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Internet of Things (IoT) in Industry: Contemporary Application Domains, Innovative Technologies and Intelligent Manufacturing

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ABSTRACT

Internet of Things (IoT) is a rapidly growing innovative technology with various applications, functions and services in everyday life and in a wide range of markets and industries. It can be defined as a global dynamic information network that involves interconnected devices and objects and aims at the mutual interconnection and interaction among people, services and devices at any time and regardless of location. IoT utilizes numerous innovative and advanced technologies in order to integrate intelligence into devices so that they can process information and data and gain knowledge. As an outcome, real-time, autonomous and human like intelligent decision-making systems that reduce the need for human involvement and intervention, are developed. Using this advanced network of interconnected devices in addition to its novel technologies, applications and services cannot only enhance life quality, but can also result in personal, professional and economic benefits. Hence, it has rapidly attracted the interest of organizations, industries and enterprises and has been regarded as an innovation enabler and explorer of new initiatives in industrial domains. Nonetheless, there are still challenges and open research issues that need to be investigated and addressed in order for IoT to be adopted and fully utilized by industries and enterprises. This study scrutinizes IoT from an industrial perspective and presents some of its numerous application domains (i.e. transportation and logistics, healthcare and sanitary, smart cities, smart environments and industry). It describes the context of Industry 4.0 and analyzes its involved innovative key technologies (i.e. cloud computing, Big Data (BD), Industrial Internet of Things (IIoT) and Cyber-Physical Systems (CPSs) along with their benefits. Moreover, it explores the concept of intelligent manufacturing and looks into the main IoT challenges and open research issues.

Key Words: *Internet of Things (IoT), IoT applications, Industry 4.0, Intelligent (Smart) manufacturing, Industrial Internet of Things (IIoT), Cloud computing.*

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1. INTRODUCTION

With the advancement of technology, the processing power and storage capabilities of devices have increased significantly, while simultaneously their sizes have been reduced. These smart devices are equipped with different types of sensors and actuators and are capable of interconnecting, communicating and interacting over the Internet. The Internet of Things (IoT) provides the potential of connectivity between and among people and things/devices/objects at any time and regardless of location in a barrier-free manner, thus contributing further to the fulfillment of Machine-to-Machine (M2M) communication and interconnectivity. It aims at implementing autonomous, robust and secure connections and data exchange between devices and real-world applications and it also contributes to integrating intelligence into devices so that they can process information and data and make autonomous decisions [1]. Furthermore, using a network of such interconnected devices can produce novel and innovative applications and services that can result in personal, professional and economic benefits [2]. Based on the estimation by Manyika et al. (2015), the potential annual economic impact caused by the IoT will be in range of united states dollar (USD) 3.9 trillion to USD 11.1 trillion by 2025 [3].

In recent years, IoT has attracted interest from industries, enterprises, governmental organizations and academic community and gained popularity thanks to the value and the future potential it promises to offer. A further key factor which has contributed to increasing IoT popularity is the magnitude of solutions it offers to industries and the multitude of its contemporary and advanced applications and services. Moreover, IoT allows "people and devices to be connected anytime, anywhere, with anything and with anyone" [4-5]. Such a technology could contribute to creating a potentially better world for people, in which the objects around them know what they like, what they want and what they need and act accordingly, without having to take explicit instructions from people [6-7].

Atzori et al. (2010) carried out a survey in regard with IoT [8]. More specifically, they elaborated on different IoT visions and paradigms and reviewed key enabling technologies. Furthermore, they analyzed the application domains of IoT and they grouped them into transportation and logistics, healthcare, personal and social, smart environment and futuristic domains. Finally, they examined relevant open issues and challenges such as standardization activities, addressing and networking, security and privacy. Gubbi et al. (2013) conducted a study in which they presented a "Cloud" based centric vision for worldwide implementation of IoT [9]. They also discussed the overall IoT vision as well as key enabling technologies and application domains along with some trends and taxonomy of IoT. Moreover, they went through open challenges and future trends in IoT and they presented a case study of data analytics on the Aneka/Azure cloud platform. Finally, they emphasized the need for convergence of wireless sensor network (WSN), the Internet and distributed computing. Al-Fuqaha et al. (2015), in their study, focused on technical details that pertain to enabling technologies, the most relevant protocols (application, service discovery infrastructure etc.) and key IoT issues and challenges. Furthermore, they presented a 5-layer model of IoT architecture which consists of objects, object abstraction, service management, application and business layers, as well as six main elements vital to promote IoT functionality and more specifically identification, sensing, communication, computation, services and semantics [10]. Ngu et al. (2016), with a view to emphasizing the need for advanced IoT middleware, conducted a survey regarding the capabilities, the issues and the enabling technologies of the existing IoT middleware [11]. They presented state-of-the-art middleware solutions to realizing IoT applications and a thorough analysis of the challenges and the enabling technologies in developing an IoT middleware. Furthermore, they classified the different architecture types of IoT middleware and presented a comparative analysis of emerging IoT middleware systems. Finally, they assessed and outlined relevant key research challenges.

