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Review

Internet of Things and Its Applications: A Comprehensive Survey

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Abstract: With the evolution of the fifth-generation (5G) wireless network, the Internet of Things (IoT) has become a revolutionary technique that enables a diverse number of features and applications. It can able a diverse amount of devices to be connected in order to create a single communication architecture. As it has significantly expanded in recent years, it is fundamental to study this trending technology in detail and take a close look at its applications in the different domains. It represents an enabler of new communication possibilities between people and things. The main asset of this concept is its significant influence through the creation of a new world dimension. The key features required for employing a large-scale IoT are low-cost sensors, high-speed and error-tolerant data communications, smart computations, and numerous applications. This research work is presented in four main sections, including a general overview of IoT technology, a summary of previous correlated surveys, a review regarding the main IoT applications, and a section on the challenges of IoT. The purpose of this study is to fully cover the applications of IoT, including healthcare, environmental, commercial, industrial, smart cities, and infrastructural applications. This work explains the concept of IoT and defines and summarizes its main technologies and uses, offering a next-generation protocol as a solution to the challenges. IoT challenges were investigated to enhance research and development in the fields. The contribution and weaknesses of each research work cited are covered, highlighting eventual possible research questions and open matters for IoT applications to ensure a full analysis coverage of the discussed papers.

Keywords: IoT applications; IoT protocols; healthcare; environmental; smart cities; commercial; industrial

1. Introduction

With an extensive growth in demand for a higher throughput, larger capacity, and lower latency for users, the 5G network is greatly expected to fulfill the desired requirements [1]. The throughput is expected to be very high, the energy consumption will be significantly lower, and the end-to-end will be reduced to less than 1 ms, which all comply with the International Mobile Telecommunications (IMT) standard for the beyond 5G wireless networks [2]. To achieve this milestone, research and industrial communities have both suggested that future wireless systems will take advantage of the numerous emerging technologies, such as the Millimeter-Wave (mm-wave) frequency band [3,4]; Cognitive Radio (CR) [5]; Massive-Multiple Input Multiple Output (M-MIMO) [6]; Cooperative Networks (CR) using Relay Nodes (RNs) [7]; Coordinated Multipoint Operation (CoMP) [8]; Wireless Sensor Networks (WSN) [9]; Mobile Ad Hoc Networks (MANETs) [10,11]; Device-to-Device (D2D) communication [12,13]; Internet of Things (IoT) [14,15]; Ethernet Passive Optical Networks (EPON) [16]; Heterogeneous Networks (HetNet) [17]; and cellular cloud computing, including big data [18]. Moreover, the use of various power optimizations [19], handover processes [20], interference cancellation [21], data security management [22], routing protocols [23], and scheduling algorithms [24] with optimal enhancement can also deliver ultimate results. New approaches, such as satellite communication in the mmWave spectrum [25], Artificial Intelligence [26], machine learning-based communication [27,28], blockchain [29], and human-centric communication [30], are promising ideas for designing efficient base stations in future networks [31,32]. The next-generation networks will provide ubiquitous internet and cellular services to cater to the more than fifty billion devices forecasted to be internet-enabled, including the human-type and machine-type communication systems [33]. Indeed, being able to provide wireless services to such an unprecedented number of smart nodes will be the aim of the next generations of wireless networks [34].

The term IoT has been considered as an expanding technique applied in various applications and functions, from smart environments and houses to personal healthcare and others [35]. It is described as a smart concept for the internet relating everything to the Internet and data organization and information exchange [36]. Large-scale IoT intelligent systems have become more efficient and effective by using the properties of "symmetry" and "asymmetry". This can help in a range of IoT applications, for example, in water quality analytics, bee colony status monitoring, accurate agriculture, data communication balancing, smart traffic management, spatiotemporal predicting, and intelligent engineering. Several studies are currently working on IoT technologies to sustain their necessity in platforms developing technology [37]. Although there are diverse definitions and explanations for understanding IoT, it has a subsequent edge associated with the assimilation of the physical world with the virtual one of the internet [38]. The paradigm of IoT is simplified as *any-time, any-place, and any-one* connected [39]. The implementation of this technology makes things and people closer and everyday life easier [40]. The purpose of IoT is to ensure a connection between devices, where each provides information and data. These devices are generally personal objects that are frequently carried, including smartphones, vehicles, healthcare devices, and office connected devices [41]. Moreover, Radio-Frequency Identification (RFID) is considered to be one of the first applications that saw the light and has played a crucial role in numerous technologies, such as sensors, smart objects, and actuators [42]. However, Machine-to-Machine communication (M2M) [43] and Vehicle-to-Vehicle communication (V2V) [44] represent the actual applications showing the significant advantages of IoT [45,46].

2. Methodology

The main objective of this paper is to systematically categorize and investigate the definitive research procedures regarding IoT application methods and approaches. It explores the expansion and growth of IoT, along with its deployment in various application fields. The main areas covered in this study include healthcare, environmental, smart city, commercial, industrial, and infrastructural aspects of IoT applications. The next section shows that extensive research has been conducted to ensure full comprehension of IoT technology, including an overview, its architecture, and protocols. It presents various related literature studies that have been conducted on several aspects of IoT, such as its architecture, protocols, and specific applications. However, to the best of the author's knowledge, no such work has been conducted where all of these aspects are collectively discussed while focusing on various IoT applications, i.e., healthcare, environmental, smart city, commercial, industrial, and infrastructural applications. Moreover, the IoT architecture layers represented are the main focus of this paper, which include the network, perception, interface, and service layers. It investigates the robust standardization issue, security, software and hardware elements, cost decrease, scalability problems, and proper compatibility. The strength of this review consists of providing a complete overview of the issues and challenges faced in IoT; however, the approaches related to artificial intelligence and the compatibility of the approaches are not covered. Figure 1 represents the topics that are discussed in this study.

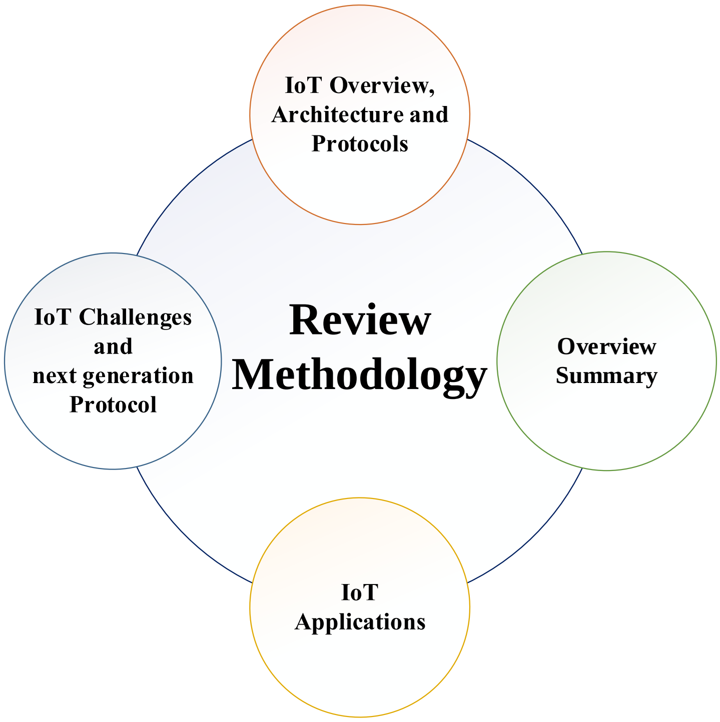

Figure 1. Review methodology.

The principal components employed to review this work include sources, selection, and extraction methods.

2.1. Sources

In total, around 250 research articles associated with the subject were selected. We made use of libraries as our primary resources, where 60% of the articles were selected from IEEE Xplore, 25% from ScienceDirect, 10% from Scopus, and 5% from others. Queries relating to the recent progress and the searching keyword pattern were applied for the IoT architecture and applications. Then, the Boolean operators "OR" and "AND" were used to elucidate the keywords in the Web of Science and Scopus databases.

2.2. Selection

In order to select particle articles, we applied three filter procedures to include the criteria in the search. First, around 75 articles that were unrelated references were excluded during the search process. Then, the second filtering process was employed to look at the title and abstract to review the accuracies. Third, the material of an article was read, especially the contribution and conclusion parts, to finalize the selected studies. The research selection was conducted on the basis of the following questions: (1) Is the research article published between the years 2015 and 2020?; (2) is the research article reported in any of referred data sources?; and (3) is the research article suggesting or discussing anything related to the protocols, standardization, security, software and hardware elements, costs, scalability, general applications, services, environment and agriculture, smart objects, and architecture in IoT?

2.3. Extraction

At this stage, we had analyzed each preliminary study to identify the research gaps, strengths and opportunities related to the protocols, standardization, security, software and hardware elements, costs, scalability, applications, services, environment and agriculture, smart objects, and architecture in IoT. The spreadsheet was used and maintained the name, description, and reasoning. We performed the search process in June 2020, at which time we identified more than 250 publications. A total of 169 papers cited in this research work were selected from the IEEE Xplore Digital Library, ScienceDirect, Scopus, and others, and around 80 papers were discarded by applying the three filtering process stated above.

Overall, the selection of articles is varied with respect to the focus areas, working applications, and employed protocols.

Overall, this paper is organized as follows: Section 3 is composed of an IoT structure description; Section 4 discusses the related work regarding the current applications of IoT in different domains; Section 5 consists of a discussion regarding IoT applications founded on its benefits and limitations; Section 6 presents a summary and discussion of IoT applications; Sections 7 and 8 briefly summarize the challenges of IoT with research opportunities and IoT generation protocols for various application areas, respectively; and finally, the conclusion is drawn in Section 9.

3. Background

The principal advantage of IoT consists of its ability to enable communication between an infinite amount of machines incorporated into a large-scale wireless network [47]. These automated devices and sensors together produce and transmit information in real-time, which is useless in the case of incorrect or insufficient filtering and data processing. Moreover, data storage and transmission are the most important and challenging matters in a dynamic IoT network. This section discusses the structure and protocols that have been used in the IoT network [48].

A hybrid IoT architecture consists of the things involved, followed by the insight data processes which end with the action that needs to be done (as shown in Figure 2) [49,50]. The benefit of it is that it can comprise several subsystem architectures [51]. Listed below are the functions of each component in a conventional IoT architecture, as shown in Figure 2:

- **IoT Edge Devices** form the smart IoT actuator since they are able to conduct some processing themselves;
- **IoT Sensors** are connected to the cloud, where they can transmit and receive the data;
- **Device Provision** helps to connect a large number of devices to be registered;
- **IoT Gateway/Framework** proves a cloud hub to the IoT devices and provides command, management, and control of the devices;
- **Stream Processing** analyzes complex execution using time windowing ductions, stream aggregation, and external source combing;
- **Machine Learning** allows the algorithms to be predicted and executed using extreme data. It also analyzes and enables predictive maintenance, according to different scenarios;
- **Reporting Tools** help to hold and store the data, while providing the necessary tools for batch processing;
- **User Management** can restrict and permit which users or groups are authorized to perform an action on the device. The process is done by using the capacities of the application of each user.

Generally, IoT systems are designed with two management architectures, including time-based and event-driven architectures. The event-driven architecture consists of sensors transmitting data when activity is sensed, the same as when an alarm is activated once a gate is opened [52]. However, for the time-based architecture, the components of the system transmit data continuously at a specified interval of time [53]. Additionally, it works recurrently after a break to be separately adjusted for each device or setup in a central management system sending queries to endpoint devices and sensors [54].

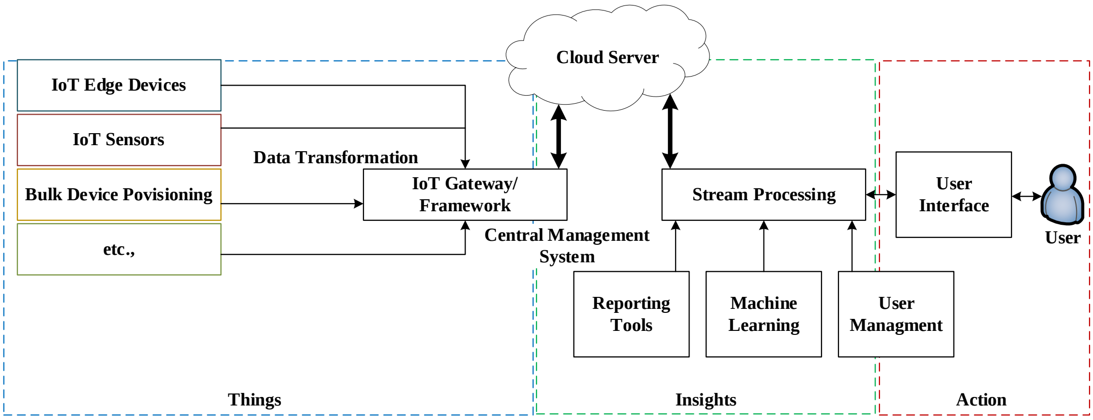

Figure 2. Internet of Things (IoT) architecture.

