

We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

6,300

Open access books available

170,000

International authors and editors

185M

Downloads

Our authors are among the

154

Countries delivered to

TOP 1%

most cited scientists

12.2%

Contributors from top 500 universities



WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com



Critical Review on Internet of Things (IoT): Evolution and Components Perspectives

Benjamin Appiah Osei and Emmanuela Kwao-Boateng

Abstract

Technological advancement in recent years has transformed the internet to a network where everything is linked, and everyday objects can be recognised and controlled. This interconnection is popularly termed as the Internet of Things (IoT). Although, IoT remains popular in academic literature, limited studies have focused on its evolution, components, and implications for industries. Hence, the focus of this book chapter is to explore these dimensions, and their implications for industries. The study adopted the critical review method, to address these gaps in the IoT literature for service and manufacturing industries. Furthermore, the relevance for IoT for service and manufacturing industries were also discussed. While the impact of IoT in the next five years is expected to be high by industry practitioners, experts consider the current degree of its implementation across industry to be on the average. This critical review contributes theoretically to the literature on IoT. In effect, the intense implementation of the IoT, IIoT and IoS will go a long way in ensuring improvements in various industries that would in the long run positively impact the general livelihood of people as well as the way of doing things. Practical implications and suggestions for future studies have been discussed.

Keywords: internet of things, evolution, components, internet of services, industrial internet of things, fourth industrial revolution

1. Introduction

In the words of Schwab [1], “Internet of Things (IoT) is one of the main bridges between the physical and digital applications enabled by the fourth industrial revolution”. The concept of IoT is more focused on enabling and accelerating the adoption of Internet-connected technologies across industries, both manufacturing and non-manufacturing [2]. Also known as the Internet of all things; it is a promising direction in productions systems and expected to bring to bear the full potential of the fourth industrial revolution [3]. Likewise Cyber Physical Systems (CPS), most researchers and scholars have attributed IoT as the key enabler or initiator of the fourth industrial revolution [4–6].

In this sense, Lee et al. [7] opined that, “all the items that can be imagined in terms of the Fourth Industrial Revolution have their basis on all the technologies required

for manufacturing and implementation of the IoT evolution”. The researchers further explained that, unless all the IoT-related technologies are developed and implemented, all the possibilities mentioned and discussed regarding the fourth industrial revolution cannot be realised. IoT enables objects to be sensed and/or controlled remotely across existing network infrastructure, creating opportunities for more direct integration of the physical world into based systems [8].

Sharma, Shamkuwar and Singh [9] elucidated that, the technological advancement in recent years has transformed the internet to the network where everything is linked, and everyday objects can be recognised and controlled via Radio Frequency Identification (RFID) tags, sensors and smart phones. This interconnection is made possible with a combination of software, sensor, processor, and communication technologies. Kamble et al. [10] also explained the role and/or relationship between CPS and IoT in the fourth industrial revolution. They posited that, the IoT is connected alongside Cyber-Physical Systems in such a way that the system develops the potential to generate and feed information, adding value to the manufacturing and service process. This project the relevance of the IoT for manufacturing and service industries.

Nevertheless, limited studies have focused their argument on the evolution and components of this disruptive technology in our industries. Additionally, there exist non-consensual agreement among researchers on the evolution of the IoT scholars [9, 11]. Furthermore, there is non-consensual theorisation on the IoT technological concept among scholars [12–14]. Also, there is differing information on the components of IoT in the literature [2, 10]. Hence, there is the need to understand the etymology, evolution, and the components of this interesting technology. Therefore, the objective of this review is to explore the evolution, components, benefits as well as the implications of the IoT for manufacturing and service industries.

2. Literature review

2.1 Evolution of internet of things (IoT)

The term IoT was first coined by British entrepreneur, Kevin Ashton in 1999, to highlight the power of connecting Radio Frequency Identification tags globally to the internet, in the context or domain of supply chain management [12, 15]. According to Zhong et al. [11], the concept of IoT first came from RFID (Radio Frequency Identification) fields; stating that it is the information network constructed by the radio frequency identification technology and communication technology. **Figure 1** illustrates the chronology of IoT evolution from 1969 till date.

Although the term IoT have been attributed to the works of Ashton in 1999, Sharma et al. [9] also elucidated that that technologies behind IoT had already existed and were under development many years ago. The researchers highlighted the evolution of IoT and its supporting or associated technologies in chronological order from 1969 to the 2000s. In 1969, the Internet, which is the main technology behind IoT emerged as Advanced Research Project Agency Network (ARPANET). It was mainly used by academic and research fraternity to share research work, to develop new interconnection techniques and to link computers to many general-purpose computer centres of the United States Defence Department and in public and private sectors.

