motion and other information, from vehicles in motion and transmit the information wirelessly to weather stations. The information is attained by installing sensors on the vehicles and even on buildings after which it is stored and analyzed to assist in weather forecasting. Radiation is also a threat to the environment, human and animal health as well as agricultural productivity. 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 [14].

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 [3, 15]. 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 [16, 17]. 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.

There is a need for more research to be conducted on cryptographic security services that have the capability to operate on resource constrained IoT devices. This would enable different skilled users to securely use and deploy IoT systems regardless of the inadequate user interfaces that are available with almost all IoT devices. In addition to the protection and security aspects of the IoT, additional areas like confidentiality in communication, trustworthiness, and authenticity of communication parties, and message integrity, and supplementary safety requirements should also be incorporated. These may include features like being able to prevent communication of various parties. As an example, in business transactions, smart objects must be prevented from facilitating competitors' access to confidential information in the devices and thus using this information maliciously.

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 [18]. 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 [19]. 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.

Another research direction as regards data management is applying Information Centric Networking (ICN) in the IoT. Since these information centric systems offer

support in the efficient content retrieval and access to services, they appear to be quite valuable not just in accessing but also transferring as well as managing generated content and its transmission. This solution, however, brings about various challenges such as; how to extend the ICN paradigm competently over the fixed network edge, how to take in IoTs static and mobile devices as well as how to apportion the functionality of ICN on resource constrained devices [19].

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 networks, 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/biotechnology and miniaturization have allowed the development of actuators and sensors at the Nano-scale.

D. M2M (Machine to Machine) Communication and Communication Protocols

While there are already existing IoT oriented communication protocols like Constrained Application Protocol (CoAP) and Message Queuing Telemetry Transport (MQTT), there is still no standard for an open IoT. Although all objects require connectivity, it is not necessary for every object to be made internet capable since they only need to have a certain capability to place their data on a particular gateway. Additionally, there are a lot of options in terms of suitable wireless technologies such as LoRa, IEEE 802.15.4, and Bluetooth even though it is not clear whether these available wireless technologies have the needed capacity to continue covering the extensive range of IoT connectivity henceforth.

The communication protocols for devices are the driving force in actualizing IoT applications, and they form the main support of data flow between sensors and the physical objects or outer world. While various MAC protocols have been projected for several domains with Frequency Division Multiple Access, Time Division Multiple Access and Carrier Sense Multiple Access (FDMA, TDMA and CSMA) for low traffic efficiency that is collision free, more circuitry in nodes are required respectively. The main objectives of the transport layer include guaranteeing an end-to-end reliability as well as performing end-to-end control of congestion. In this aspect, most protocols are unable to cooperate appropriate end to end reliability [20].

E. Blockchain of Things (BCoT): Fusion of Blockchain and 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 [21]. Miraz argues that both IoT and Blockchain can strengthen each other, in a reciprocal manner, by eliminating their respective inherent architectural limitations [22]. The underlying technology of IoT is WSN. Therefore, analogous to WSN, IoT also suffers from security and privacy issues. On the contrary, the primary 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 [22]. Thus, blockchain enabled IoT ecosystems will provide enhanced overall security [23] as well as benefit from each other.

F. 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 [24].

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 [25], 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. Countless research groups have been, and continue to be, initiated from different parts of the world, and their main objective is to follow through IoT related researches. As more and more research studies are conducted, new dimensions to the IoT processes, technologies involved and the objects that can be connected, continue to emerge, further paving way for much more application functionalities of IoT. 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. The paper highlights various potential application domains of the internet of things and the related research challenges.

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