Various protocols have been used to enable data transmission for the IoT network [55]. It consists of a syntactic and semantic set of regulations determining the operating activity block of the computer network during data transmission [56]. The role of the utilized protocol is to determine the behavior of an entity during data transmission [57]. The traditional Internet Protocols (IPs) are unfortunately not appropriate for ensuring proper data exchange. It is very challenging to design an IoT network, as it comprises several sensors that cannot be added to the general address schema, affecting the possibility of obtaining a fully-fledged node. Besides, these nodes are strongly dependent on a constant energy source, the channel throughput capacity, and the storage parameters, requiring advanced management of the resources. Concerning Wireless Sensor Networks (WSNs), it is necessary to add a data sink to the network [58]. The process consists of first storing the data collected in the sink, before reaching to the other nodes and repeating the process [59]. The proper selection of a strategy for transferring data has a significant impact, as the sensor and sink disposition may enhance the IoT network bandwidth. It ensures security and privacy through the prevention of sending and receiving the same data from multiple sensors, which reduces the energy costs [60–62]. Moreover, several messaging protocols are being developed to support the use of IoT and make it easy to employ. These messages are essential for ensuring a connection between devices. The Constrained Application Protocol (CoAP) and Message Queue Telemetry Transport (MQTT) are the most used messaging protocols; however, some other famous protocols, including the Extensible Messaging and Presence Protocol (XMPP) and Advanced Message Queuing Protocol (AMQP), result in an efficient overall network performance [63]. The application of these four protocols is as follows and is simplified in Table 1 below:

- **CoAP:** This is used in an IoT communication load susceptible to performance deprivation that occurs from traffic congestion. It is a web transfer protocol mainly developed for limited devices with a restricted processing memory and power, usually operating in low bit rate environments [64]. This Hypertext Transfer Protocol (HTTP) is similar to a web transfer protocol that is capable of extending the Representational State Transfer (RST) architecture to Low-Power Wireless Personal Area Networks (LoWPANs) [65]. Furthermore, the Low-Power Wide-Area Network (LoRaWAN) protocol provides the Medium Access Control (MAC) mechanism, which helps to enable communication between various devices and network gateways [66]. This protocol is based on a star topology and has several advantages in IoT applications, such as its low cost, low power, secure nature, and ease of deployment [67]. It follows the RST architecture and comprises a 4-byte header-only, including the User Datagram Protocol (UDP), as a default fundamental transport protocol. Moreover, it provides reliability through the retransmission timeout mechanism [68]. As CoAP works on top of UDP, it presumes possible end-to-end trustworthiness and primary control of congestion. This protocol operates in the application layer and is in charge of formatting the data formatting handshaking connection [69]. To communicate data, CoAP provides four types of messages, including the Confirmable message, the Non-Confirmable message, the Acknowledgement message, and the Reset message. All in all, CoAP operates following a request/response approach [70];

- **MQTT**: This is used for lightweight M2M communications. It acts as an asynchronous protocol that follows the publish/subscribe protocol. The main goal of this protocol is to connect implanted devices and networks to middleware and applications. The advantages of MQTT are its ability to ensure routing in small cases, the fact that it is economical, its low memory, and its low power devices for susceptible and low bandwidth networks [71]. This protocol is extremely lightweight, which makes it suitable for M2M, WSN, and IoT [72]. It allows the transfer of telemetry-style data from devices to the server as messages, along with high latency or constrained networks [73];
- **XMPP**: This is mostly used for message exchange. It follows the publish/subscribe approach, which is more appropriate for IoT, contrary to the architecture of the CoAP request/response. Moreover, it represents an early protocol endorsed across the internet, regardless of relatively newer protocols, i.e., MQTT [74]. It is based on the Instant Messaging/Presence Protocol (IETF standards) that is used for multi-party chatting, voice and video calling, and telepresence [75]. The main benefits of XMPP consist of it being a secure protocol and the fact that it permits the addition of new applications on top of the core protocols [76];
- **AMQP:** This was developed for the financial industry. It is characterized by its capability in orientating messages, queuing, switching, security, reliability, and privacy [77]. Similar to XMPP, the AMQP protocol follows the same architecture of the publish/subscribe approach. The principal benefit of using AMQP consists of the store-and-forward element that guarantees reliability and trustworthiness, although it can involve possible network disruptions [78]. This protocol maintains reliable communication through message delivery and ensures delivery primitives involving at-most-once, at-least-once, and exactly once. It needs a trustworthy transport protocol that explains its use of the Transmission Control Protocol (TCP) for message exchange [79].

Table 1. IoT protocol applications.

Protocol	Application	Reference
CoAP	IoT communication load from traffic congestion	[64]
	Extend RST to LoWPANs	[65]
	Reliability through retransmission timeout mechanism	[68]
	Application layer	[69]
	Formatting handshaking connection	[70]
MQTT	Lightweight M2M communication	[71]
	M2M, WSN, and IoT	[72]
	Transfer of telemetry-style data	[73]
XMPP	Message exchange	[74]
	Multi-party chatting, voice, video calling, and telepresence	[75]
	Security	[76]
AMQP	Financial industry	[77]
	Reliable and trustworthy network	[78]
	TCP for exchanging messages	[79]

4. Related Work

Several studies and reviews have been conducted regarding IoT applications. This section gives a global and general overview of the main topics discussed in related studies regarding IoT applications. Asghari et al. [80] conducted a systematic review regarding IoT applications and focused on analytically and statistically categorizing the latest studies on IoT. This study is unique in that it uses the Systematic Literature Review (SLR) method as a selection and comparison review technique. In another review presented in [81], the current IoT services were investigated and the article focused on explaining how quality of service (QoS) needs and essentials might be satisfied to guarantee a smart ecosystem. The study presented a detailed analysis regarding the various applications and the threat that the shortage of cross-domain integration may pose. The research summarized the interoperability and explained QoS necessities, including the reliability, security, privacy, scalability, and availability. However, the study lacks statistics concerning the reported results. Another study presented in [82], focusing on IoT, discusses work related to the environment and agriculture. This study mainly focuses on four domains, including logistics, control, monitoring, and prediction. Two main points are discussed, starting with the significant technological attempts used in IoT applications to address environmental and agro-industrial problems. This work discusses the storage approach, communication technique, visualization approach, power sources, edge computing technology, sensing variables, and actuators. Another review presented by Han et al. [83] discusses the Internet protocol employed for smart objects, target applications, service modeling, service composition structures, and target platforms. The factors include the scalability, response period, accessibility, and expenditure. The main IoT techniques have been investigated in [84]. Table 2 summarizes the main focus of the above-discussed related reviews.

Table 2. Discussed reviews on IoT applications.

Reference	Applications
>m[80]	General applications
[81]	Services
[82]	Environment and agriculture
[83]	Smart objects
[84]	Architecture

5. IoT Applications

This section of the paper mainly focuses on reporting IoT applications discussed in recent studies. Figure 3 represents a complete taxonomy of IoT in the significant fields of application. The principal areas of application are focused on health care, the environment, smart cities, commercial, industrial, and infrastructural fields [85,86].

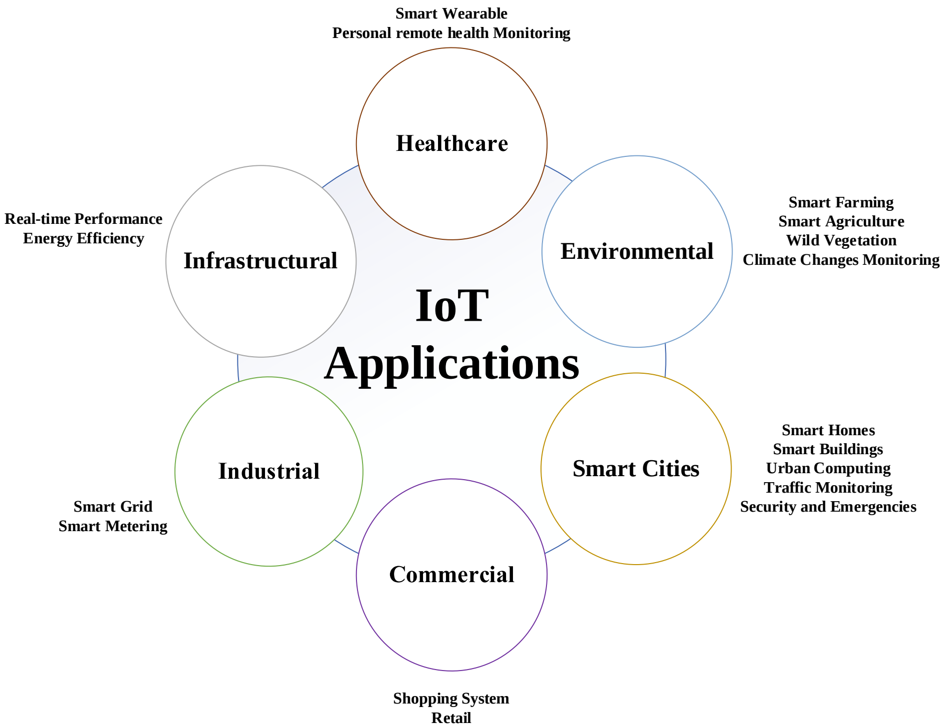

Figure 3. Taxonomy of IoT applications.

The applications and use of IoT in the different domains are what drive and explain the development of this new trend, leading to the acceptance of IoT by the new world [87]. The study of IoT applications improves the understanding and enhancement of IoT technology, and thus, the design of new systems for newly developed cases [88]. The concept of IoT can be summarized as generating daily information from an object and transferring it to another one. Therefore, enabling communication between objects makes the range of IoT applications extensive, variable, and unlimited [89,90].

5.1. Healthcare Applications

In [91], a guide for IoT healthcare services is given for providers following operators' point of view. The study suggests some significant features that have greater effects on users, enabling them to validate healthcare services. The methodology consists of performing analysis that evaluates the indicated parameters, including risk sensitivity and trust, in order to qualify and validate the services. The results were obtained based on lifestyle disease and showed that the South Korean population requires reliable, trustworthy, secure, and safe healthcare services. This study provides a guideline for manufacturers so that they can enhance the reliability and trustworthiness in order to deliver IoT healthcare services. However, the findings are issued from a hypothetical service, rather than a commercial one. Furthermore, this study lacks an evaluation of the response time. Another study developed a healthcare monitoring system aimed at diagnosing and avoiding chronic diseases, such as obesity, diabetes, and depression [92]. It investigates a solution for energy management, since battery recharging and changing generates additional costs. By implementing the irregularity of the system, the energy and spectrum efficiency of devices could be increased. In this approach, biological sensors are used for obtaining an instant understanding and making decisions through machine learning techniques. The proposed structure has been evaluated by designing a wearable device as a prototype, as well as receiver units. The results demonstrated a significant impact on the energy efficiency through an evaluation of the transmission power and received signal strength indication (RSSI).

In another study presented in [93], a health monitoring system employed for an extended period of time was developed. The elaborated ad-hoc examining structure verifies the patient's natural components, along with the ecological information, including the temperature and humidity detected by the current or new sensors that are complemented throughout the system's execution time. The benefit of this research work is the use of low-cost sensors, as well as devices that consume less energy and that are readily available in the houses. However, the elaborated system is limited to a lower number of devices and only satisfies the minimum service level. Another study presented in [94] consists of suggesting an IoT system for isolated mobile medical management. It proposes a structure of human contact and biological parameters through intelligent nodes. The idea is to ensure an effective emergency alarm system and principally confirm the safety of the critical and essential patient information in the databases of clinics and hospitals. This research study has greatly contributed to improvements of the speed and accuracy measurement of the biological factors using devices that consume less energy. However, the cost was not evaluated in this study.

Security management concerning security metrics was investigated in a high-level mechanism in [95]. The objective of this study consisted of enhancing the security and privacy of IoT applications in healthcare services. It analyzed the treatment and cure of chronic diseases and the security intention of IoT applications in e-health, more specifically for older age patients. In this paper, the authors discuss the needs and necessities of adaptive security management, along with decision-making. These are considered to be essential for establishing security requirements and applying ample security controls, as long as security threats are changed. The security parameters include the effectiveness, accuracy, efficiency, privacy, and confidentiality. However, the study does not cover any analysis of the security metrics or the adaptive decision. A multi-layer context-aware approach for the data combination of IoT healthcare applications was investigated in [96]. The suggested methodology is based on a framework achievement, condition structure, and implications. It explains that the Body Sensor Networks (BSN) or Wireless Body Area Networks (WBAN) are usually placed in contact with the patient's body, in order to sense and gather physiological information to be stored and saved in the database. Since the information is collected from various sources, a procedure for combining the collected data is required, which is known as data fusion. The authors presented a new approach for displaying the gathered information in a manner that supports making a precise and specific decision at the proper time. The results addressed a few challenges, including the limited coverage, sensor deficiency, ambiguity, and irregularity. However, this work does not present any algorithm for an evaluation of the presented approach.

Another study is presented in [97], which focuses on proposing a negligible inaccuracy altered IEEE 802.15.4 transceiver for IoT healthcare applications. The study aimed to improve the frequency offset evaluator to ensure a better and higher performance in modifying errors compared to the current evaluators of IEEE 802.15.4. It helps to enhance the total bit error and the frequency of packet error in comparison to the standard architecture. Moreover, this study contributes to diminishing the power consumption as less retransmission is involved, in order to ensure a successful packet broadcast. An investigation conducted by Lin et al. [98] established a new concept of sensor detections in Cognitive Radio Sensor Networks (CRNs). A theoretical approach of the recommended paradigm, in contrast with the Primary User Emulation Attack (PUEA), is presented in this work, where an elaborated method highly enhances the effectiveness of strike exposure. However, this study does not consider the reliability, trustworthiness, and operability of the system in terms of the node movement influence regarding detection implementation. In [99], Damis et al. present a theoretical and experimental analysis of three epidermal loop antennas to measure the biological parameters for IoT healthcare applications. This work examines the error-vector magnitude (EVM) and evaluates the Bit Error Rate (BER) parameters to endorse the accuracy of the global system for mobile communication (GSM) and Bluetooth Low Energy (BLE) communications in Quadruple Loop (QL) antennas. The results show the appropriate reliability and constancy between the factor of refection and the forms of radiation. The evaluation of data communication shows that the achieved BER is appropriate for the studied antenna expertise and can work in 4 Quadrature Amplitude Modulation (QAM) wireless connectivity.