In 1973, another essential technology for IoT called Radio-Frequency Identification (RFID) resurfaced, although the roots of RFID can be traced back to the second world war. For instance, the developments associated with RFID continued through 1950s and

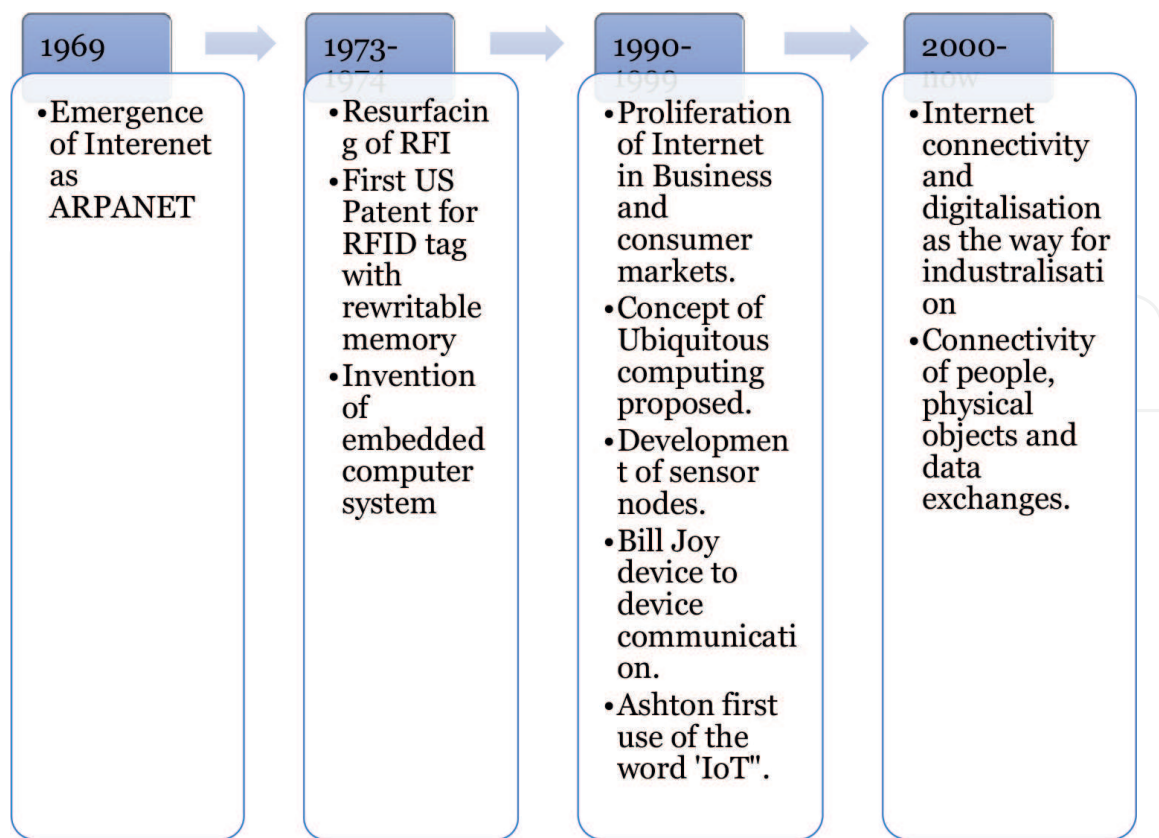


Figure 1.
Chronology of IoT evolution.

1960s, but the first U.S. patent for RFID tag with rewritable memory was received by Mario W. Cardullo in 1973. In the same year, Charles Walton, a California based entrepreneur, also received a patent for passive transponder to unlock the door remotely. In the year 1974, embedded computer system, which is also another important technology for IoT was invented. These systems are implemented using single board computers and microcontrollers and are embedded in the bigger system to form its integral part.

IoT was earlier used in 1984 without it being christened. Sharma et al. [9] explained that a coke machine was connected to internet to report the availability and temperature of the drink. During the year 1990, there was a proliferation of internet in business and consumer markets. However, its use was still limited due to low performance of network connectivity. In 1991, Mark Weiser proposed the concept of ubiquitous computing, another essential technological component for IoT. Weiser's ubiquitous computing made use of advanced embedded computing as a computer to be present in everything, yet invisible. It later became known as pervasive computing.

In the mid-90s, sensor nodes were developed to sense the data from uniquely identified embedded devices and seamlessly exchange the information to realise the basic idea of IoT [15]. Bill Joy in 1999 introduced device to device communication in his taxonomy of internet and the term 'IoT' was used for the first time [12]. During that same time, the RFID technology was boosted by an establishment of the Auto-ID Center at the Massachusetts Institute of Technology (MIT) to produce an inexpensive chip which can store information and can be used to link objects to the internet [9].

From the year 2000, because of digitalization, internet connectivity became the sine qua non for many applications because of digitalisation and automation. Most

businesses and products were expected to have their presence on the internet and provide information and services online [16]. Since then, the true potential of IoT begun; with imperceptible technology being operated behind the scenes and dynamically responding to our expectations for the “things” to act and behave.