This study explores IoT and more specifically, some of its numerous application domains (Section 2). It presents and analyzes the context of Industry 4.0 and the involved key technologies as well as the benefits they offer (Section 3). Furthermore, it describes the concept of intelligent (smart) manufacturing (Section 4) and it points out main IoT challenges and open research issues (Section 5). Finally, conclusions and suggestions for the direction of future research are given (Section 6).

2. APPLICATION DOMAINS OF IoT

Although IoT is still at an early stage, it is considered to be a rapidly growing innovative technology with various applications, functions and services in everyday life and in a wide range of markets and industries, facilitating and enhancing, thus, the role of Information and Communication Technology (ICT) as an innovation enabler in industrial domains. It is important that IoT applications be designed with caution, bearing in mind the satisfaction of multiple objectives and requirements as well as the overall cost of implementation without decreasing the Quality of Experience (QoE) and Quality of Service (QoS) levels. In addition, depending on the intended application domain and the complexity and the scale of the problem to be solved, developers should strive to maintain balance between production cost and Return of Investment (RoI). In general, IoT solutions should be designed to improve life quality and support infrastructure and general-purpose operations in industrial domains. Some of the application domains based on [1], [8], [12-16] are the following:

2.1 Transportation and logistics

Advanced vehicles, as well as roads and transported goods, have already been equipped with more sophisticated technological devices such as Radio-Frequency Identification (RFID) tags, actuators, sensors etc., in order to communicate, share and exchange mission-critical information and data promptly, timely and accurately. IoT technologies can be used to enhance the potential of these systems and optimize their use in the domains of transportation, logistics and suppliers, which are regarded as essential components to the productivity of many industries. Utilizing all these contemporary resources, applications and services that IoT provides in combination with the development and the evolution of ubiquitous 5G mobile networks, the novel intelligent transportation and logistics system helps industries:

- Accelerate productivity, profitability and operations by providing solutions designed specifically for their needs and goals;
- Maintain efficient transportation control and cost-effective management and increase end-to-end visibility by using real-time monitoring and tracking throughout the entire supply chain;

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- Reduce system downtime while allowing better energy efficiency by conducting more effective route planning and optimization.

2.2 Healthcare and sanitary

The medical domain is one of the first industries which adopted IoT. Utilizing IoT technologies can create new opportunities, services and applications so as to improve the healthcare and sanitary domain as well as enhance current living solutions and quality and effectiveness of services. By offering a means of automation, supervision and communication for remote outpatients, IoT provides the potential of independent living and ameliorates life quality as a consequence. Furthermore, given the fact that all objects in the healthcare industry will be equipped with sensors and patients will carry mobile medical sensors, the interconnection of these heterogeneous sensors will enable objects and patients to be traced and monitored in real time. IoT technologies can capitalize on this fact and enable healthcare providers to prevent the onset of health problems more efficiently by:

- optimizing workflow and operations;
- decreasing operational costs;
- improving patient treatment and well-being;
- taking advantage of rapidly automated decisions and continuous advanced remote patient state monitoring;
- improving and personalizing QoE and QoS;
- enhancing drug management;
- analyzing medical records effectively.

2.3 Smart cities

The United Nations Department of Economic and Social Affairs in its "2018 World Urbanization Prospects report" states that the urban migration has been increasing rapidly and it has been predicted that by the year 2030, 43 cities around the globe will have at least 10 million dwellers creating, thus, more megacities. It has also been estimated that due to the urbanization, two out of every three people will be living in cities or other urban centers by the year 2050 [17]. This rapid urban growth is already placing a considerable strain on the existing infrastructure and utilities and highlighting the need for more sustainable urban planning and public services. Governments and private organizations are trying to exploit the potential of IoT applications and services in order to satisfy these new requirements and to respond to the societal changes commensurate with this rapid growth. Moreover, they are striving to improve every aspect of urban life by creating smart cities that infuse the already established city services and utilities that residents interact with on a daily basis, optimizing the usage of city infrastructure, resources and facilities and enhancing city dwellers' life quality. In regard to smart cities, IoT technologies can be utilized in a number of diverse applications and services such as [18]:

- Reduced long-term costs;
- Innovative solutions to traffic congestion, parking and route planning;
- Energy efficient utilities, buildings and facilities (e.g. smart houses etc.);
- Novel and effective resource consumption and distribution management optimization (e.g. lightning, water supply etc.);
- Groundbreaking technological advancements for efficient energy consumption and renewal (e.g. smart grid etc.);
- Advanced traffic control and monitoring systems;
- More reliable public transportation means and pedestrian support;
- Remote and advanced security surveillance systems for city activity monitoring so as to improve public safety and security as well as violation detection for forensics usage.

Zanella et al. (2014), in their study, analyzed the concept of smart cities and urban IoT in detail, along with their numerous application domains and services [18]. They presented key enabling technologies, protocols and a three-layer urban IoT architecture. Finally, they described their practical implementation of urban IoT, named “Padova Smart City”, which aimed at promoting the early adoption of open data and ICT solutions in the public administration. Moreover, Alaverdyan et al. (2018), in their study, analyzed the smart city concept in the European Union (EU), by looking into the importance of smart city governance, relevant EU policies, promotion tools and best practices for implementing this concept [19]. Finally, they presented and compared five municipalities based on the way they adopted and applied the smart city concept.

2.4 Smart environments

By using sensors, actuators and other technological devices and embedded systems, IoT technologies aim at pervading our everyday environment and its objects creating, thus, new ways to interact with these so called smart environments. Cook & Das

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(2005) described these environments as “a smart environment is a small world where all kinds of smart devices are continuously working to make inhabitants’ lives more comfortable” and they defined that “smart” refers to the ability to autonomously acquire and apply knowledge, while “environment” refers to our surroundings [20]. Furthermore, according to Weiser et al. (1999), the concept of smart environments evolves from ubiquitous computing and promotes the idea of "a physical world that is richly and invisibly interwoven with sensors, actuators, displays, and computational elements, embedded seamlessly in the everyday objects of our lives, and connected through a continuous network" [21]. By utilizing IoT in combination with automated software agents for real time tracking and monitoring, smart environments become a technological ecosystem of various interconnected devices that can securely communicate and interact as well as gather, process, store and exchange data in real time. By integrating these heterogeneous data into global applications, the adaptation process to dwellers’ continuously changing needs is facilitated, resulting in their requirements being promptly and satisfactorily met. Moreover, IoT applications in this domain aim at improving the current environmental safety by reducing and mitigating the potential impact of damage and disaster. IoT technologies allow the development of innovative real time monitoring and decision-making support systems and applications regarding environmental issues, such as:

- Weather conditions;
- Fire detection;
- Air pollution;
- Snow level;
- Landslide and avalanche prevention;
- Early prediction and detection of natural disasters;
- Agriculture and farming;
- Mining conditions.

2.5 Industry

Almost by definition, IoT comprises a key component to the industrial domain and is closely related to the fourth industrial revolution (Industry 4.0). This specific domain is characterized by its diverse innovative applications and services, its various interconnected devices as well as its novel manufacturing operations and is analyzed in detail further below.

3. INDUSTRY 4.0 AND THE INVOLVED INNOVATIVE KEY TECHNOLOGIES

Industry 4.0, with a view to addressing the dynamic global market and the competitive nature of today’s industries in line with the continuously changing customers’ needs, aims at enhancing and upgrading the current manufacturing facilities, management and maintenance systems and technologies to an intelligent level by using key technologies such as novel IoT technologies, Cyber-Physical Systems (CPSs), Big Data Analytics (BDA), ICT and advanced networking technologies (e.g. cloud computing etc.) [22], [23], [24]. Furthermore, Zhong et al. (2017) [24], in the systematic review which they conducted, analyzed the major involved technologies, fundamental key concepts and world-wide applications in the context of intelligent manufacturing in industry 4.0. In their study, they stated that intelligent manufacturing will pave the way for the advancement of modern industry and economy as it will apply cutting-edge technologies to various traditional products and systems. Some of the key technologies involved in Industry 4.0 are described and analyzed below:

3.1 Industrial Internet of Things (IIoT)

IoT is well aligned with the architecture of intelligent manufacturing industries [25], therefore IoT includes a specific category focusing on its applications and use cases in modern industries and manufacturing, named Industrial Internet of Things (IIoT). IIoT, which is used in the context of Industry 4.0, combines several contemporary key technologies so as to produce a system which functions more efficiently than the sum of its parts and focuses on automation, services, cloud computing, BD, CPSs and people. Hence, it can be considered to be a complex system of diverse systems. It offers enormous potential for unprecedented levels of economic growth and productivity efficiency in the coming years, attracting, thus, the interest both of businesses and governments as well as researchers and academics which have collaborated closely and feverishly in order to harness and exploit this huge opportunity. According to the latest market report of Markets and Markets (2018), which used both top-down and bottom-up approaches along with several data triangulation methods to estimate and validate the size and value of the IIoT market and other dependent submarkets, “the IIoT market was valued at USD 59.54 billion in 2017 and is expected to reach USD 91.40 billion by 2023, at a Compound Annual Growth Rate (CAGR) of 7.39%” [26]. Moreover, they state that the major factor driving the growth of the IIoT market includes technological advancements, availability of automation solutions, improved data rates and coverage of communication technologies, increasing use of cloud computing platform, growing adoption of internet protocol version 6 (IPV6) and so forth.

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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. As a consequence and based on the results which were obtained by going through large volumes of data using advanced analytics as feedback, a method for converting business procedures is provided. Moreover, enterprises, which utilize IoT, can enhance their operational efficiency, accelerate productivity and decrease their product time-to-market by reducing unplanned downtime and optimizing their overall operational efficiency attaining, thus, a higher growth of profits [12]. 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 [25].

3.2 Cyber-physical Systems

The technological advancements in the domains of computer science, ICT and manufacturing have led to the increase of the potential of adopting cyber-physical technologies and frameworks, also known as Cyber-Physical Systems (CPSs) in industry [27], [28], [29]. CPS-enabled systems involve a large number of transdisciplinary methodologies and unlike traditional embedded systems, they contain “cybertwined services such as control algorithms and computational capacities” [24] along with specialized computational capabilities, physical assets and networked interactions [23]. Furthermore, CPSs are designed and developed to have both physical input and output so as to enable the interaction with humans using innovative modalities [30], [31]. As such, they are defined as transformative technologies that can seamlessly link the physical with the virtual world through their advanced and novel systems [27].

3.3 Cloud Computing

Cloud computing or simply “Cloud” is a kind of outsourcing that combines large numbers of compute servers and resources so as to offer, in real time, computer programs, high-level services and resources on an on-demand or pay-per-cycle basis [32]. Hence, it plays a leading role in enhancing and transforming the current manufacturing industry. Wang et al. (2010) defined cloud computing as “a set of network enabled services, providing scalable, QoS guaranteed, normally personalized, inexpensive computing infrastructure on demand, which could be accessed in a simple and pervasive way” [33].

The fact that applications, programmes and services can be rapidly provisioned with minimal management effort and are hosted in the “Cloud” enables users and enterprises to have access to them at any time and from any place. Therefore, various applications, such as Customer Relationship Management (CRM), Human Resource Management (HRM) etc., are widely used by enterprises in the industrial domain. According to Bhardwaj et al. (2010) cloud computing is divided into three levels of service offerings, namely Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS) that support different levels of virtualization and management and are described below [32]:

- SaaS: consists mainly of applications and system infrastructure software (SIS) that run on distant computers in the “Cloud” and is accessible through an internet application or service since the underlying hardware and Operating Systems (OS) are most commonly of little significance to the majority of end users.
- PaaS: includes and provides a cloud-based environment with all the required tools and software (e.g. middleware, database management etc.) so as to support the complete lifecycle of developing, delivering and maintaining web-based (cloud) applications.
- IaaS: is regarded as the main infrastructure that powers the “Cloud” as it provides computing and hardware resources, relevant software along with the necessary backup, security and maintenance tools and systems.

According to Lu & Cecil (2015), one of the main benefits of using cloud computing services and approaches is the use of advanced applications and services that dynamically scale with the increased number of users [29]. Furthermore, enterprises that utilize cloud computing can avoid the complexity of owning and maintaining their own Information Technology (IT) infrastructure and the up-front costs, which can be accomplished by a “pay-as-you-go” method [29] allowing, thus, the enterprises to start small and invest into more resources if there is more service demand [24], [34]. Some further benefits include high availability and maintainability, consistent accessibility to data and services from any connected device, as well as reduced development cost and product time-to-market and so forth. Taking into account the continuously evolving nature, the numerous application domains and multiple benefits of cloud computing, a lot of profits can be yielded in the industrial domain, thus, more and more organizations of different sizes and types are rapidly adopting this advanced technology in order to enhance their capabilities and capacity at a minimum cost [24].