A further study on healthcare applications was conducted by Ellapila et al. [100], where a routing approach for WSN was focused on improving the interference and energy effectiveness, following blockage and interface perception of the energy efficiency. Since many IoT devices share the same focus point, the network poses extreme traffic and delays in the link between the devices. The elaborated algorithm uses a function to determine the following party node, which operates the following three parameters: (1) The signal to interference plus noise ratio (SINR); (2) the route sustainability; and (3) node blockage. It can be seen that the data the proposed approach is able to deliver enhanced the data rate and lowered the energy consumption and packet loss. Moreover, Jebadurai and Peter [101] suggested a new design for IoT applications in healthcare, enabling the processing of retinal images that are taken by a smartphone fundoscopy. To enhance the quality of the images, an algorithm that has a super-resolution using the Kernel support vector regression process was recommended. The obtained results show that the proposed algorithm has a more effective performance compared to various current super-resolution algorithms. Concerning the study in [102], the authors performed an analysis regarding the performance of a narrowband IoT (NB-IoT) that requires considerable communication with less throughput for simple sensors and long-life batteries. The main objective of the research work was to analyze and evaluate the latency and throughput of NB-IoT in healthcare services. Another study conducted by Dauwed et al. [103] assessed the human factors affecting information exchange in the healthcare environment. The study aimed to provide the knowledge required to develop new models of IoT applications in healthcare and focused on gathering and exchanging information among healthcare professionals. The obtained results reported that the major serious factors are the intention of usage, user satisfaction, trust effort, quality of the service, and collaboration environment. Islam et al. [104] suggested a healthcare managing system developed through MySignals following the LoRa wireless network (low-power long-range). In addition to LoRa and MySignals, sensors for the body temperature, oxygen saturation, electrocardiogram, and pulse rate were used in the circuit.

The authors evaluated the efficiency and performance of each sensor, as well as the wireless platform devices following physiological and statistical data analysis. The purpose of MySignals consisted of ensuring a possible gathering of information. The purpose of the developed circuit was to transmit the collected information from MySignals to a computer through the LoRa implementation system. The obtained results revealed that MySignals was effective with the electrocardiogram, pulse rate, temperature, and pulse rate sensors. Another study conducted by Dauwed et al. in [105] presented information regarding the actual necessities and challenges faced in the healthcare department in terms of the use of available healthcare systems. The purpose of the study consisted of examining and evaluating the main factors associated with the use of IoT regarding exchanging health information. Table 3 summarizes the health applications for IoT.

Table 3. IoT healthcare applications.

Reference	Focus Area	Application	Protocol	Device
[91]	Disease management system to improve reliability	A guide for IoT healthcare service providers	-	Independent hand-held device and smartphones
[92]	Healthcare monitoring for chronic diseases like depression and diabetes	Battery energy efficiency approach using a machine learning technique	-	Wearable devices
[93]	Healthcare monitoring system which uses low-cost sensors and ensures a lower energy consumption	New architecture and paradigm of monitoring	XMPP	Smartphone
[94]	Mobile medical home monitoring system to improve the rapidity of factor measurements and ensure a low energy consumption	A new paradigm for mobile medical home monitoring	-	Wearable device
[95]	Adaptive security management based on metrics to enhance security	Adaptive security management standard	-	Boy sensors
[96]	Synthesis method for e-health to ensure high availability	A new structure for e-health		In connection with the patient's body
[97]	IEEE 802.15.4 transceiver with a low error rate and a higher probability	Framework	IEEE 802.15.4	Wearable device
[98]	An efficient protocol to counter PUEA attacks	Algorithm and structure protocol	Multi-tier device-based authentication protocol	-
[99]	Biotelemetry application to ensure lower costs and energy consumption	Implementation and algorithm	-	Wearable antennas
[100]	Energy-efficient routing protocol to ensure a lower energy consumption		The path routing protocol in WSN	-
[101]	Super-resolution algorithm for healthcare images with slower response time and cost		-	Multi-kernel SVR learning-based image super-resolution
[102]	Healthcare monitoring system with lower delay rate and time response	A new algorithm for healthcare monitoring system	NB-IoT	-
[103]	Human factor evaluation in information exchange in the healthcare environment	It promotes data exchange among healthcare staff and healthcare providers	-	EPR system in hospital emergency department

Table 3. *Cont.*

Reference	Focus Area	Application	Protocol	Device
[104]	Healthcare managing system developed through MySignals following LoRa wireless network	Collecting human body data	LoRa	Biosensors attached to the body
[105]	Focusing on chronic conditions beyond the office visit	Iraqi health information system	-	Wearable sensors

5.2. Environment Applications

Numerous research has been conducted to evaluate the use of IoT in an environmental context. To begin with, Li et al. [106] developed an online monitoring system equipped with a WSN and directed for henhouses to monitor the environmental aspects, including the humidity, temperature, carbon dioxide, and ammonia (NH3). The authors stated that, in previous studies, the majority of applications had been related to the development of systems, where the reliability of data transmission was not taken into consideration. Therefore, in this work, the authors tried to solve the problem by suggesting a transport protocol focusing on a loss recovery approach. Moreover, duplicated data auto filtering and lost data filling were performed to estimate the data rate and to increase the system integrity. Additionally, the web remote controlling system was designed to enable the operators to access the collected information through smartphones and computers to manage the henhouse environment with a better user interface. Moreover, additional expansions of this study are improving the data collection precision and reliability of the system, as well as reducing small update and maintenance costs. However, the energy consumption was not evaluated in this study. In [107], a platform for an ecological controlling system using IoT is introduced. The main target constituted the wild vegetation community by focusing on climate changes. The architecture suggested in this research work consists of low power consumption WSN. Regarding the control of a wild vegetation environment, numerous significant features, including the soil humidity and temperature, tilt, carbon dioxide, illumination of the habitat environment, and growth conditions represented by the tree diameter and sap movement, are measured. In order to assess the recommended program, a model was established and analyzed for a test-bed used for rough trees. Unfortunately, the results showing the effectiveness and execution of the suggested approach are not available.

In a study conducted by Nordin et al. [108], the authors focused on the revival of a rural hydrological control system, with the emphasis on the link, in Lake Chini (Malaysia). This research study contributed to understanding of the reliability of the central sensor used in the network infrastructure system through LoRa and 2G and the performance restriction of the low data sensor network, especially in a rural environment. These two factors are significant for reviving a countryside water station controlling center and highlighting the possible development of wireless communication in rural areas. Yen et al. [109] created a high-efficiency smart home with a low cost for people suffering from visual or hearing incapacities or pet owners. The suggested smart home uses different and numerous sensors that aim to ensure a real-time reaction to users in four major features, including clothing, shelter, traveling, and food. It also uses a web server that enables storage of the collected information, and helps to provide statistics and support data analysis. In particular, the created smart home focused on several features, including the temperature and humidity control, security, health control, safety, pets, elderly, and disabled control functions. The tests were successful, resulting in an easy connection and low-cost machines for distant control using the internet.

The study conducted by Sukmaninsigh et al. [110] categorizes technology and information related to natural disaster management and monitoring through the concept of the smart city. It suggests a prototype for monitoring smart disasters using Information and Communications Technology and the Smart City domain, in order to avoid the significant impact that natural disasters may have on the sustainability and prevent environmental impacts. Ahamad et al. [111] worked on challenges in ozone migration through observations of the ozone surface of three Malaysian locations that were investigated using IoT. The collected information was analyzed to display the variation in closer stations. The statistically obtained results show a significant difference in the total maximum ozone concentration frequency. The IoT represents a feasible and practical way of determining the sensitivity to foundations and meteorological conditions. A recent study concerning the greenhouses gases monitoring system was performed by Suparta et al. [112]. This study developed a system to control gases in greenhouses through the Netduino 3 WIFI microcontroller. The elaborated system was able to collect meteorological data of the surface, including the humidity, temperature, and pressure. It could calculate the precipitable water vapor through the ANFIS PWV model inserted in the Netduino 3 WIFI board. The authors claim that the suggested system can be deployed to work efficiently for a remote area and showed success after the experimental testing in the laboratory. Table 4 summarizes the environmental applications for IoT.

Table 4. IoT environmental applications.

Reference	Focus Area	Application	Protocol	Device
[106]	Monitor and control many environmental factors of henhouses in chicken farms	Henhouse system	MAC Protocol	Smart devices
[107]	IoT ecological monitoring system	A prototype for wild vegetation environment monitoring	-	Wireless sensor network
[108]	The revival of a rural hydrological/ water monitoring system	Link located in Tasik Chini	LoRaWAN TCP/IP	Cellular BS and PC
[109]	Design and modeling of a sensible home automation system	Smart home	RFID	Smart home system
[110]	A model for smart disaster management using ICT	Smart cities	-	-
[111]	Identify critical challenges in ozone mitigation	Department of Environment Malaysia	-	-
[112]	Development of a Greenhouse Gases monitoring system	Remote area	-	NetDuino 3 WIFI

5.3. Smart City Applications

The use of IoT has been expanded for applications of the smart city. Montori et al. [113] proposed a SenSquare structural design focused on observing consumer tests of current data flows for the smart city through a mobile sensing crowd. The presented facility structure utilized the data mining categorization process to evaluate the possibility of the proposed approach. However, the data quality and users' privacy were not measured; thus, the scalability cannot be endorsed. Zia et al. [114] introduced a software design for a particular numerical forensics experimental prototype. Their work investigates the forensics approach for assessing the conventional rules and manufacturing procedures. It helps to support collecting, inquiry, evaluation, and recording in an IoT numerical forensics finding application. In order to assess the proposed approach, three IoT application situations involving wearable devices, the smart home, and the smart city were studied. It introduced a model that may be able to evaluate the range of forensics data of an adjustable IoT environment. However, the proposed model does not consider security protocols, but appears to be advantageous for making the process more useful and secure. Lin et al. [115] presented various applications that have been developed and applied, founded on a program called IoTtalk, which is based on a locale-based IoT system. It is based on four different applications, i.e., (1) dog tracking, (2) an emergency, (3) PM2.5 checking, and (4) collecting information. First, the movements of dogs on campus are monitored. Second, the police are notified in the case of an emergency. Third, PM2.5 is checked by several sensors. Fourth, a robot containing various sensors is employed to collect the building information. It introduces a mechanism to find the location through insertion, which helps to create a system for position determination that enhances the stability of the energy efficiency and accurate tracking. Zeng et al. [116] created an emulator named IoT-Sim, whose main objective is to deliver and strengthen big data managing simulations through IoT. It is built on Cloudsim through the use of MapReduce in cloud computing practice. This study evaluates and assists IoT applications in real cloud computing environments and is a stimulating mission as it is a significant challenge to parallel the cost of management of a large scale of data centers with active configuration supplies. The benefit of the developed emulator is that it provides an appropriate platform for exploring and examining IoT-based environments.

The research work conducted by Chen et al. [117] introduced a structure for offloading for adaptive computation. The paper presents a model to distribute calculation on the fly by applying the adaptation. Furthermore, it establishes a paradigm that calculates the implementation period and determines a suitable approach for managing the computation process. This study is of significant importance as it explains a new way of using the manage computation process, which delivers a reduction of 45 to 50% of the execution time. The study performed by Urbieta et al. [118] presented a new context for an adaptive structure. This structure is founded on a non-concrete facility prototype for pervasive software methods concerning their abilities and context-specific essentials, such as their pre- and post-condition effects. Moreover, the paper mentions the discussion process involving the behavioral effect related to dataflow and context-flow limits. The implementation was performed at three levels of flexibility: (1) Integration; (2) interleaving; and (3) adaptive rearranging. This work summarized the improvement of the performance, the enhancement of the value of the outcomes, and the increase of the accuracy of the service composition engine. However, user assignment validation was not considered with a higher number of skills. Seo et al. [119] suggested a new design founded for ubiquitous computing scenarios. It refers to a prototype of the regrouping of mainframes to control information that is analytically assimilated with daily objects and daily life. Therefore, ubiquitous computing represents a fundamental requirement in ubiquitous IoT technology that displays several complex problems. The authors found it essential to conduct context awareness and to consider adopting the performance of distributed applications. The proposed architecture is composed of three major layers involving a (1) cloud service, (2) M2M service, and (3) ubiquitous service. The obtained results show that a useful structure for mobile applications is provided in ubiquitous environments. Unfortunately, the reliability was not considered.