Following the pronouncement of the “IoT” in 1999, its connotation has been in continuous development and expansion. The connotation of IoT has been continuously enriched. The ideal goal of IoT is that any person, any physical object, any transaction, or any process can communicate with each other by using any network at any time in anywhere [11, 15]. In other words, making a computer sense information without the aid of human intervention.

Gubbi et al. [15] writes a beautiful explication of the fast-rising industry-changing technology (i.e. IoT). They write, “a radical evolution of the current Internet into a network of interconnected objects that not only harvests information from the environment (sensing) and interacts with the physical world (actuation/command/control), but also uses existing Internet standards to provide services for information transfer, analytics, applications, and communications”. Contemporarily, IoT has outgrown its infancy and is transforming the current state of the internet into the inclusive internet of the future, covering wide range of systems in industries like transport, healthcare, logistics, etc.

3. Methodology

Based on the literature gaps highlighted, and the relative novelty of the areas considered for this study, the researchers adopted the critical review method [13, 16]. With this, the study broadened its search strategies, to unearth seminal papers on IoT by different scholars from diverse academic fields. Particular interest and attention were also given to the evolution and the concept of the IoT, as well as the components and relevance of IoT for industries. Tables were prepared to summarise the areas the study captured and their supportive references.

Specifically, these include the evolution, components and further developments of the IoT (i.e. IIoT and IoS). After this, an exegesis was done on IoT implications for manufacturing and service industries. Additionally, a table was prepared and organised to show the major findings or references that were identified for the conceptualisation of IoT. Finally, practical implications of the IoT for the industry practitioners and suggestions for future research were also discussed.

4. Discussion

4.1 Conceptualising IoT

Since the introduction of the concept of IoT in academic literature, it has received various definitions from different scholars and researchers. Most definitions of IoT emerged in the past ten years based on the latest technology and applications in existence at that time. These definitions depended on the way the researchers conceived and perceived the potency of IoT. Nonetheless, there is yet no universally agreed definition of IoT in the academic literature. Sharma et al. [9] clarified that, “different researchers, scientists define the term in their own way; some focus more objects, devices, Internet Protocols and Internet, while others focus on the communication

No.	Definition	Author(s)
1.	IoT is defined as the “interconnection of sensing and actuating devices providing the ability to share information across platforms through a unified framework, developing a common operating picture for enabling innovative applications. This is achieved by seamless ubiquitous sensing, data analytics and information representation with Cloud computing as the unifying framework”.	Gubbi et al. [15]
2.	IoT is “a network in which CPS cooperate with each other through unique addressing schemas. Use of the IoT can be, for example, the Smart factories, homes or networks.”	Hermann et al. [4]
3.	IoT is “a world where basically all (physical) things can turn into so-called “smart things” by featuring small computers that are connected to the internet”.	Hofmann and Rüsç [5]
4.	“IoT represents a fundamental concept in the integration of all smart devices that are parts of major smart projects”.	Roblek et al. [14]
5.	IoT in its simplest form is “as a relationship between things (products, services, places, etc.) and people that is made possible by connected technologies and various platforms”.	Schwab [1]
6.	World Economic Forum in its publication, Impact of the Fourth Industrial Revolution on Supply Chains, defined the IoT as “the virtual interconnection of intelligent assets and devices to achieve improved user experience and/or usability”.	World Economic Forum [17]
7.	World Economic Forum [18] in its publication, ‘Harnessing the Fourth Industrial Revolution for the Earth’, explained IoT as “a network of advanced sensors and actuators in land, air, oceans and space embedded with software, network connectivity and computer capability, which can collect and exchange data over the internet and enable automated solutions to multiple problem sets”.	World Economic Forum [18]
8.	IoT is “an inter-networking world in which various objects are embedded with electronic sensors, actuators, or other digital devices so that they can be networked and connected for the purpose of collecting and exchanging data. In general, IoT is able to offer advanced connectivity of physical objects, systems, and services, enabling object-to object communication and data sharing”.	Zhong et al. [11]
9.	IoT is “a new industrial ecosystem that combines intelligent and autonomous machines, advanced predictive analytics, and machine-human collaboration to improve productivity, efficiency, and reliability”.	Kamble et al. [10]
10.	IoT is “enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies”.	Turcu and Turcu [2]
11.	IoT is “an evolution of mobile, embedded application and everything that is connected to internet to integrate greater communication ability and use data analytics to extract meaningful information”.	Sharma et al. [9]
12.	IoT is “as a global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies”.	Lee et al. [7]
13.	IoT is “the inter-networking of physical devices, vehicles, buildings, and other items embedded with electronics, software, sensors, actuators, and network connectivity that enable these objects to collect and exchange data”.	Oztemel and Gursev [8]

Table 1.
Definitions of IoT by authors in their publications.

processes involved”. **Table 1** summarises some notable definitions of IoT by scholars and researchers in their papers.