Moreover, according to the latest update of International Data Corporation (IDC) Worldwide Semiannual Public Cloud Services Spending Guide (2018), the worldwide spending on public cloud services and infrastructure is forecast to reach USD 160 billion

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in the year 2018, an increase of 23.2% over the previous year and by the year 2021 and during the period of 2016-2021 the specific market will achieve a compound annual growth rate (CAGR) of 21.9% totaling USD 277 billion [35].

3.4 Big Data

The digitalization of everyday life, by the adoption of smart devices and advanced technologies (e.g. IoT, Artificial Intelligence (AI), Social Networks (SNS) etc.) has led to the increase of data sources and the diversity of data types, forms and structures, as well as digital content (e.g. structured, semi-structured and unstructured) [36]. As a result, an enormous volume of heterogeneous data, named Big Data (BD), is generated and increases exponentially on a daily basis. The key factors that characterize and differentiate BD from traditional data are its volume, variety, veracity, velocity and value [36], [37].

BD can provide a lot of predictive and prescriptive insight, in addition to numerous business advantages and as such, it plays a key role in industries and Intelligent Manufacturing (IM). Hence, it is imperative that enterprises, which want to remain competitive, should implement and utilize contemporary advanced analytical tools, techniques, methods and applications, in order to process BD, glean intelligence and retrieve the value of the vital data in each case. These tools are named Big Data Analytics (BDA) and use parallel and analytic techniques to analyze huge volume of diverse, rapidly transforming data enabling, thus, the collection, the process and the management of vital information and statistics [36], [38]. Enterprises can generate invaluable insights by utilizing all this newly gained knowledge so as to gain immense benefits and optimize operations by enhancing productivity and efficiency and reducing operational costs [12]. Moreover, enterprises must first change their decision-making culture in order to fully utilize BD and exploit all of its potential benefits. They should also take into consideration that no matter how much the power of BD increases, the need for vision or human insight should not be overlooked [37].

4. INTELLIGENT (SMART) MANUFACTURING

Manufacturing comprises one of the largest and highly interconnected IoT markets and it involves a wide variety of operations, processes, services, products etc., hence, it is regarded as a core component in industries, having a huge impact on people's livelihood and a nation's economy. IoT can provide a lot of solutions to the manufacturing domain, which is characterized by its complexity and breadth of applications, its diverse CPSs and its Manufacturing Operation Management (MOM) methodologies [24]. Some IoT applications and services, which enhance overall production, productivity and Product Quality Management (PQM) (e.g. quality planning, control, assurance and improvement etc.) throughout the various stages of the life-cycle of products, include advanced monitoring and tracking, performance and maintainability optimization and human machine interaction.

In the context of Industry 4.0, IM, also known as Smart Manufacturing (SM), uses Service-Oriented Architecture (SOA) and is considered to be a novel manufacturing model that takes advantage of and fully utilizes not only the above mentioned key technologies but also other advanced information and manufacturing techniques, methodologies and technologies (e.g. advanced robotics etc.) [24]. It aims at fundamentally transforming traditional enterprises into intelligent ones so as to effectively respond to demand-dynamic economics keyed on "customers, partners and the public; enterprise performance and variability management; real-time integrated computational materials engineering and rapid qualification, demand-driven supply chain services; and broad-based workforce involvement" [39]. IM uses the combined intelligence of people, processes and machines so as to increase production, product quality and productivity efficiency, detect and monitor potential damage, malfunctions and breakdowns, enhance control and management, improve maintainability and availability, as well as optimize resource management and sharing resulting, thus, in having an impact on the overall economics state of manufacturing.

A major distinguishing factor between IM and traditional manufacturing is that IM uses AI, Machine Learning (ML), Genetic Algorithms (GA) and other advanced technologies and techniques in order to develop real-time, autonomous and human like intelligent decision-making systems that reduce the need for human involvement and intervention. Nonetheless, the goal of both manufacturing domains remains the same, that is, to satisfy customers' preferences and requirements and market needs, as well as maximize profits while simultaneously minimizing possible cost and waste [40].