Lee et al. [120] conducted a study to introduce an application-based methodology to encompass the directed-acyclic-graph type structure of component facilities. To execute this, the authors proposed a Software as a Service (SaaS) layer approach. A workflow process specifying a blueprint flow description was taken into consideration to fulfill the existing facility in the intelligent house condition. The outcome indicated the blueprint flow exhibits more inadequate memory utilization and a shorter computation time. However, is the study considered a limited size network to demonstrate the effectiveness of the suggested approach. A new method for data stream evaluation and comparison was developed by Akbar et al. [121], and aimed to afford a dependable, practical, and accessible solution. A multi-layered design was considered, including a layer to present a platform for examining and exploring data from diverse structures of IoT in a convenient system and a layer to provide a probabilistic explanation based on the Bayesian network. The objective of the authors in [122,123] was to develop a technique for dynamic IoT resource collection using the CoAP protocol. The purpose of the study is represented in the NP-hard issue of resource accumulation that can help to achieve the optimal energy efficiency of servers. Krishna et al. [124] investigated the performance of IPv6 based on the Routing Protocol for Low power (RPL). The authors opted for a Contiki test-bed and assessed the latency, node packet received, routing component in a low power WSN module, and wireless sensor module (WiSMote). In [125], a new Fog-supported design named the Fog Computing Architecture Network (FOCAN) was designed. The suggested architecture includes a multitier structure where the applications can communicate with each other and perform on objects in smart cities. The proposed architecture decreases the delay and improves the QoS between objects with a variety of amenities by enhancing energy provisioning. The designed FOCAN devices involve three categories of transmissions, i.e., (1) inter-primary, (2) primary, and (3) secondary transmissions. This can help to manage the system while meeting the QoS requirements and guidelines for the IoT. Moreover, it can ensure the energy-efficiency of services through devices. The outcome of the results demonstrated a significant improvement in terms of the energy efficiency for various smart city applications. Table 5 summarizes the smart city applications for IoT.

Table 5. IoT smart city applications.

Reference	Focus Area	Application	Protocol	Device
[113]	Semantic-aware mobile crowd-sensing	Service composition in smart city	Cellular	Smartphone and laptop
[114]	Digital forensics	• Smart cities • Smart homes • Wearables smart grids		
[115]	Location finding along with the updated location configuration features	• Emergency informing • Dog tracking • Monitoring indoor conditions	LoRa	Sensor device inside an 'umbrella tube'
[116]	Big Data processing	Smart home	Bluetooth low energy (BLE)	MapReduce
[117]	Analyze and predict the performance of applications used in scalable platforms	Smart home	LoRa	Remote device and server
[118]	Context-aware service composition	Smart home	wEASEL	Smartphone
[119]	Cloud computing service composition	Vehicular monitoring	OIDM2M	
[120]	QoS service composition	Smart home	Bayesian networks	Smart devices
[121]	Manage heterogeneous data streams	Weather systems	ITS	
[122,123]	Traffic management and dynamic resource caching management	Street parking system	CoAP	WSN Devices
[124]	Real-time low power routing protocol	Smart city	RPL	
[125]	Fog-based architecture to manage IoT applications		3G/4G Cellular WiFi ZigBee	

5.4. Commercial Applications

In recent times, the IoT commercial applications have been greatly expanded. In a study conducted by Alodib [126], a prototype-driven technique used to mechanize the QoS-aware facility structure involving real-time control was designed. The author mentioned the violation of the service-level agreements (SLAs) as a major worry. Therefore, the SLAs were plotted to combine the Petri net model with the UML QoS model by indicating users. An analysis of the Discrete Event System (DES) is essential and showed that the suggested approach could deliver a combined facility to be employed in the Petri net model. It created a review for evaluating the implementation cost-effectively, in order to satisfy QoS; however, the scalability was not considered in the research. In another research work performed by Han and Crespi [127], the design of semantic maintenance supplying for smart devices is presented. The primary objective was to provide a web-based smart device service through numerous conventional Application Programming Interfaces (API) concerning their constraints, including assets (ROM, RAM, and CPU), low-speed transmission paths, and energy-efficient microcontrollers. It was evaluated in several situations by samples and functions on the web simulated by Contiki Cooja (simulator). The outcome of this research is represented in the improvement of IoT applications on the web and development of essential elements, including the security, reliability, and scalability for service provisioning. However, this study did not present the differences in a comparison with similar available studies. Huo et al. [128] recommended a multi-purpose prototype for facility composition concerning a cost-efficient optimization. The QoS features, including the response period, accessibility, data rate, and reputation, were measured. The recommended approach was established by using the Artificial Bee Colony (ABC) algorithm, following the purpose of growth of the stated QoS considerations and reducing the costs. The designed model was evaluated through two datasets. The results focusing on enhancing the effectiveness and the quality of the elaborated model were compared to previous solutions. However, the environments, as clouds with a fast data flow that produces additional serious needs, were not considered. Another ABC algorithm was proposed by Huo and Wang [129], in order to select appropriate combined facilities in a dynamic approach. The designed plan gives a proper and suitable response period and improved precision compared to other techniques, such as a genetic algorithm, mainly in a chaotic solution space. The quality elements are studied following the Internet Protocol (IP) case study to attain an optimum solution for service selection and the composition recommended methodology. The results obtained from MATLAB software show a low response period and lower average convergence repetition. Unfortunately, this designed algorithm has not examined the effect of sequential optimization of the task nodes. In another study conducted by Temglit et al. [130], a web service collection and structure, obtained through a multi-agent QoS-aware methodology, has been suggested. The recommended method is founded on a context-aware supplied optimization method for service management design. To prevent transmission expenses, it introduces a multi-agent method to coordinate and compile various service implementations.

In this research, the authors applied the simple additive weighting (SAW) technique to investigate the effectiveness of the collection and structure of current QoS-aware services. It consisted of employing the chart concept to explain a shorter response period and combine the service with existing methods. Cao et al. [131] recommended a solution for IoT Mashup application through the Relational Topic Model (RTM) and Factorization Machines (FMs). The RTM was used to characterize the relationships among services and Mashup. In contrast, the FMs were employed to understand and model the communication among defined variables of high shortage, as well as to estimate the relation between Mashup and services. The authors claimed that the recommended approach significantly improves the service accuracy. Cuomo et al. [132] designed a new method of using the one-step HullWhite model for an IoT-based financial situation [133]. It directed three major phases, starting with the extraction from different databases, followed by the investigation and the checking phase, and ending with the reporting phase. The gathered data are used to evaluate the interest rate in a HullWhite model concerning various issues through the software (R.). This approach helps to decrease the complexity period through the suggested parallel method. Pustišek et al. [134] suggested three possible designs for front-end BlockChain (BC) services. The recommended approach diverges in establishing the Ethereum BC users, including a local object or remote server, as well as in disposing of essential stores necessary for affable operation management. The limitations of the intended approach are the need to access the Ethereum main store, need to find the position and contribution of the BC module, and the data volumes. The authors also covered the applicability of the elaborated architectures with unique and restricted communication among the distant BC client and IoT device. This helped to enhance and increase the safety with better privacy and lower system congestion. The advantage of the proposed architecture is its higher throughput and energy-efficient approach for wireless communication. Table 6 summarizes the commercial applications for IoT.

Table 6. IoT commercial applications.

Reference	Focus Area	Application	Protocol	Device
[126]	QoS-aware service composition	Ecosystem	SoA	Smart devices
[127]	Semantic-aware service composition	Smart homes Smart devices	6LoWPAN CoAP	Smart objects
[128]	QoS-aware multi-objective service composition	Composite service Optimization service	-	-
[129]	QoS-aware service composition	Optimization service	IP	-
[130]	QoS-aware multi-agent composition	Web services	XMPP	-
[131]	Service accuracy	IoT Mashup application	RTM and FM	IoT sensors
[132,133]	Finance data flow system	Financial and banking sector	NFC	-
[134]	Etherum BC	Smart grid	BC	-

5.5. Industrial Applications

Another important application of IoT technology is in the field of industrial business [135]. Several significant studies have been conducted on the use of IoT in this area. Li et al. [136] proposed a three-stage planning methodology to enhance the QoS through top-down choice-making procedures by utilizing the Markov decision method. The authors designed the scenario model and assessed the recommended approach by using MATLAB software. Several QoS factors, including the response period, end-to-end delay, accessibility, and bandwidth, were taken into consideration during the assessment process. The suggested resource planning method was evaluated, which helped to reduce the overall network latency. Venticinque and Amato [137] studied and developed a new approach for IoT Fog applications to answer and explain the Fog service implementation matter. This approach determines the ideal component among computational resources and IoT applications, such as the smart energy domain. The benefit of this research work consists of giving an autonomous understanding of energy profiles and enhancing the program strategy through the introduction of several computational resources. In another study conducted by Jin et al. [138], a subject-based multi-level planning structure called CONCISE for industrial IoT applications is suggested. It offers a new prototype to supervise and gather data through Time Synchronized Channel Hop-Ping (TSCH) planning. The obtained findings demonstrate a reduction of the network traffic congestion, enhancement of the communication reliability, and minimization in the end-to-end latency.

Kiran et al. [139] suggested a novel approach to facilitate the use of the Personal Area Network (PAN) for an analysis of the IEEE 802.15.4-2015 MAC layer for beacon and non-beacon network communication. In this approach, a Markov chain-based mathematical model is designed for the node's power feeding, reliability, and lag in packet transmission. The benefit is that the overall network operating efficiency is enhanced. Ahmad et al. [140] suggested an energy-efficient robust Tunnel Field-Effect Transistor Static Random Access Memory (TFET SRAM) cell for a wide variety of IoT applications. The recommended approach may be largely employed, such as in environmental sensing, health monitoring sensors, traffic control, and related managing and controlling systems. The proposed cell outcomes show that it achieves a higher margin value, decreased delay, lower energy consumption, energy per operation, and energy leakage reduction compared to the prior 9T TFET (7T FET) cells. Daell et al. [141] focused on the health management system for industrial applications. It introduces the concept of prognostics and systems health management (PHM) with the following four main dimensions: Sensing; diagnosis; prognosis; and management. The study concluded that the PHM is likely to have a significant influence on the development, prediction, risk management, assessment, and creation of new business opportunities. Michele et al. [142] discussed the idea of Industrial IoT

(IIoT), focusing on Low-Power Wide-Area Networks (LPWANs). The idea was to design a realistic simulation model of LoRaWAN that allowed the performance of network designs typically employed for industrial monitoring to be examined. A comparison to a design of a similar WPAN, for example, IEEE 802.15.4, has also been conducted and offered promising outcomes. Daniele et al. [143] defined the execution of a transferable, platform-agnostic, and reliable Industrial Blockchain Tokenizer (IBT) for IoT applications. Its function is to gather industrial data in the attainment center, which is able to collect information from both new and conventional systems while also precisely communicating with sensors. Table 7 summarizes the industrial applications for IoT.

Table 7. IoT industrial applications.

Reference	Focus Area	Application	Protocol	Device
[136]	QoS-aware scheduling for service-oriented IoT devices	Scheduling if IoT	WSN	Mobile devices
[137]	Automatic learning of energy profiles and enhancing platform strategy	IoT Fog application	-	-
[138]	Content-based cross-layer scheduling	Industrial plant	IEEE 802.15.4-2015 TSCH MAC	-
[139]	Nonbeacon-enabled personal area network	Industrial monitoring and automation	IEEE 802.15.4-2015	-
[140]	Ultra-low-power robust cell	Electronics industry	-	TFET SRAM
[141]	Concept of prognostics and systems health management (PHM)	Medical industry	-	Smart object appliance
[142]	The idea of Industrial IoT (IIoT) focusing on Low-Power Wide-Area Networks (LPWANs)	The indoor industrial monitoring system	LoRaWAN SF 7 LoRaWAN Fair Mod. IEEE 802.15.4	Industrial sensors
[143]	Industrial Blockchain Tokenizer (IBT) technology	Industrial robot security	Ad-hoc Haye	Sensors

5.6. Infrastructural Applications

IoT-based networks can be used in various applications at a time. Therefore, this section discusses the studies that have been conducted regarding the infrastructural usage of IoT. Diro et al. [144] proposed an incorporated structure for IoT/Fog and SDN. This helps to achieve significant features, including packet delay reduction and the possibility of misplaced packets, overflow space conflict, and the highest throughput. This study emphasizes the divergence and necessity of flow space allocation that is capable of producing essential and risky flows. It explains the balance between ordinary packet flows in the Fog communication model and SDN process programmability. This structure opts for the level of flow space allocation variance following the preference of QoS requirements. The obtained results show that critical flow classes offered more efficient support in comparison to the Naïve method, devoid of trading with a typical flow class fairness distribution. The results mainly focus on improving QoS elements, including the delay, data rate, and probability; however, scenarios with numerous and virtualized devices were not considered. Another approach in which a process for resource management of Fog virtualized networks with energy efficiency was suggested by Vinueza Naranjo et al. [145]. The proposed structure operates at the Middleware layer to sustain active immediate clearing in interacting virtualized assets. It consists of satisfying QoS features, especially the energy consumption, but does not include any earlier statistics and evidence. Chen et al. [146] introduced a new paradigm of effective resource processing for IoT smart applications. The authors developed a resource-efficient computation discharging technique through a device using a hybrid approach. The objective of this study was to enable smart IoT users to reduce the cloud resource practice concerning QoS limitations. The results show the improvement in the performance of the recommended algorithm in view of the resource effectiveness.

In a study conducted by Mangia et al. [147], a technique for rankness-based condensed detection for IoT functions was introduced. This technique is employed in the case of multiple-graph signals and is an effective way of controlling and regulating the ideal balance of short and prolonged types of communications. It focuses on infrastructural IoT advancement and expansion, requiring local WSN and physical data centers. The findings obtained from the conducted experiments indicate that the consumption of the recommended technique leads to about 25% power-saving. In the study performed by Taghadosi et al. [148], a fully incorporated and highly effective power-conserving rectifier circuit was developed. A critical circuit prototype was designed to sustain the rectifier model that was created with regards to two upgraded rectifiers manufactured using a 65nm complementary metal-oxide-semiconductor (CMOS) GlobalFoundries (GF) Radio-Frequency (RF) procedure and the Dickson charge circuit. The suggested design relates to the flip-chip approach that has been utilized to avoid low QoS results. The results obtained from the simulation demonstrate the high performance of the two rectifiers, and the benefit is the development of a very sensitive circuit. Alabady et al. [149] studied the correction code and error detection called the Low Complexity Parity Check (LCPC) code for WSN IoT applications. The authors performed BER performance evaluations within the suggested LCPC codes, Bose–Chaudhuri–Hocquenghem (BCH) codes, and binary/non-binary LDPC codes. The obtained findings show an enhancement of the BER performance for the suggested LCPC code compared to the Low Density Parity Check Code (LDPC), and Hamming, Reed–Solomon (RS), and BCH codes.