For the purpose of this study, IoT is conclusively theorised based on the varying cues of definitions as *“the network of physical and virtual objects (things) connected with sensors, RFID and actuators, for the purpose of collecting, sharing and/or exchanging information through a unified platform over the internet which enables automated solutions to multiple problem sets”*.

4.2 Components of IoT

Gubbi et al. [15] presented a taxonomy that aided in defining the components required for the IoT from a high-level perspective. According to the researchers, there are three IoT components which enables seamless ubiquitous computing. These are Hardware, Middleware and Presentation. They classified hardware component of IoT as those objects made up of sensors, actuators, and embedded communication hardware. This level also includes central units. Leloglu [19] described the central unit as a source of centralised services in IoTs; and has a capability of storing, processing, and delivering data to users.

Middleware component of IoT comprises on-demand storage and computing tools for data analytics [9, 15]. An example of middleware is cloud computing. This style of computing relies on sharing of resources are provided as a service over the Internet to achieve coherence and economy of scale [20]. Also, Presentation component includes new and easy-to-understand visualisation and interpretation tools which can be widely accessed on different platforms, and which can be designed for different applications.

Some enabling technologies in these categories that make up the three components given above include RFID, wireless sensor networks, cloud computing, addressing schemes, data storage & analytics, visualisation [4, 19]. These technologies help in realising the fruitful operations of the entire IoT network. The development of IoT ecosystem or network enables the object to be uniquely identified and be able to connect and communicate with other objects anytime and anywhere. According to Sharma et al. [9], the two main components of an “IoT object” are its ability to capture data via sensors and transmit data via the Internet. This internet connectivity allows object to have their own identities as well as receive and send valuable communication making them smart.

Again, these objects are embedded with electronics (Microcontrollers and transceivers), software, sensors, actuators, and network connectivity that enables them to collect and exchange the data using various protocols. In other words, the IoT allows “‘things’ and ‘objects’, such as RFID, sensors, actuators, mobile phones, which, through unique addressing schemas, interact with each other and cooperate with their neighbouring ‘smart’ components, to reach common goals [4]. IoT technology is purposely utilised for collecting, analysing, controlling, and managing data in manufacturing systems [20]. Hence, IoT offers connectivity of devices, systems, and services; and caters to variety of application in different domains. Kamble et al. [10] elucidated that IoT products are allotted unique identifiers and are intricately linked to information about their provenance, use, and destination.

Leloglu [19] also proposed four layers of a secured IoT architecture to guide theoretical research. The scholar referenced that the architecture of IoT should be an open architecture, using open protocols to support a variety of existing network

applications; additionally, incorporating security, adaptability, and semantic representation middleware to promote data world integration with Internet. The four layers proposed by the researcher are Perception, Network, Support and Application layers. Perception Layer consists of the sensor technology, intelligence embedded technology, nano technology and tagging technology. He explained that the main purpose of this layer is the identification of unique objects and the collection of information from the physical world with the help of its sensors.

Additionally, network layer contains Wireless Sensor Networks (WSN), optical fibre communication networks, broad television networks, 2G/3G communications networks, fixed telephone networks and closed IP data networks for each carrier. The researcher further added that the responsibility of this layer also includes the transfer of collected information from sensors, devices, etc., to an information processing system. Thirdly, the support layer involves information processing systems which takes information in one form and processes (transforms) it into another form. This processed data is stored in a database and will be available when there is a demand. According to Leloglu [19], this layer works very closely with applications. Last but not least, application layer harbours practical and useful applications which are developed based on user requirements or industry specifications such as smart traffic, precise agriculture, smart home, mining monitor, etc.

Another indispensable part of IoT worth noting is, smart connectivity with existing networks and context-aware computation using network resources. Gubbi et al. [15] highlighted three IoT demands that will allow technology to disappear from the consciousness of the user; and evolve into connecting everyday existing objects and embedding intelligence into our environment. First, a shared understanding of the situation of its users and their appliances. Secondly, software architectures and pervasive communication networks to process and convey the contextual information to where it is relevant. Thirdly, the analytics tools in the IoT that aim for autonomous and smart behaviour. With these three fundamental grounds in place, smart connectivity and context-aware computation can be accomplished.

No.	Components	Reference(s)
1.	Hardware, Middleware and Presentation	Gubbi et al. [15]
2.	Electronics (Microcontrollers and transceivers), software, sensors, actuators, and network connectivity	Hermann et al. [4]
3.	RFID, wireless sensor networks, cloud computing, addressing schemes, data storage & analytics, visualisation	Kamble et al. [10]; Mourtzis et al. [20]; Sharma et al. [9]
4.	Perception, Network, Support and Application layers of a secured IoT architecture	Leloglu [19]
5.	Industrial Internet of Things	Ardito et al. [21]; Chen [22]; Lampropoulos et al. [23]; Turcu & Turcu [2]
6.	Internet of Services	Contreras et al. [24]; Hofmann & Rüsçh, [5]

Table 2.
Summary of the components of IoT.