5. CHALLENGES AND OPEN RESEARCH ISSUES OF IoT

It is apparent that IoT, which is an innovative and rapidly growing technology, can enhance and transform the current industries and yield a lot of benefits such as operational, economic etc., thanks to its advanced technologies, applications and services. Nonetheless, in order for IoT to be adopted, implemented and fully utilized by industries and enterprises, a lot of challenges and open issues should be looked into and addressed.

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A lot of elaborate studies, which analyze vital IoT challenges, integration and implementation problems and open research issues, have been conducted. More specifically, Atzori et al. (2010) analyzed open research issues involving standardization activities, addressing and networking (e.g. mobility, naming etc.) as well as security and privacy (e.g. authentication, data integrity) [8]. Khan et al. (2012) described key IoT challenges, such as interoperability and standardization, data and information confidentiality, encryption and privacy, naming and identity management, IoT greening as well as object and network security [1]. Miorandi et al. (2012) looked into research challenges including communication and identification technologies, distributed systems technologies and intelligence and emphasized security issues such as data confidentiality, privacy and trust [14]. Gubbi et al. (2013) examined and analyzed open challenges such as secure reprogrammable networks and privacy, QoS, energy efficient sensing, architecture and protocols, Geographic Information System (GIS) based visualization, data mining and cloud computing [9]. Borgia (2014) went over the following challenges and issues: object mobility, M2M communications, device and data management, network architecture and system design, addressing, naming and traffic characterization and security [15]. Perera et al. (2014a) referred to interoperability on products and services as well as resources and energy management as challenges and they also emphasized on privacy and data analytics [7]. Al-Fuqaha et al. (2015) examined key IoT challenges and QoS criteria such as availability and reliability, mobility, performance and management, scalability and interoperability as well as security and privacy [10]. Breivold & Sandström (2015) described the management of fault tolerance, functional safety, latency and scalability of data, mixed criticality and scalable and secure real-time collaboration as key IIoT challenges [41]. Lee & Lee (2015) regarded data management and mining, security and privacy as main challenges in IoT development faced by enterprises [42]. Sadeghi et al. (2015) focused on security and privacy challenges in IIoT and their vulnerability to a variety of cyberattacks [43].

To sum up, the most significant and common IoT challenges and open research issues referred in the above mentioned studies and which can be applied in industries and enterprises are:

- Data confidentiality, security and privacy;
- Scalability and interoperability;
- Data, operation, resource and energy management;
- Functionality safety and fault tolerance;
- Availability, reliability, mobility and other QoS criteria;
- Standardization activities, architecture and protocols;
- Identification and networking addressing.

It is also essential to point out that IoT not only aims at transforming industries and increasing their productivity but also at adding value to the core purpose of enterprises and mitigating the weaknesses caused by legacy systems. IoT should be compatible with existing devices, systems and infrastructure and be able to embed intelligence into them. Hence, it will be easier for enterprises that are undergoing digital transformation to adopt and implement IoT and exploit its numerous benefits and solutions without having to directly invest in totally brand-new equipment as cost might far outweigh the immediate benefits.

6. CONCLUSION

IoT is an innovative and rapidly growing technology which can offer a lot of benefits and transform the current industries, as well as improve the quality of our lives. It aims at embedding intelligence into systems, creating thus, autonomous and human like decision making systems. In addition, it renders mutual communication and interaction between and among people and devices feasible. Industries and enterprises have an enormous interest in IoT, thanks to the novel solutions, applications and services that it offers, as it makes it possible to address the competitive and dynamic global market and meet with the continuously changing customers’ needs.

Moreover, in the context of Industry 4.0, IoT, and more specifically IIoT, can be utilized in combination with other innovative technologies such as BD, cloud computing, CPSs etc., in order to transform the current manufacturing systems into intelligent ones. By using IoT and IM, enterprises can gain a lot of benefits such as enhancing their operation and functionality, increasing their productivity and reducing their costs and waste. Furthermore, enterprises that fully adopt and utilize these cutting-edge technologies will be able to be ahead of their competitors, become more agile, adapt to the ever-changing market, create products of higher quality that satisfy customers’ needs and requirements and finally to make more profits.

Although IoT innovations have already been deployed in numerous industries and use cases, IoT is still at an early stage of development, adoption and implementation, thus, further research into coping with and solving the various current challenges and open issues should be carried out. Finally, we conclude that the complete implementation and prompt adoption of IoT along with appropriate utlization of its novel technologies, applications and services cannot only improve life quality, but can also yield significant personal, professional and economic benefits in the near future.

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