Ouedraogo et al. [150] suggested an answer for QoS management of the IoT-based HetNet scenario. The authors show a significant interest in expanding network functions through traffic-made middleware-oriented applications. A rerouting network function was developed and operated without troubling the transmission of data dynamically. Kolomvatsos et al. [151] recommended an intelligent supplied paradigm to improve the impartial nature of IoT nodes for revising management in IoT applications. The study suggested that each node processes the update procedure independently by examining certain network implementation elements. A simulated neural network was designed to determine the appropriate phase with which to complete the update process. Moreover, the authors suggested an alternative for the load settling matter in the improvement process. The proposed scheme prevents excessive and unnecessary messages and retrievals, which leads to the use of a maximum bandwidth, in order to diminish the energy supply and enhance the lifespan of network and IoT devices. However, the system is not over-charged with the update messages, which ensures a high-performance level for each node compared to centralized systems. The research work conducted by Limonad et al. [152] introduces a conventional paradigm for the appearance of a hazard centric enterprise following *Shield*. The developed design is the establishment of IoT methodologies recognized for a user's daily actions, such as job-related safety, personal wellness, and home insurance. The recommended *Shields* model is responsible for the significant ideas needed for the development of hazard-oriented IoT applications. The principal function of IoT applications is currently being verified through the identification of risks in associated environments. The proposed *Shields* model was founded on three physical computational topologies that were tested, starting with the edge topology, and followed by the mobile-based and cloud-centric topologies. These three tests offer limited challenges involving the dynamic composition of the performance through various computational nodes. Furthermore, a device was implemented following the suggested model to ensure transmission among the parts required in the process of needs collection and domain assessment. The designed model is suitable for analysis and the development of any IoT application. Unfortunately, this investigation lacks a verification and confirmation procedure to evaluate the recommended template and consider the QoS property.

Abedin et al. [153] investigated the guarantee of QoS for end-users by effectively assigning limited network supplies to various IoT applications (see Table 8). A systematic hierarchy procedure based on a corresponding methodology was suggested for self-organizing and separated user groups and source provision, which remain suitable and accessible for dense Fog scenarios. The researchers conducted an experiment that verified the recommended solution for user association and resource allocation in the Fog environment. The effectiveness and productivity of the suggested spectrum sharing technique and the constancy of the user involvement of a higher value and efficiency represent the benefits of this research. The work in [154] suggests an IoT-based WSDN architecture directed to operate with the usage-particular requirement and necessities. The architecture has sensors and a managing node, which can support SDN in WSN. Two elements have been suggested to ensure the QoS network: (1) A controller device manager, which is used to manage the device-specific responsibilities, and (2) a topology manager, which is adapted to handle the network topology. The suggested solution focusing on sensors and protocol management was compared to the actual SDN approaches for WSNs. The obtained results show that this solution is valuable for usage-particular service offerings, at the same time as enhancing and boosting the network routines with conventional sensor networking techniques. The suggested solution does not take into consideration the decrease in the network delay and control messages overhead.

Table 8. IoT infrastructural applications.

Reference	Focus Area	Application	Protocol	Device
[144]	SDN allocation method and IoT/fog	Very low and predictable latency applications	Openflow	Smart devices
[145]	Energy-efficient resource management	• Industry 4.0 • Internet of energy • Big data streaming • Vehicular mobility • Smart city	TCP/IP 5G	Smart devices
[146]	Resource-efficient edge computing	• Flying ad hoc networks for precision agriculture • E-health • Smart homes	Cellular	Intelligent IoT device
[147]	Compressed sensing based on reakness for IoT applications	• IoT scenarios consisting of local WSN	-	-
[148]	Energy-efficient saving rectifier circuits	• Energy harvesting • Biomedical applications	Bluetooth/ WLAN	-
[149]	Low complexity parity checking	Wireless sensor networks	-	• Wearable devices • Smart sensors • Smartphones
[150]	QoS-independent and dynamic management	M2M	Cellular 3G and 4G	PC and smartphone
[151]	Software update management	Pervasive IoT applications	CoAP	-
[152]	Hazard-oriented analysis and implementation	Hazard-centric IoT application	-	-
[153]	Mobile broadband resource allocation in Fog networks	Mobile broadband	Cellular	Smartphones
[154]	WSDN management system	• Device management • Network management	IEEE.802.15.4 IEEE 802.11	-

6. Discussion

With the expansion of the internet and exploring various ideas of bringing networks into the physical domain, the evolution of the IoT structure is rapidly increasing. It employs the extensive implementation of spatially distributed devices with embedded detection, sensing, and actuation abilities. IoT foresees a potential in which digital and physical entities can be connected, through suitable knowledge and communication tools, in order to facilitate an entirely new category of applications and services. The purpose of this study consisted of examining and evaluating the main factors associated with the use of IoT regarding exchange, including healthcare, environmental, commercial, industrial, smart city, and infrastructural applications. The IoT has opened up a world of opportunities in healthcare: When linked to the internet, ordinary health machines can collect important supplementary records, provide additional understanding on symptoms and indications, permit remote healthcare systems, and mostly give patients extra control over their survival and treatment. Similarly, the applications of IoT in environmental examining are extensive, such as environmental safety, severe weather prediction, water protection, compromised species safety, viable agriculture, and more.

Moreover, IoT-enabled smart cities utilize examples that span numerous areas, from providing a better ecosystem and advancing traffic flow to improving people's safety and optimizing road lighting. As IoT technology advances, municipalities are becoming more and more linked in a struggle to increase the effectiveness of infrastructure systems, enhance consistency and responsiveness in disaster situations, manage budgets, and more. Additionally, commercial IoT targets our daily environment outside of the home (consumer IoT). There is a set of applications that can be deployed in places which people frequently visit, such as commercial office buildings, supermarkets, stores, hotels, healthcare facilities, and entertainment venues. The applications for these places vary from variable monitoring to environmental conditions, personal control scheduling, and building access, as well as connected lighting, asset tracking, and many more. Likewise, industrial IoT targets existing automated industrial systems looking for dramatic improvements in productivity and efficiency. The most common sectors are large-scale factories or manufacturing plants, but these are also known to have monitoring utilities and expensive assets. In short, it can be observed that by using IoT devices, industries can advance in terms of automation, software, and connectivity and deliver enormous productivity and efficiency benefits to their operations.

7. IoT Challenges

Table 9 summarizes the research challenges and opportunities for IoT applications.

Table 9. IoT application challenges and opportunities.

IoT Application	Challenges	Opportunities
Healthcare applications	• User's privacy and data leakage [155] • Standardization challenges [156] • Scalability [157] • Availability [158]	• Intelligent systems [156] • Wide consumer market demand • IoT-based applications with higher intrinsic value, but longer expected payback on investment [157]
Environmental applications	• Authentication and authorization [156] • Manage interdependencies between objects [156] • Cost and modularity [159] • Different granularity levels [157]	• Intelligent systems [156] • Energy sustainability [156]
Smart city applications	• Authentication and authorization architecture challenges [156] • Technical challenges [156] • Mobility challenges [160] • Interoperability [161] • Big data analytics [161]	• Safety [162] • Mobility-as-a-service [162] • Traffic management and parking [162] • Smart grid [163]
Commercial applications	• Privacy and security challenges [156] • Encryptions vs. efficiency [161] • Cost efficiency [48] • Weakness in implementation methods [48]	• Exponential business growth [155] • Internetworking [155]

Table 9. *Cont.*

IoT Application	Challenges	Opportunities
Industrial applications	• Authentication and authorization [155] • Hardware challenges [156] • Efficiency and product loss [155] • SW/HW and data attacks [155] • Lack of willingness to share information [156]	• Smart factories [155] • Smart grids [155] • Intelligent coal mine [156] • Energy sustainability [156] • Smart factories [156]
Infrastructural applications	• Standardization challenges [156] • Trust management [48]	• Energy efficiency [164] • Real-time performance [164]

8. IoT and Next Generation Protocol

The IPv6 suite primary protocol is neighbor discovery protocol (NDP), and is considered a replacement for the address resolution protocol (ARP) function in IPv4 [165]. The IPv6 protocol considers an extremely auspicious protocol for complicated and dispersed network applications in the era of IoT and Industry 4.0. However, its industrial implementation is slowly increasing in smart manufacturing methods [166]. As the number of devices in the network grows, the received data becomes complex and complicated, which requires more efficient approaches to be collected, sorted, and processed to achieve higher QoS values [167]. This has led researchers and developers to focus on designing various smart network protocols with self-organizing, self-management, and self-configure features, which can able full 3GPP standards and establish an uninterrupted network [168].

Moreover, the IoT6, which is the research project of the future IoT, is progressing positively, yet the unification of IPv6 and IoT is struggling with some challenges. The aim is to exploit the potential of IPv6 and related standards to overcome current shortcomings and fragmentation of the IoT [169]. Currently, the prime issue is the need to integrate the IPv6 and corresponding protocol with IoT, which can help to offer various applications such as automation, smart homes, and smart cities. However, due to wish to design an efficient protocol, some of the significant issues, such as the integration, complexity, scalability, security, reliability, flexibility, and homogeneity, need to be investigated for more IoT applications.

9. Conclusions

The objective of this paper was to explain and describe new trends in IoT applications. This paper presents a survey of the latest studies conducted regarding IoT applications in the most important fields, including healthcare, the environment, smart cities, commercial, and industrial application domains. This study aimed to survey and review the various and most famous IoT application areas, in order to understand the diverse methodologies. The study has summarized the various challenges, such as data privacy and scalability for the healthcare applications, authorization and cost issues for environmental applications, mobility and architecture challenges for smart city applications, cost and implementation difficulties for commercial applications, hardware and production problems for industrial applications, and standardization and trust issues for infrastructural applications. It has stated that various IoT applications still need to be exploited, such as blockchain technology, in order to maintain transaction information, enhance the existing structure performance, or develop next-generation systems. This can help to achieve extra safety, automatic business management, distributed platforms, offline-to-online information authentication, and so on. Moreover, the security and privacy characteristics of IoT are the key factors that can lead to its ability to be developed into a universally implemented technology in the future. However, the self-organizing and accessible nature of IoT makes it susceptible to numerous insider and outsider attackers. This may compromise the users' security and privacy, enabling access to a user's private data, financial damage, and eavesdropping. Therefore, more advanced optimized algorithms and protocols are required to secure data privacy. It can be concluded that by designing an energy- and cost-efficient intelligent network with potential business growth for IoT systems, the next generation of development technology can be produced.

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References

1. Holma, H.; Toskala, A.; Nakamura, T. *5G Technology: 3GPP New Radio*; John Wiley & Sons: Hoboken, NJ, USA, 2020.
2. Faizan, Q. Enhancing QOS Performance of the 5G Network by Characterizing Mm-Wave Channel and Optimizing Interference Cancellation Scheme/Faizan Qamar. Ph.D. Thesis, University of Malaya, Kuala Lumpur, Malaysia, 2019.
3. Polese, M.; Giordani, M.; Zugno, T.; Roy, A.; Goyal, S.; Castor, D.; Zorzi, M. Integrated Access and Backhaul in 5G mmWave Networks: Potential and Challenges. *IEEE Commun. Mag.* **2020**, *58*, 62–68. [CrossRef]
4. Qamar, F.; Siddiqui, M.H.S.; Hindia, M.N.; Dimyati, K.; Abd Rahman, T.; Talip, M.S.A. Propagation Channel Measurement at 38 GHz for 5G mm-wave communication Network. In Proceedings of the 2018 IEEE Student Conference on Research and Development (SCOReD), Selangor, Malaysia, 26–28 November 2018; pp. 1–6.
5. Hindia, M.N.; Qamar, F.; Ojukwu, H.; Dimyati, K.; Al-Samman, A.M.; Amiri, I.S. On Platform to Enable the Cognitive Radio Over 5G Networks. In *Wireless Personal Communications*; Springer: New York, NY, USA, 2020; pp. 1241–1262.
6. Bogale, T.E.; Le, L.B. Massive MIMO and mmWave for 5G wireless HetNet: Potential benefits and challenges. *IEEE Veh. Technol. Mag.* **2016**, *11*, 64–75. [CrossRef]
7. Mohamed, E.M.; Elhalawany, B.M.; Khallaf, H.S.; Zareei, M.; Zeb, A.; Abdelghany, M.A. Relay Probing for Millimeter Wave Multi-Hop D2D Networks. *IEEE Access* **2020**, *8*, 30560–30574. [CrossRef]
8. Hindia, M.N.; Qamar, F.; Abbas, T.; Dimyati, K.; Abu Talip, M.S.; Amiri, I.S. Interference cancelation for high-density fifth-generation relaying network using stochastic geometrical approach. *Int. J. Distrib. Sens. Netw.* **2019**, *15*, 1550147719855879. [CrossRef]
9. Dahnil, D.P.; Hassan, R. Wireless Sensor Networks: A framework for community and educational gardens. *Adv. Sci. Lett.* **2018**, *24*, 1153–1157. [CrossRef]
10. Tilwari, V.; Hindia, M.N.; Dimyati, K.; Qamar, F.; Talip, A.; Sofian, M. Contention Window and Residual Battery Aware Multipath Routing Schemes in Mobile Ad-hoc Networks. *Int. J. Technol.* **2019**, *10*, 1376–1384. [CrossRef]
11. Amiri, I.; Dong, D.S.; Pokhrel, Y.M.; Gachhadar, A.; Maharjan, R.K.; Qamar, F. Resource Tuned Optimal Random Network Coding for Single Hop Multicast future 5G Networks. *Int. J. Electron. Telecommun.* **2019**, *65*, 463–469.
12. Li, J.; Lei, G.; Manogaran, G.; Mastorakis, G.; Mavromoustakis, C.X. D2D communication mode selection and resource optimization algorithm with optimal throughput in 5G network. *IEEE Access* **2019**, *7*, 25263–25273. [CrossRef]
13. Qamar, F.; Dimyati, K.; Hindia, M.N.; Noordin, K.A.; Amiri, I.S. A stochastically geometrical poisson point process approach for the future 5G D2D enabled cooperative cellular network. *IEEE Access* **2019**, *7*, 60465–60485. [CrossRef]
14. Elijah, O.; Rahman, T.A.; Orikumhi, I.; Leow, C.Y.; Hindia, M.N. An Overview of Internet of Things (IoT) and Data Analytics in Agriculture: Benefits and Challenges. *IEEE Internet Things J.* **2018**, *5*, 3758–3773. [CrossRef]