Table 2 below summarises the various components of IoT that are discussed in this paper and their associated references.

4.3 Further developments of the IoT

4.3.1 Industrial internet of things (IIoT)

IoT serve as a foundation that allows objects to interact and communicate with each other in order to collect and share information among themselves. To this end, an industry-hardened IoT was needed to provide the reliability and security that were required by industry for manufacturing applications. An industry consortium initiated by General Electric (GE) is developing Internet technology for industry, resulting in a special IoT system for industrial application called the Industrial Internet of Things (IIoT) [22]. Lampropoulos et al. [23] opined that, “IoT is well aligned with the architecture of intelligent manufacturing industries, therefore IoT includes a specific category focusing on its applications and use cases in modern industries and manufacturing, named IIoT”.

Just as IoT, the IIoT do not have a universally agreed definition in the academic literature. IIoT have been used along with other technological terms like IoT, CPS, Industry 4.0, Big Data, Machine Learning, Machine-to-Machine Communication [2, 22, 23]. However different researchers have given different definitions for IIoT. For instance, Chen [22] postulated that, “the IIoT refers to the integration and connectivity of complex physical machines and devices, humans, and resources through networked sensors and software for the purposes of industry production and operations”.

Later, Ardito, Petruzzelli, Panniello and Garavelli [21] also defined Industrial IoT as the use of IoT technologies in demand-focussed and supply-focussed process; which favours the interoperability between devices and machines that use different protocols and have different architectures, thus allowing to have real-time data across the value-chain. Turcu and Turcu [2] also added their voice and defined the IIoT as, “a universe of intelligent industrial products, processes and services that communicate with each other and with people over a global network. It is a distributed network of smart sensors that enables precise control and monitoring of complex processes over arbitrary distances”. IIoT is considered to be a complex system of many independent systems. It combines several contemporary key technologies to produce a system which functions more efficiently than the sum of its parts; and focuses on automation, services, cloud computing, big data, CPS and people [23].

The term IIoT was first introduced by Frost and Sullivan around the turn of the 21st century [21]. According to Chen [22], the Industrial Internet, which is the fundamental tool for the implementation of IIoT, was used as a collective toolset for a digital enterprise transformation at that time. Other than regular Internet applications, such as office automation, the Industrial Internet requires conditions such as a hardened environment on the factory floor and extreme dependence on its reliability. Furthermore, IIoT provides functions that help develop insight and improve the ability to monitor and control company processes and assets through the use of appropriate services, networking technologies, applications, sensors, software, middleware and storage systems [23].

IIoT is of great importance and has a lot of benefits for industries that attend to its use. Turcu and Turcu [2] gave some key benefits of IIoT in an industrial context. They highlighted, “monitoring production flow and inventory; enhancing automation,

productivity, industrial safety, efficiency, security and quality control; enabling easy maintenance, inventory management, products tracking and tracing, development of new business models, services and/or products; optimisation of packaging, logistics and supply chain; reduction of human errors and manual labour, and of costs (both in terms of time and money)", as some key benefits of IIoT ([2]; p. 57). In addition, Lampropoulos et al. [23] elaborated that, IIoT offers enormous potential for unprecedented levels of economic growth and productivity efficiency in the years ahead. They further added that, IIoT will attract the interest both of businesses and governments as well as researchers and academics who will have to collaborate closely and feverishly in order to harness and exploit this huge opportunity.

4.3.2 Internet of services (IoS)

Another technological concept, Internet of Services (IoS), is emerging which is similar to IoT. This is as a result of the world being classified as a "service society" and the idea that services are made easily available through web technologies than physically. Internet of Services is allowing companies and private users to combine, create and offer new kind of value-added services via the internet [5]. Internet of Services can be simply defined as platforms that allows internet users to provide services via the internet [24]. Chen [22] also defined Internet of Services as the connection of non-physical systems (service or social elements) to the internet through embedded systems, sensors, software, and network devices.

Internet of Services are characterised by participants, infrastructure services, business models and the services themselves. The services are offered and merged into value-added services from different vendors, and communications via various communication channels. This approach allows different variants of distribution in the value chain. Hofmann and Rüscher [5] agreed with Barros and Oberle, with regards to their proposed definition of the term service, which reads "a commercial transaction where one party grants temporary access to the resources of another party in order to perform a prescribed function and a related benefit. Resources may be human workforce and skills, technical systems, information, consumables, land and others".

The main goal or destination of Internet of Services is to enable service providers to offer services via the Internet. Contreras et al. [24] elaborated that, the CPS, the hardware and software are represented as services. They further added that, this way of conceiving the elements as services, allows a new form of dynamic variation distribution in individual activities of the value chain [24]. Using the IoS during the fourth industrial revolution implies that, the elements of the value chain adopt a service-oriented architecture (SOA); which requires a platform for networking and a series of layers in each element than can be accessed from other elements as services [5, 24]. From a pure technological perspective, concepts such as Service-Oriented Architecture (SOA), Software as a Service (SaaS) or Business Process Outsourcing (BPO) are closely related to the IoS. It is quite promising and prospective that that internet-based market places of services are playing and will continue to play a key role in future industrial operations.

Penultimately, while the impact of IoT in the next five years is considered to be high by business leaders, experts consider the current degree of implementation of IoT applications across businesses and organisations to be on the average [17, 18]. Some developed countries such as France and developing countries such as China and India are working collaboratively to employ the IoT for specific projects. These

collaborations not only enhance the development of IoT technologies, but also address global issues, since it is necessary for countries and districts to work collaboratively, especially when adopting a cutting-edge technology such as the IoT [11].

5. Conclusion

IoT technologies have been widely used in industrial fields such as smart cities, manufacturing, and healthcare. To achieve improvements, specific applications of IoT is employed. Sensors and numerous other means of connecting things in the physical world to virtual networks are proliferating at an astounding pace. Smaller, cheaper, and smarter sensors are being installed in homes, clothes and accessories, cities, transport and energy networks, as well as manufacturing processes. Today, there are billions of devices around the world such as smart phones, tablets and computers that are connected to the internet. Their numbers are expected to increase dramatically over the next few years, with wider application in Agriculture, healthcare, manufacturing as well as the tourism and services provision.

Penultimately, while the impact of IoT in the next five years is considered to be high by business leaders, experts consider the current degree of implementation of IoT applications across businesses and organisations to be on the average. Some developed countries such as France and developing countries such as China and India are working collaboratively to employ the IoT for specific projects. The IoT application even though not so advanced in Africa, a lot of effort are being made to ensure the very good use of IoT, IIoT and IoS to achieve massive developmental changes in the African continent. The intense implementation of the IoT, IIoT and IoS will go a long way in ensuring improvements in various industries that would in the long run positively impact the general livelihood of people as well as the way of doing things. Minimization of human errors and process down times due to human interventions and errors could be readily achieved.

5.1 Practical implications of IoT for industries

The IoT Technology, as identified in academic literature, is impacting every aspect of our daily lives as well as the way we work [11, 20]. This implies that a large number of traditional areas with regards to our daily lives and living, will be affected by IoT technology. The quality of life is undergoing fast transformation and will be improved drastically in future. The IoT is expected to open up numerous economic opportunities and is considered one of the most promising technologies with a huge disruptive potential [5]. Sharma et al. [9] opined that, governments are believed to be the second-largest adopter of such technological solutions; and will also take a keen interest in such technologies to improve the quality of life of their people. The prospects of IoT will dramatically improve security, energy efficiency, education, health, and many other aspects of daily life for consumers, through amazing solutions. The ecosystem or network of connected devices has great benefit in all industries and fields, including energy, safety and security, industry, manufacturing, retail, healthcare, independence of elderly persons, people with reduced mobility, environment, transport, smart cities, entertainment, etc. [10, 22].

Again, IoT offers a lot of prospects or benefits for business and enterprises that utilise its technology. The business intelligence sector will adopt IoT solutions at a bit faster rate than other sectors. These business sectors are expected to increase their

productivity, have a higher growth of profit as well as lower their costs of operations, with the adoption of IoT technology. This will be possible as a result of IoT technology enhancing their operational efficiency, decreasing their product time-to-market by reducing unplanned downtime, and optimising their overall operational efficiency. IoT also improve decision-making and productivity of businesses in retail, supply chain management, manufacturing, agriculture, and other sectors by reinforcing solutions. Enterprises can further enhance overall availability and maintainability thanks to the vital solutions for more effective scheduling, planning, and controlling of manufacturing operations and systems that IoT provides [23].

Interestingly, the IoT Technology provides a unique and much-needed foundation that is capable of connecting all the elements of a manufacturing system together [22]. Smart-connected products offer exponentially expanding opportunities for new functionality, far greater reliability, much higher product utilisation, and capabilities that cut across and transcend traditional product boundaries [5]. In this way, not only can the efficiency of data collection be improved, but the quality of the data can also be significantly improved. The IoT also enables network control and the management of manufacturing equipment, assets, and information flow.

In this line of thought, Kamble et al. [10] explained the use of the IoT in helping the effective co-ordination and synchronisation of product, and information flows. The researchers postulated that, “the CPSs based on IoT technology find applications in smart manufacturing to achieve intelligent perception and access to various manufacturing resources, to connect multiple parties using social networks to facilitate open innovations, for process control using RFID to provide more flexibility to the manufacturing process, to improve the productivity of the microdevices assembly, and to manage dynamics in production logistics processes”.