15. Aman, A.H.M.; Yadegaridehkordi, E.; Attarbashi, Z.S.; Hassan, R.; Park, Y.J. A Survey on Trend and Classification of Internet of Things Reviews. *IEEE Access* **2020**, *8*, 111763–111782. [CrossRef]
16. Udeshi, D.; Qamar, F. Quality Analysis Of Epon Network For Uplink and Downlink Design. *Asian J. Eng. Sci. Technol.* **2014**, *4*, 78–83.
17. Gachhadar, A.; Qamar, F.; Dong, D.S.; Majed, M.B.; Hanafi, E.; Amiri, I.S. Traffic Offloading in 5G Heterogeneous Networks using Rank based Network Selection. *J. Eng. Sci. Technol. Rev.* **2019**, *12*, 9–16. [CrossRef]
18. Hashem, I.A.T.; Yaqoob, I.; Anuar, N.B.; Mokhtar, S.; Gani, A.; Khan, S.U. The rise of "big data" on cloud computing: Review and open research issues. *Inf. Syst.* **2015**, *47*, 98–115. [CrossRef]
19. Gachhadar, A.; Hindia, M.N.; Qamar, F.; Siddiqui, M.H.S.; Noordin, K.A.; Amiri, I.S. Modified genetic algorithm based power allocation scheme for amplify-and-forward cooperative relay network. *Comput. Electr. Eng.* **2018**, *69*, 628–641. [CrossRef]
20. Hassan, R.; Aman, A.H.M.; Latiff, L.A. Framework for Handover process using Visible Light Communications in 5G. In Proceedings of the 2019 Symposium on Future Telecommunication Technologies (SOFTT), Kuala Lumpur, Malaysia, 18–19 November 2019; pp. 1–4.
21. Le, A.T.; Huang, X.; Guo, Y.J. Beam-Based Analog Self-Interference Cancellation in Full-Duplex MIMO Systems. *IEEE Trans. Wirel. Commun.* **2020**, *19*, 2460–2471. [CrossRef]
22. Saizan, Z.; Singh, D. Cyber security awareness among social media users: Case study in German-Malaysian Institute (GMI). *Asia Pac. J. Inf. Technol. Multimed.* **2018**, *7*, 111–127. [CrossRef]
23. Muniyandi, R.C.; Qamar, F.; Jasim, A.N. Genetic Optimized Location Aided Routing Protocol for VANET Based on Rectangular Estimation of Position. *Appl. Sci.* **2020**, *10*, 5759. [CrossRef]
24. Mamode, M.I.S.; Fowdur, T.P. Survey of Scheduling Schemes in 5G Mobile Communication Systems. *J. Electr. Eng. Electron. Control Comput. Sci.* **2020**, *6*, 21–30.
25. Giordani, M.; Zorzi, M. Satellite communication at millimeter waves: A key enabler of the 6G era. In Proceedings of the 2020 International Conference on Computing, Networking and Communications (ICNC), Big Island, HI, USA, 17–20 February 2020; pp. 383–388.
26. Letaief, K.B.; Chen, W.; Shi, Y.; Zhang, J.; Zhang, Y.J.A. The roadmap to 6G: AI empowered wireless networks. *IEEE Commun. Mag.* **2019**, *57*, 84–90. [CrossRef]
27. Jameel, F.; Sharma, N.; Khan, M.A.; Khan, I.; Alam, M.M.; Mastorakis, G.; Mavromoustakis, C.X. Machine learning techniques for wireless-powered ambient backscatter communications: Enabling intelligent IoT networks in 6G era. In *Convergence of Artificial Intelligence and the Internet of Things*; Springer: Cham, Switzerland, 2020; pp. 187–211.
28. Kato, N.; Mao, B.; Tang, F.; Kawamoto, Y.; Liu, J. Ten Challenges in Advancing Machine Learning Technologies toward 6G. *IEEE Wirel. Commun.* **2020**, *27*, 96–103. Available online: https://ieeexplore.ieee.org/document/9061001 (accessed on 1 September 2020). [CrossRef]
29. Hewa, T.; Gür, G.; Kalla, A.; Ylianttila, M.; Bracken, A.; Liyanage, M. The Role of Blockchain in 6G: Challenges, Opportunities and Research Directions. In Proceedings of the 2020 2nd 6G Wireless Summit (6G SUMMIT), Levi, Finland, 17–20 March 2020; pp. 1–5.
30. Liu, Y.; Yuan, X.; Xiong, Z.; Kang, J.; Wang, X.; Niyato, D. Federated Learning for 6G Communications: Challenges, Methods, and Future Directions. *arXiv* **2020**, arXiv:2006.02931.
31. Hindia, M.N.; Qamar, F.; Majed, M.B.; Rahman, T.A.; Amiri, I.S. Enabling remote-control for the power sub-stations over LTE-A networks. *Telecommun. Syst.* **2019**, *70*, 37–53. [CrossRef]
32. Qamar, F.; Siddiqui, M.U.A.; Hindia, M.; Hassan, R.; Nguyen, Q.N. Issues, Challenges, and Research Trends in Spectrum Management: A Comprehensive Overview and New Vision for Designing 6G Networks. *Electronics* **2020**, *9*, 1416. [CrossRef]
33. Mahmood, N.H.; Alves, H.; López, O.A.; Shehab, M.; Osorio, D.P.M.; Latva-Aho, M. Six key features of machine type communication in 6G. In Proceedings of the 2020 2nd 6G Wireless Summit (6G SUMMIT), Levi, Finland, 17–20 March 2020; pp. 1–5.
34. Leloglu, E. A review of security concerns in Internet of Things. *J. Comput. Commun.* **2016**, *5*, 121–136. [CrossRef]
35. Mohd Zaki, I.; Rosilah, H. The Implementation of Internet of Things using Test Bed in the UKMnet Environment. *Asia Pac. J. Inf. Technol. Multimed.* **2019**, *8*, 1–17.

36. Hassan, R.; Nori, S.S.; Othman, N.E. The improvement of the protection for 6LoWPAN in IoT through non-causal hash function scheme. In Proceedings of the 2018 15th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON), Chiang Rai, Thailand, 18–21 July 2018; pp. 600–603.
37. Whitmore, A.; Agarwal, A.; Da Xu, L. The Internet of Things—A survey of topics and trends. *Inf. Syst. Front.* **2015**, *17*, 261–274. [CrossRef]
38. Ali, Z.M.; Arshad, M.A.B.M.; Bakar, M.A. POLIoT: Internet Of Things Framework In Managing Network Threats At Metro Polytechnic Tasek Gelugor. In Proceedings of the 2018 Cyber Resilience Conference (CRC), Putrajaya, Malaysia, 13–15 November 2018; pp. 1–4.
39. Jain, P.; Adrangi, F.; Venkatachalam, M. Cellular IoT Network Architecture. Google Patents US 10,623,942 B2, 14 April 2020.
40. Korade, S.; Kotak, V.; Durafe, A. A review paper on internet of things (IoT) and its applications. *Int. Res. J. Eng. Technol.* **2019**, *6*, 1623–1630.
41. Wu, F.; Wu, T.; Yuce, M.R. An internet-of-things (IoT) network system for connected safety and health monitoring applications. *Sensors* **2019**, *19*, 21. [CrossRef]
42. Pungus, S.R.; Yahaya, J.; Deraman, A.; Bakar, N.H.B. A data modeling conceptual framework for ubiquitous computing based on context awareness. *Int. J. Electr. Comput. Eng.* **2019**, *9*, 5495–5501. [CrossRef]
43. Alsharif, M.H.; Nordin, R.; Abdullah, N.F.; Kelechi, A.H. How to make key 5G wireless technologies environmental friendly: A review. *Trans. Emerg. Telecommun. Technol.* **2018**, *29*, e3254. [CrossRef]
44. Zhang, H.; Lu, X. Vehicle communication network in intelligent transportation system based on internet of things. *Comput. Commun.* **2020**, *160*, 799–806. [CrossRef]
45. Udoh, I.S.; Kotonya, G. Developing IoT applications: Challenges and frameworks. *IET Cyber Phys. Syst. Theory Appl.* **2018**, *3*, 65–72. [CrossRef]
46. Afzal, B.; Umair, M.; Shah, G.A.; Ahmed, E. Enabling IoT platforms for social IoT applications: Vision, feature mapping, and challenges. *Future Gener. Comput. Syst.* **2019**, *92*, 718–731. [CrossRef]
47. Mekki, K.; Bajic, E.; Chaxel, F.; Meyer, F. A comparative study of LPWAN technologies for large-scale IoT deployment. *ICT Express* **2019**, *5*, 1–7. [CrossRef]
48. Hassan, W.H. Current research on Internet of Things (IoT) security: A survey. *Comput. Netw.* **2019**, *148*, 283–294.
49. Raeespour, A.K.; Patel, A.M. Design and Evaluation of a Virtual Private Network Architecture for Collaborating Specialist Users. *Asia Pac. J. Inf. Technol. Multimed.* **2016**, *5*, 13–50. [CrossRef]
50. Stackowiak, R. Azure IoT Solutions Overview. In *Azure Internet of Things Revealed*; Springer: Berkeley, CA, USA, 2019; pp. 29–54.
51. Mojib, G.; Aman, A.H.M.; Khalaf, M.; Hassan, R. Simulation analysis for QoS in Internet Of Things wireless network. *3C Tecnol.* **2019**, *2019*, 77–83. [CrossRef]
52. Almeida, R.B.; Junes, V.R.C.; da Silva Machado, R.; da Rosa, D.Y.L.; Donato, L.M.; Yamin, A.C.; Pernas, A.M. A distributed event-driven architectural model based on situational awareness applied on Internet of Things. *Inf. Softw. Technol.* **2019**, *111*, 144–158. [CrossRef]
53. Hu, B.; Guan, Z.H.; Chen, G.; Shen, X. A distributed hybrid event-time-driven scheme for optimization over sensor networks. *IEEE Trans. Ind. Electron.* **2018**, *66*, 7199–7208. [CrossRef]
54. Windley, P.J. API Access Control with OAuth: Coordinating interactions with the Internet of Things. *IEEE Consum. Electron. Mag.* **2015**, *4*, 52–58. [CrossRef]
55. Johnson, D.; Ketel, M. IoT: Application Protocols and Security. *Int. J. Comput. Netw. Inf. Secur.* **2019**, *11*, 1–8. [CrossRef]
56. Kambourakis, G.; Kolias, C.; Geneiatakis, D.; Karopoulos, G.; Makrakis, G.M.; Kounelis, I. A State-of-the-Art Review on the Security of Mainstream IoT Wireless PAN Protocol Stacks. *Symmetry* **2020**, *12*, 579. [CrossRef]
57. Sudarshan, A.; Dirisam, S.; Shetty, J.; NS, G.R.S. Review of Protocols used in Enterprise Networks. *Int. J. Eng. Res. Technol.* **2019**, *8*, 53–56.
58. Deebak, B.D.; Al-Turjman, F. A hybrid secure routing and monitoring mechanism in IoT-based wireless sensor networks. *Ad Hoc Netw.* **2020**, *97*, 102022.
59. Malathy, S.; Porkodi, V.; Sampathkumar, A.; Hindia, M.N.; Dimyati, K.; Tilwari, V.; Qamar, F.; Amiri, I.S. An optimal network coding based backpressure routing approach for massive IoT network. *Wirel. Netw.* **2020**, 1–18. [CrossRef]