IoT is radically transforming the way supply chains are managed for businesses and customers as well. It is enabling businesses to monitor and optimise assets and activities to the very granular level. This transformative impact on supply chains will also cut across all industries in its process, from manufacturing to infrastructure to healthcare. Also, IoT systems like the RFID allows a company to track its products as they move through the supply chain. A widespread application of the IoT that makes this possible is termed as remote monitoring [1]. With remote monitoring, any package, container or pallet can now be equipped with a sensor, transmitter or radio frequency identification (RFID) tag that allows it to be tracked, know how it is performing, and how it is being used. Similarly, IoT also allows customers to practically and continuously track the progress and location of their product or package they are expecting in real time.

Furthermore, IoT does not only ensure effective collection and gathering of data but also acquisition of real-time data for effective decision-making and data analytics. Connected devices ensure the availability of real-time data, enable the geographic distribution of operations and manufacturing, and result in improvements in operational efficiency, processing time and operating and management costs [17, 18]. Ardito et al. [21] highlighted three ways IoT benefit in the acquisition of real-time data for marketing and supply chain functions. They include real-time acquisition of market data (customer data and product-customer interactions); real-time acquisition of operational data (e.g. products life-cycle and material flow); and possibility to elaborate and integrate both market and operational data. The IoT provides real-time sensing/actuating ability and fast transmission capability of data/information, so that the remote operation of manufacturing activities and efficient collaboration among stakeholders are greatly facilitated.

For instance, the RFID technology provides one such example; and this influence most of industries, especially manufacturing sectors. Zhong et al. [11] explained that, “RFID technology has been used for identifying various objects in warehouses, production shop floors, logistics companies, distribution centres, retailers, and disposal/recycle stages. After identification, such objects have smart sensing abilities so that they can connect and interact with each other through specific forms of interconnectivity, which may create a huge amount of data from their movements or sensing behaviours. The interconnectivity between smart objects is predefined; such objects are given specific applications or logics, such as manufacturing procedures, that they follow after being equipped with RFID readers and tags. RFID facilities not only help end-users to fulfil their daily operations, but also capture data related to these operations so that production management is achieved on a real-time basis”.

In addition, the application of IoT, especially in industry, results into the creation of vast amounts of heterogeneous information that needs special manipulation and analysis to perform meaningful reasoning and extract the actual value. The extraction of the knowledge from the data collected in all levels of manufacturing systems can create autonomous smart manufacturing system. Oztemel & Gursev [8] elucidated that, IoT manufacturing systems make decisions that are quick, more optimistic, and faster than those of others. However, this depends upon the architecture and related intelligence embedded into the system. Moreover, the information networks that are based on the IoT application also create new business models, improve business processes, and reduce costs and risks [20].

There are a lot of independent technologies that come together or involved in the IoT eco-system. They include RFID, cloud computing, communication technologies, sensor technologies, advanced analytics, Big Data, machine learning [2, 19]. However, they are also prone to cyber risk, which exerts pressure on both stakeholders (government and business) to implement appropriate security and privacy policies across organisations, manufacturing networks and supply chains [17, 18].

5.2 Limitations and suggestions for future research

Notably, this review serves as a theoretical foundation for further studies. Future studies should empirically evaluate the IoT components that are in use at manufacturing and service firms. Furthermore, studies can also explore the prospects of the use of the IoT systems for industries using pragmatic methods. Also, other studies can also focus on the extent to which IoT systems of the Fourth Industrial Revolution apply to industries. Again, the impact of IoT operations on employee productivity, organisational performance and customer satisfaction can also be investigated. Additionally, an empirical study could be done to understand the challenges associated with the implementation of IoT and solutions that could be used to address these challenges. Finally, factors that would enhance the adoption of IoT systems in the face of the incoming technology revolution, could be the focus of future studies.

IntechOpen

Author details

Benjamin Appiah Osei^{1*} and Emmanuela Kwao-Boateng²

1 Department of Human Resource and Organisational Development, Kwame Nkrumah University of Science and Technology, Ghana

2 Department of Chemical Engineering, Kwame Nkrumah University of Science and Technology, Ghana

*Address all correspondence to: oseibenjaminappiah@gmail.com

IntechOpen

© 2022 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/3.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. 