60. Dohare, A.; Tulika; Mallikarjuna, B. Data Collection in Wireless Sensor Networks Using Prediction Method. *J. Adv. Res. Dyn. Control Syst.* **2019**, *11*, 815–820. [CrossRef]
61. Martin, T.; Geneiatakis, D.; Kounelis, I.; Kerckhof, S.; Fovino, I.N. Towards a Formal IoT Security Model. *Symmetry* **2020**, *12*, 1305. [CrossRef]
62. Popescu, C.R.G.; Popescu, G.N. Risks of cyber attacks on financial audit activity. *Audit Financ. J.* **2018**, *16*, 140–147. [CrossRef]
63. Bahashwan, A.A.O.; Manickam, S. A brief review of messaging protocol standards for internet of things (IoT). *J. Cyber Secur. Mobil.* **2019**, *8*, 1–14. [CrossRef]
64. Hassan, R.; Jubair, A.M.; Azmi, K.; Bakar, A. Adaptive congestion control mechanism in CoAP application protocol for internet of things (IoT). In Proceedings of the 2016 International Conference on Signal Processing and Communication (ICSC), Noida, India, 26–28 December 2016; pp. 121–125.
65. Tukade, T.M.; Banakar, R. Data transfer protocols in IoT—An overview. *Int. J. Pure Appl. Math.* **2018**, *118*, 121–138.
66. Haxhibeqiri, J.; De Poorter, E.; Moerman, I.; Hoebeke, J. A survey of LoRaWAN for IoT: From technology to application. *Sensors* **2018**, *18*, 3995. [CrossRef] [PubMed]
67. Khutsoane, O.; Isong, B.; Abu-Mahfouz, A.M. IoT devices and applications based on LoRa/LoRaWAN. In Proceedings of the IECON 2017-43rd Annual Conference of the IEEE Industrial Electronics Society, Beijing, China, 29 October–1 November 2017; pp. 6107–6112.
68. Järvinen, I.; Daniel, L.; Kojo, M. Experimental evaluation of alternative congestion control algorithms for Constrained Application Protocol (CoAP). In Proceedings of the 2015 IEEE 2nd World Forum on Internet of Things (WF-IoT), Milan, Italy, 14–16 December 2015; pp. 453–458.
69. Bhattacharjya, A.; Zhong, X.; Wang, J.; Li, X. CoAP—Application layer connection-less lightweight protocol for the Internet of Things (IoT) and CoAP-IPSEC Security with DTLS Supporting CoAP. In *Digital Twin Technologies and Smart Cities*; Springer: Cham, Switzerland, 2020; pp. 151–175.
70. Akpakwu, G.A.; Hancke, G.P.; Abu-Mahfouz, A.M. CACC: Context-aware congestion control approach for lightweight CoAP/UDP-based Internet of Things traffic. *Trans. Emerg. Telecommun. Technol.* **2020**, *31*, e3822. [CrossRef]
71. Soni, D.; Makwana, A. A survey on mqtt: A protocol of internet of things (iot). In Proceedings of the International Conference On Telecommunication, Power Analysis And Computing Techniques (ICTPACT-2017), Chennai, India, 4–8 April 2017.
72. Luzuriaga, J.E.; Cano, J.C.; Calafate, C.; Manzoni, P.; Perez, M.; Boronat, P. Handling mobility in IoT applications using the MQTT protocol. In Proceedings of the 2015 Internet Technologies and Applications (ITA), Wales, UK, 8–11 September 2015; pp. 245–250.
73. Hwang, H.C.; Park, J.; Shon, J.G. Design and implementation of a reliable message transmission system based on MQTT protocol in IoT. *Wirel. Pers. Commun.* **2016**, *91*, 1765–1777. [CrossRef]
74. Chien, H.Y.; Chen, Y.J.; Qiu, G.H.; Liao, J.F.; Hung, R.W.; Lin, P.C.; Kou, X.A.; Chiang, M.L.; Su, C. A MQTT-API-compatible IoT security-enhanced platform. *Int. J. Sens. Netw.* **2020**, *32*, 54–68. [CrossRef]
75. Chen, Y.; Kunz, T. Performance evaluation of IoT protocols under a constrained wireless access network. In Proceedings of the 2016 International Conference on Selected Topics in Mobile & Wireless Networking (MoWNeT), Cairo, Egypt, 11–13 April 2016; pp. 1–7.
76. Joe, M.M.; Ramakrishnan, B. Review of vehicular ad hoc network communication models including WVANET (Web VANET) model and WVANET future research directions. *Wirel. Netw.* **2016**, *22*, 2369–2386. [CrossRef]
77. Yassein, M.B.; Shatnawi, M.Q. Application layer protocols for the Internet of Things: A survey. In Proceedings of the 2016 International Conference on Engineering & MIS (ICEMIS), Agadir, Morocco, 22–24 September 2016; pp. 1–4.
78. Karagiannis, V.; Chatzimisios, P.; Vazquez-Gallego, F.; Alonso-Zarate, J. A survey on application layer protocols for the internet of things. *Trans. IoT Cloud Comput.* **2015**, *3*, 11–17.
79. Dizdarević, J.; Carpio, F.; Jukan, A.; Masip-Bruin, X. A survey of communication protocols for internet of things and related challenges of fog and cloud computing integration. *ACM Comput. Surv.* **2019**, *51*, 116. [CrossRef]
80. Asghari, P.; Rahmani, A.M.; Javadi, H.H.S. Internet of Things applications: A systematic review. *Comput. Netw.* **2019**, *148*, 241–261. [CrossRef]

81. Bello, O.; Zeadally, S. Toward efficient smartification of the Internet of Things (IoT) services. *Future Gener. Comput. Syst.* **2019**, *92*, 663–673. [CrossRef]
82. Talavera, J.M.; Tobón, L.E.; Gómez, J.A.; Culman, M.A.; Aranda, J.M.; Parra, D.T.; Quiroz, L.A.; Hoyos, A.; Garreta, L.E. Review of IoT applications in agro-industrial and environmental fields. *Comput. Electron. Agric.* **2017**, *142*, 283–297. [CrossRef]
83. Han, S.N.; Khan, I.; Lee, G.M.; Crespi, N.; Glitho, R.H. Service composition for IP smart object using realtime Web protocols: Concept and research challenges. *Comput. Stand. Interfaces* **2016**, *43*, 79–90. [CrossRef]
84. Li, S.; Da Xu, L.; Zhao, S. The internet of things: A survey. *Inf. Syst. Front.* **2015**, *17*, 243–259. [CrossRef]
85. Souri, A.; Asghari, P.; Rezaei, R. Software as a service based CRM providers in the cloud computing: Challenges and technical issues. *J. Serv. Sci. Res.* **2017**, *9*, 219–237. [CrossRef]
86. Souri, A.; Rahmani, A.M.; Jafari Navimipour, N. Formal verification approaches in the web service composition: A comprehensive analysis of the current challenges for future research. *Int. J. Commun. Syst.* **2018**, *31*, e3808. [CrossRef]
87. Chettri, L.; Bera, R. A comprehensive survey on Internet of Things (IoT) toward 5G wireless systems. *IEEE Internet Things J.* **2019**, *7*, 16–32. [CrossRef]
88. Tun, S.Y.Y.; Madanian, S.; Mirza, F. Internet of things (IoT) applications for elderly care: A reflective review. *Aging Clin. Exp. Res.* **2020**. [CrossRef]
89. Redhu, S.; Maheshwari, M.; Yeotikar, K.; Hegde, R.M. Joint Data Latency and Packet Loss Optimization for Relay-Node Selection in Time-Varying IoT Networks. In Proceedings of the 24th Annual International Conference on Mobile Computing and Networking, New Delhi, India, 29 October–2 November 2018; pp. 711–713.
90. De Almeida, I.B.F.; Mendes, L.L.; Rodrigues, J.J.; da Cruz, M.A. 5G waveforms for IoT applications. *IEEE Commun. Surv. Tutor.* **2019**, *21*, 2554–2567. [CrossRef]
91. Kim, S.; Kim, S. User preference for an IoT healthcare application for lifestyle disease management. *Telecommun. Policy* **2018**, *42*, 304–314. [CrossRef]
92. Fafoutis, X.; Clare, L.; Grabham, N.; Beeby, S.; Stark, B.; Piechocki, R.; Craddock, I. Energy neutral activity monitoring: Wearables powered by smart inductive charging surfaces. In Proceedings of the 2016 13th Annual IEEE International Conference on Sensing, Communication, and Networking (SECON), London, UK, 27–30 June 2006; pp. 1–9.
93. Jimenez, F.; Torres, R. Building an IoT-aware healthcare monitoring system. In Proceedings of the 2015 34th International Conference of the Chilean Computer Science Society (SCCC), Santiago, Chile, 9–13 November 2015; pp. 1–4.
94. Ding, Y.; Gang, S.; Hong, J. The design of home monitoring system by remote mobile medical. In Proceedings of the 2015 7th International Conference on Information Technology in Medicine and Education (ITME), Huangshan, China, 13–15 November 2015; pp. 278–281.
95. Atlam, H.F.; Wills, G.B. IoT security, privacy, safety and ethics. In *Digital Twin Technologies and Smart Cities*; Springer: Cham, Switzerland, 2020; pp. 123–149.
96. Baloch, Z.; Shaikh, F.K.; Unar, M.A. A context-aware data fusion approach for health-IoT. *Int. J. Inf. Technol.* **2018**, *10*, 241–245. [CrossRef]
97. Subrahmanyam, V.; Zubair, M.A.; Kumar, A.; Rajalakshmi, P. A low power minimal error IEEE 802.15. 4 Transceiver for heart monitoring in IoT applications. *Wirel. Pers. Commun.* **2018**, *100*, 611–629. [CrossRef]
98. Lin, S.C.; Wen, C.Y.; Sethares, W.A. Two-tier device-based authentication protocol against PUEA attacks for IoT applications. *IEEE Trans. Signal Inf. Process. Over Netw.* **2017**, *4*, 33–47. [CrossRef]
99. Damis, H.A.; Khalid, N.; Mirzavand, R.; Chung, H.J.; Mousavi, P. Investigation of epidermal loop antennas for biotelemetry IoT applications. *IEEE Access* **2018**, *6*, 15806–15815. [CrossRef]
100. Elappila, M.; Chinara, S.; Parhi, D.R. Survivable path routing in WSN for IoT applications. *Pervasive Mob. Comput.* **2018**, *43*, 49–63. [CrossRef]
101. Jebadurai, J.; Peter, J.D. Super-resolution of retinal images using multi-kernel SVR for IoT healthcare applications. *Future Gener. Comput. Syst.* **2018**, *83*, 338–346. [CrossRef]
102. Malik, H.; Alam, M.M.; Le Moullec, Y.; Kuusik, A. NarrowBand-IoT performance analysis for healthcare applications. *Procedia Comput. Sci.* **2018**, *130*, 1077–1083. [CrossRef]
103. Hamdan, R. Human factors for IoT services utilization for health information exchange. *J. Theor. Appl. Inf. Technol.* **2018**, *96*, 2095–2105.

104. Shahidul Islam, M.; Islam, M.T.; Almutairi, A.F.; Beng, G.K.; Misran, N.; Amin, N. Monitoring of the human body signal through the Internet of Things (IoT) based LoRa wireless network system. *Appl. Sci.* **2019**, *9*, 1884. [CrossRef]
105. Dauwed, M.A.; Yahaya, J.; Mansor, Z.; Hamdan, A.R. Determinants of internet of things services utilization in health information exchange. *J. Eng. Appl. Sci.* **2018**, *13*, 10490–10501.
106. Li, H.; Wang, H.; Yin, W.; Li, Y.; Qian, Y.; Hu, F. Development of a remote monitoring system for henhouse environment based on IoT technology. *Future Internet* **2015**, *7*, 329–341. [CrossRef]
107. Kim, N.S.; Lee, K.; Ryu, J.H. Study on IoT based wild vegetation community ecological monitoring system. In Proceedings of the 2015 Seventh International Conference on Ubiquitous and Future Networks, Sapporo, Japan, 7–10 July 2015; pp. 311–316.
108. Nordin, R.; Mohamad, H.; Behjati, M.; Kelechi, A.H.; Ramli, N.; Ishizu, K.; Kojima, F.; Ismail, M.; Idris, M. The world-first deployment of narrowband IoT for rural hydrological monitoring in UNESCO biosphere environment. In Proceedings of the 2017 IEEE 4th International Conference on Smart Instrumentation, Measurement and Application (ICSIMA), Putrajaya, Malaysia, 28–30 November 2017; pp. 1–5.
109. Yuen, M.C.; Chu, S.Y.; Hong Chu, W.; Shuen Cheng, H.; Lam Ng, H.; Pang Yuen, S. A low-cost IoT smart home system. *Int. J. Eng. Technol.* **2018**, *7*, 3143–3147.
110. Sukmaningsih, D.W.; Suparta, W.; Trisetyarso, A.; Abbas, B.S.; Kang, C.H. Proposing Smart Disaster Management in Urban Area. In Proceedings of the Asian Conference on Intelligent Information and Database Systems, Yogyakarta, Indonesia, 8–11 April 2019; pp. 3–16.
111. Ahamad, F.; Latif, M.; Yusoff, M.; Khan, M.; Juneng, L. So near yet so different: Surface ozone at three sites in Malaysia. *EES* **2019**, *228*, 012024. [CrossRef]
112. Suparta, W.; Alhasa, K.M.; Singh, M.S.J. Preliminary Development of Greenhouse Gases System Data Logger Using Microcontroller Netduino. *Adv. Sci. Lett.* **2017**, *23*, 1398–1402. [CrossRef]
113. Montori, F.; Bedogni, L.; Bononi, L. A collaborative internet of things architecture for smart cities and environmental monitoring. *IEEE Internet Things J.* **2017**, *5*, 592–605. [CrossRef]
114. Zia, T.; Liu, P.; Han, W. Application-specific digital forensics investigative model in internet of things (iot). In Proceedings of the 12th International Conference on Availability, Reliability and Security, Reggio Calabria, Italy, 29 August–1 September 2017; pp. 1–7.
115. Lin, Y.B.; Lin, Y.W.; Hsiao, C.Y.; Wang, S.Y. Location-based IoT applications on campus: The IoTtalk approach. *Pervasive Mob. Comput.* **2017**, *40*, 660–673. [CrossRef]
116. Zeng, X.; Garg, S.K.; Strazdins, P.; Jayaraman, P.P.; Georgakopoulos, D.; Ranjan, R. IOTSim: A simulator for analysing IoT applications. *J. Syst. Archit.* **2017**, *72*, 93–107. [CrossRef]
117. Chen, S.; Liu, B.; Chen, X.; Zhang, Y.; Huang, G. Framework for adaptive computation offloading in iot applications. In Proceedings of the 9th Asia-Pacific Symposium on Internetware, Shanghai, China, 23 September 2017; pp. 1–6.
118. Urbieta, A.; González-Beltrán, A.; Mokhtar, S.B.; Hossain, M.A.; Capra, L. Adaptive and context-aware service composition for IoT-based smart cities. *Future Gener. Comput. Syst.* **2017**, *76*, 262–274. [CrossRef]
119. Seo, D.; Jeon, Y.B.; Lee, S.H.; Lee, K.H. Cloud computing for ubiquitous computing on M2M and IoT environment mobile application. *Clust. Comput.* **2016**, *19*, 1001–1013. [CrossRef]
120. Lee, C.; Wang, C.; Kim, E.; Helal, S. Blueprint flow: A declarative service composition framework for cloud applications. *IEEE Access* **2017**, *5*, 17634–17643. [CrossRef]
121. Akbar, A.; Kousiouris, G.; Pervaiz, H.; Sancho, J.; Ta-Shma, P.; Carrez, F.; Moessner, K. Real-time probabilistic data fusion for large-scale IoT applications. *IEEE Access* **2018**, *6*, 10015–10027. [CrossRef]
122. Sun, X.; Ansari, N. Traffic load balancing among brokers at the IoT application layer. *IEEE Trans. Netw. Serv. Manag.* **2017**, *15*, 489–502. [CrossRef]
123. Sun, X.; Ansari, N. Dynamic resource caching in the IoT application layer for smart cities. *IEEE Internet Things J.* **2017**, *5*, 606–613. [CrossRef]
124. Krishna, G.G.; Krishna, G.; Bhalaji, N. Analysis of routing protocol for low-power and lossy networks in IoT real time applications. *Procedia Comput. Sci.* **2016**, *87*, 270–274. [CrossRef]
125. Naranjo, P.G.V.; Pooranian, Z.; Shojafar, M.; Conti, M.; Buyya, R. FOCAN: A Fog-supported smart city network architecture for management of applications in the Internet of Everything environments. *J. Parallel Distrib. Comput.* **2019**, *132*, 274–283. [CrossRef]