References

- [1] Schwab K. The Fourth Industrial Revolution. United Kingdom: Penguin Random House; 2016
- [2] Turcu CO, Turcu CE. Industrial internet of things as a challenge for higher education. *International Journal of Advanced Computer Science and Applications*. 2018;**9**(11):55-60
- [3] Kumar A. Methods and materials for smart manufacturing: Additive manufacturing, internet of things, flexible sensors and soft robotics. *Manufacturing Letters*. 2018;**15**:122-125
- [4] Hermann M, Pentek T, Otto B. Design principles for industrie 4.0 scenarios. 49th Hawaii International Conference on System Sciences (HICSS). 2016. pp. 3928-3927. DOI: 10.1109/hicss.2016.488
- [5] Hofmann E, Rüsch M. Industry 4.0 and the current status as well as future prospects on logistics. *Computers in Industry*. 2017;**89**:23-34
- [6] Kagermann H, Wahlster W, Helbig J. Recommendations for Implementing the Strategic Initiative Industrie 4.0. Berlin: Industrie 4.0 Working Group of Acatech; 2013
- [7] Lee M, Yun JJ, Pyka A, Won D, Kodama F, Schiuma G, et al. How to respond to the fourth industrial revolution, or the second information technology revolution? Dynamic new combinations between technology, market, and society through open innovation. *Journal of Open Innovation: Technology, Market, and Complexity*. 2018;**4**(21):1-24
- [8] Oztemel E, Gursev S. Literature review of industry 4.0 and related technologies. *Journal of Intelligent Manufacturing*. 2020;**31**(1):127-182. DOI: 10.1007/s10845-018-14338
- [9] Sharma N, Shamkuwar M, Singh I. The history, present and future with IoT. In: Balas V, Solanki V, Kumar R, Khari M, editors. *Internet of Things and Big Data Analytics for Smart Generation*. Intelligent Systems Reference Library. Cham: Springer; 2019;**154**:27-51. DOI: 10.1007/978-3-030-04203-5_3
- [10] Kamble SS, Gunasekaran A, Gawankar SA. Sustainable industry 4.0 framework: A systematic literature review identifying the current trends and future perspectives. *Process Safety and Environmental Protection*. 2018;**117**:408-425
- [11] Zhong C, Zhu Z, Huang R-G. Study on the IoT architecture and access technology. In: 16th International Symposium on Distributed Computing and Applications to Business, Engineering and Science (DCABES), 13-16 Oct. 2017. Anyang, China; 2017. pp. 113-116
- [12] Ashton K. That “internet of things” thing. *RFID Journal*. 2009;**22**:97-114
- [13] Osei BA, Ragavan NA, Mensah HK, Kandappan B. “Hospitality revolution 4.0”: A literature review on a unified typology of IR 4.0 technologies for the tourism and hospitality industry in the era of COVID-19. *Asia-Pacific Journal of Innovation in Hospitality and Tourism*. 2020;**9**(1):25-45
- [14] Roblek V, Meško M, Krapež A. A complex view of industry 4.0. *SAGE Open*. 2016;**6**(2):1-11
- [15] Gubbi J, Buyya R, Marusic S, Palaniswami M. Internet of things (IoT): A vision, architectural elements, and future directions. *Future Generation Computer Systems*. 2013;**29**(7):1645-1660

- [16] Osei BA. Travel to emerging tourist destinations: Motivations and decision-making processes. In: Mensah I, Balasubramanian K, Jamaluddin M, Alcoriza G, Gaffar V, Rasoolimanesh SM, editors. "Marketing Tourist Destinations in Emerging Economies", Palgrave Studies of Marketing in Emerging Economies. Cham: Palgrave Macmillan; 2022. DOI: 10.1007/978-3-030-83711-2_5
- [17] World Economic Forum. Harnessing the Fourth Industrial Revolution for the Earth. Fourth Industrial Revolution for the Earth Series. Geneva, Switzerland: World Economic Forum; 2017a
- [18] World Economic Forum. Impact of the Fourth Industrial Revolution on Supply Chains. Geneva, Switzerland: World Economic Forum; 2017b
- [19] Leloglu E. A review of security concerns in internet of things. *Journal of Computer and Communications*. 2017;5:121-136
- [20] Mourtzis D, Milas N, Vlachou A. An internet of things-based monitoring system for shop-floor control. *Journal of Computing and Information Science in Engineering*. 2018;18(2):021005-1-021005-10
- [21] Ardito L, Petruzzelli AM, Panniello U, Garavelli AC. Towards industry 4.0: Mapping digital technologies for supply chain management-marketing integration. *Business Process Management Journal*. 2018;25(2):323-346
- [22] Chen Y. Integrated and intelligent manufacturing: Perspectives and enablers. *Engineering*. 2017;3(5):588-595
- [23] Lampropoulos G, Siakas K, Anastasiadis T. Internet of things (IoT) in industry: Contemporary application domains, innovative technologies and intelligent manufacturing. *International Journal of Advances in Scientific Research and Engineering*. 2018;4(10):109-118
- [24] Contreras JD, Garcia JI, Pastrana JD. Developing of industry 4.0 applications. *International journal of online and biomedical. Engineering*. 2017;13(10):30-47