126. Alodib, M. QoS-Aware approach to monitor violations of SLAs in the IoT. *J. Innov. Digit. Ecosyst.* **2016**, *3*, 197–207. [CrossRef]
127. Han, S.N.; Crespi, N. Semantic service provisioning for smart objects: Integrating IoT applications into the web. *Future Gener. Comput. Syst.* **2017**, *76*, 180–197. [CrossRef]
128. Huo, Y.; Qiu, P.; Zhai, J.; Fan, D.; Peng, H. Multi-objective service composition model based on cost-effective optimization. *Appl. Intell.* **2018**, *48*, 651–669. [CrossRef]
129. Huo, L.; Wang, Z. Service composition instantiation based on cross-modified artificial Bee Colony algorithm. *China Commun.* **2016**, *13*, 233–244. [CrossRef]
130. Temglit, N.; Chibani, A.; Djouani, K.; Nacer, M.A. A distributed agent-based approach for optimal QoS selection in web of object choreography. *IEEE Syst. J.* **2017**, *12*, 1655–1666. [CrossRef]
131. Cao, B.; Liu, J.; Wen, Y.; Li, H.; Xiao, Q.; Chen, J. QoS-aware service recommendation based on relational topic model and factorization machines for IoT Mashup applications. *J. Parallel Distrib. Comput.* **2019**, *132*, 177–189. [CrossRef]
132. Cuomo, S.; Di Somma, V.; Sica, F. An application of the one-factor HullWhite model in an IoT financial scenario. *Sustain. Cities Soc.* **2018**, *38*, 18–20. [CrossRef]
133. Hull, J.; White, A. Numerical procedures for implementing term structure models I: Single-factor models. *J. Deriv.* **1994**, *2*, 7–16. [CrossRef]
134. Pustišek, M.; Kos, A. Approaches to front-end IoT application development for the ethereum blockchain. *Procedia Comput. Sci.* **2018**, *129*, 410–419. [CrossRef]
135. Park, J.H. Advances in future Internet and the industrial Internet of Things. *Symmetry* **2019**, *11*, 244. [CrossRef]
136. Li, L.; Li, S.; Zhao, S. QoS-aware scheduling of services-oriented internet of things. *IEEE Trans. Ind. Inform.* **2014**, *10*, 1497–1505.
137. Venticinque, S.; Amato, A. A methodology for deployment of IoT application in fog. *J. Ambient Intell. Humaniz. Comput.* **2019**, *10*, 1955–1976. [CrossRef]
138. Jin, Y.; Raza, U.; Aijaz, A.; Sooriyabandara, M.; Gormus, S. Content centric cross-layer scheduling for industrial IoT applications using 6TiSCH. *IEEE Access* **2017**, *6*, 234–244. [CrossRef]
139. Kiran, M.S.; Rajalakshmi, P. Performance analysis of CSMA/CA and PCA for time critical industrial IoT applications. *IEEE Trans. Ind. Inform.* **2018**, *14*, 2281–2293. [CrossRef]
140. Ahmad, S.; Alam, N.; Hasan, M. Robust TFET SRAM cell for ultra-low power IoT applications. *AEU Int. J. Electron. Commun.* **2018**, *89*, 70–76. [CrossRef]
141. Kwon, D.; Hodkiewicz, M.R.; Fan, J.; Shibutani, T.; Pecht, M.G. IoT-based prognostics and systems health management for industrial applications. *IEEE Access* **2016**, *4*, 3659–3670. [CrossRef]
142. Luvisotto, M.; Tramarin, F.; Vangelista, L.; Vitturi, S. On the use of LoRaWAN for indoor industrial IoT applications. *Wirel. Commun. Mob. Comput.* **2018**, *2018*, 1–11. [CrossRef]
143. Mazzei, D.; Baldi, G.; Fantoni, G.; Montelisciani, G.; Pitasi, A.; Ricci, L.; Rizzello, L. A Blockchain Tokenizer for Industrial IOT trustless applications. *Future Gener. Comput. Syst.* **2020**, *105*, 432–445. [CrossRef]
144. Diro, A.A.; Reda, H.T.; Chilamkurti, N. Differential flow space allocation scheme in SDN based fog computing for IoT applications. *J. Ambient Intell. Humaniz. Comput.* **2018**, 1–11. [CrossRef]
145. Naranjo, P.G.V.; Baccarelli, E.; Scarpiniti, M. Design and energy-efficient resource management of virtualized networked Fog architectures for the real-time support of IoT applications. *J. Supercomput.* **2018**, *74*, 2470–2507. [CrossRef]
146. Chen, X.; Shi, Q.; Yang, L.; Xu, J. ThriftyEdge: Resource-efficient edge computing for intelligent IoT applications. *IEEE Netw.* **2018**, *32*, 61–65. [CrossRef]
147. Mangia, M.; Pareschi, F.; Varma, R.; Rovatti, R.; Kovačević, J.; Setti, G. Rakeness-based compressed sensing of multiple-graph signals for IoT applications. *IEEE Trans. Circuits Syst. II Express Briefs* **2018**, *65*, 682–686. [CrossRef]
148. Taghadosi, M.; Albasha, L.; Quadir, N.A.; Rahama, Y.A.; Qaddoumi, N. High efficiency energy harvesters in 65nm CMOS process for autonomous IoT sensor applications. *IEEE Access* **2017**, *6*, 2397–2409. [CrossRef]
149. Alabady, S.A.; Salleh, M.F.M.; Al-Turjman, F. LCPC error correction code for IoT applications. *Sustain. Cities Soc.* **2018**, *42*, 663–673. [CrossRef]
150. Ouedraogo, C.A.; Medjiah, S.; Chassot, C.; Drira, K. Enhancing middleware-based IoT applications through run-time pluggable Qos management mechanisms. application to a oneM2M compliant IoT middleware. *Procedia Comput. Sci.* **2018**, *130*, 619–627. [CrossRef]

151. Kolomvatsos, K. An intelligent, uncertainty driven management scheme for software updates in pervasive IoT applications. *Future Gener. Comput. Syst.* **2018**, *83*, 116–131. [CrossRef]
152. Limonad, L.; Fournier, F.; Haber, D.; Mashkif, N. "Shields": A Model for Hazard-Oriented Analysis and Implementation of IoT Applications. In Proceedings of the 2018 IEEE International Congress on Internet of Things (ICIOT), San Francisco, CA, USA, 2–7 July 2018; pp. 96–103.
153. Abedin, S.F.; Alam, M.G.R.; Kazmi, S.A.; Tran, N.H.; Niyato, D.; Hong, C.S. Resource allocation for ultra-reliable and enhanced mobile broadband IoT applications in fog network. *IEEE Trans. Commun.* **2018**, *67*, 489–502. [CrossRef]
154. Bera, S.; Misra, S.; Roy, S.K.; Obaidat, M.S. Soft-WSN: Software-defined WSN management system for IoT applications. *IEEE Syst. J.* **2016**, *12*, 2074–2081. [CrossRef]
155. Sengupta, J.; Ruj, S.; Bit, S.D. A Comprehensive survey on attacks, security issues and blockchain solutions for IoT and IIoT. *J. Netw. Comput. Appl.* **2020**, *149*, 102481. [CrossRef]
156. Chen, S.; Xu, H.; Liu, D.; Hu, B.; Wang, H. A vision of IoT: Applications, challenges, and opportunities with china perspective. *IEEE Internet Things J.* **2014**, *1*, 349–359. [CrossRef]
157. Thibaud, M.; Chi, H.; Zhou, W.; Piramuthu, S. Internet of Things (IoT) in high-risk Environment, Health and Safety (EHS) industries: A comprehensive review. *Decis. Support Syst.* **2018**, *108*, 79–95. [CrossRef]
158. Salman, T.; Jain, R. A survey of protocols and standards for internet of things. *Adv. Comput. Commun.* **2017**, *1*, 1–20. [CrossRef]
159. Granell, C.; Havlik, D.; Schade, S.; Sabeur, Z.; Delaney, C.; Pielorz, J.; Usländer, T.; Mazzetti, P.; Schleidt, K.; Kobernus, M. Future Internet technologies for environmental applications. *Environ. Model. Softw.* **2016**, *78*, 1–15. [CrossRef]
160. Islam, S.; Khalifa, O.O.; Hashim, A.H.A.; Hasan, M.K.; Razzaque, M.A.; Pandey, B. Design and Evaluation of a Multihoming-Based Mobility Management Scheme to Support Inter Technology Handoff in PNEMO. *Wirel. Pers. Commun.* **2020**, *114*, 1133–1153. [CrossRef]
161. Mehmood, Y.; Ahmad, F.; Yaqoob, I.; Adnane, A.; Imran, M.; Guizani, S. Internet-of-things-based smart cities: Recent advances and challenges. *IEEE Commun. Mag.* **2017**, *55*, 16–24. [CrossRef]
162. Nambiar, R.; Shroff, R.; Handy, S. Smart cities: Challenges and opportunities. In Proceedings of the 2018 10th International Conference on Communication Systems & Networks (COMSNETS), Banaglore, India, 3–7 January 2018; pp. 243–250.
163. Hasan, M.K.; Ahmed, M.M.; Hashim, A.H.A.; Razzaque, A.; Islam, S.; Pandey, B. A Novel Artificial Intelligence Based Timing Synchronization Scheme for Smart Grid Applications. *Wirel. Pers. Commun.* **2020**, *114*, 1067–1084. [CrossRef]
164. Sisinni, E.; Saifullah, A.; Han, S.; Jennehag, U.; Gidlund, M. Industrial internet of things: Challenges, opportunities, and directions. *IEEE Trans. Ind. Inform.* **2018**, *14*, 4724–4734. [CrossRef]
165. Obba, P.; Okakwu, I.K. Performance Evaluation of IPv6 and IPv4 for Future Technologies. In Proceedings of the Advances in Information and Communication: Proceedings of the 2020 Future of Information and Communication Conference (FICC), San Francisco, CA, USA, 5–6 March 2020; p. 15.
166. Feldner, B.; Herber, P. A qualitative evaluation of IPv6 for the Industrial Internet of Things. *Procedia Comput. Sci.* **2018**, *134*, 377–384. [CrossRef]
167. Sinche, S.; Raposo, D.; Armando, N.; Rodrigues, A.; Boavida, F.; Pereira, V.; Silva, J.S. A Survey of IoT Management Protocols and Frameworks. *IEEE Commun. Surv. Tutor.* **2019**, *22*, 1168–1190. [CrossRef]
168. Cao, J.; Ma, M.; Li, H.; Ma, R.; Sun, Y.; Yu, P.; Xiong, L. A Survey on Security Aspects for 3GPP 5G Networks. *IEEE Commun. Surv. Tutor.* **2019**, *22*, 170–195. [CrossRef]
169. Ahmadi, H.; Arji, G.; Shahmoradi, L.; Safdari, R.; Nilashi, M.; Alizadeh, M. The application of internet of things in healthcare: A systematic literature review and classification. *Univers. Access Inf. Soc.* **2019**, *18*, 837–869. [CrossRef]

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