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Internet of Things: A primer

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We admire the emerging technologies that fascinate us, as it has become part of our daily life. Internet of Things (IoT) plays a major role in simplifying human effort. It leaps forward taking the advantages of latest wireless devices and communication technologies. IoT is a combination of technologies such as ubiquitous and pervasive computing, wireless communication devices and sensors, Internet protocol, and others. IoT logically interconnects and interoperates physical objects (sensors, wired/wireless communication devices) and virtual objects (web applications, virtual machines) over existing Internet infrastructure. IoT collects and records heterogeneous data (such as documents, images, videos, audios, and others) from heterogeneous applications (such as CCTV, medical images, barcode reader, and others) with the help of Internet. People, physical objects, and virtual objects are logically connected to the network to observe and analyze for decision-making. Therefore, IoT has transformed to be an important evolving technology and inevitable in every sectors.

KEYWORDS
big data, Internet of Things, mHealth

1 | INTRODUCTION

Approximately, there are two billion Internet users around the world. Internet is being the major platform for surfing web, sending and receiving emails, social connections/networking, audio/video connectivity, online games, and others (Shahid & Aneja, 2017). Back in the days, we did not have facility to store huge data generated by various entities and these data were not related to one another. However, if all these data modelled properly and analyzed relating the entities, it may give some meaningful pattern that could reveal its behavior and actions. Therefore, we needed to store such huge data, in order to automate the management by observing environment to replace human effort. Consequently, IoT took hold in public administration, research sector, and business entities. As objects in IoT are widely deployed, they require an infrastructure to store and process the huge data for decision-making (called smart) out of human intervention. Due to the vast adaptation, IoT broadly includes many applications such as smart home, smart classroom, smart city, and others (Paul, 2013). As more and more devices are embedded with sensors that have communication abilities, we are moving toward an automated future that transforms Internet of people to Internet of things paradigm (Paul, Ahmad, Rathore, & Jabbar, 2016; Paul, Daniel, Ahmad, & Rho, 2017; Rathore, Ahmad, Paul, & Rho, 2016). Conventional Internet includes servers, and network devices like routers, people information, but it did not record subject oriented, time series data. Humans are imperfect and have limitation to remember things, save information. In this decade, as scalable storage and computing are offered over Internet at any time for pay-per-use basis by cloud, IoT entities are directly linked to the cloud services as shown in Figure 1. IoT is not just about connecting people, but connecting everything on Internet (Chernyshev, Baig, Bello, & Zeadally, 2018; Lin et al., 2015; Stankovic, 2014; Zanella, Bui, Castellani, Vangelista, & Zorzi, 2014), therefore, IoT system and environment seem like an Internet-like structure (Allhoff & Henschke, 2018; Di Martino et al., 2018; Lunardi et al., 2018).

Rest of the paper is organized as follows. An application of smart city is discussed in Section 2. An extensive review is done on IoT architecture in Section 3. A short note on IoT data processing architecture is given in Section 3. A brief survey on some significant IoT applications is presented in Section 4. Some results of IoT use cases are displayed in Section 5, while conclusion is mentioned in Section 6.

2 | SMART CITY

Smart city is one of the applications of IoT and includes many different aspects like managing smart transportation, street lighting, smart parking, video surveillance, municipal Wi-Fi, public utilities (waste

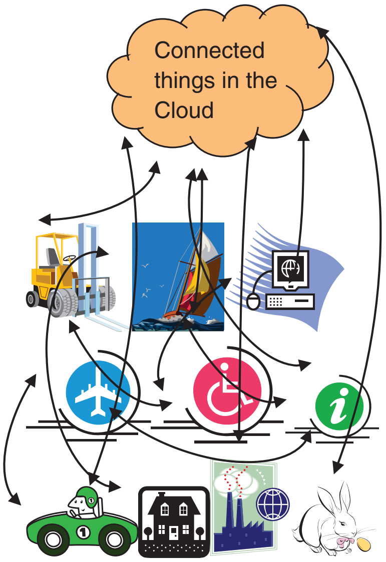

FIGURE 1 Connected things in an Internet of Things scenario

management, water management, electricity management [smart grid]), forest fire monitoring, weather prediction, finding air quality in the city, and so on. For instance,

- Waste management is highly difficult task in growing cities as population is increasing. Attaching low-cost sensors to recycling bins will send information to data center about the type of garbage and when it should be emptied.
- We cannot employ human in the dense forest to monitor animal behavior, security breach, wild fire, and others. Therefore, government deploys sensors to monitor such activities to make proactive measures.
- Nowadays, air quality in the city goes worse due to the increase in motor vehicles. Therefore, finding air quality and the cause of air quality degradation in particular region of a city will help to restore the air quality.

Therefore, smart city solutions can improve city management and quality of life. Moreover, many cities in the world regardless of its size are completely being transformed to be smart and sustainable.

3 | IoT ARCHITECTURE

As its prevalent applications and global initiatives, there is a need for researches to optimize parameters such as power consumption, size, speed, and so on. Moreover, IoT environment requires an infrastructure to store and process the data for decision-making. Because, data globally collected cannot be maintained centrally at one location or in more distributed locations. Therefore, cloud services have become an inseparable solution for IoT applications. As shown in Figure 2, IoT architecture consists of five phases: data collection, data transmission, protocol used to transport data, platform to store and process, and finally decision-making. Research in these IoT phases is rapidly growing as every sector in society is seeking for automated work environment and replace human in certain situations.

Physical devices such as sensors, actuators, transceivers, CCTV, radio-frequency identification (RFID), and others are widely deployed to cover a region of interest (called IoT environment) in various applications for various purposes. These devices are called edge devices. Table 1 categories IoT devices used in different applications. Network infrastructure such as 5G enables IoT to grow exponentially to interact and share data each other without human interaction (Li, Da Xu, & Zhao, 2018). Smart buildings and home are installed with IoT devices such as heating, ventilation, security system, and smart power consumption monitoring systems. These devices are connected with Internet and can be controlled by mobile applications (Alaa, Zaidan, Zaidan, Talal, & Kiah, 2017). The best example of environmental monitoring IoT devices could be found in agriculture. Here, IoT devices are used to measure and evaluate the condition of atmosphere, bio mass of animal and plant and soil. But, not limited to these variables, it can be expanded to check temperature, production of crop, growth of

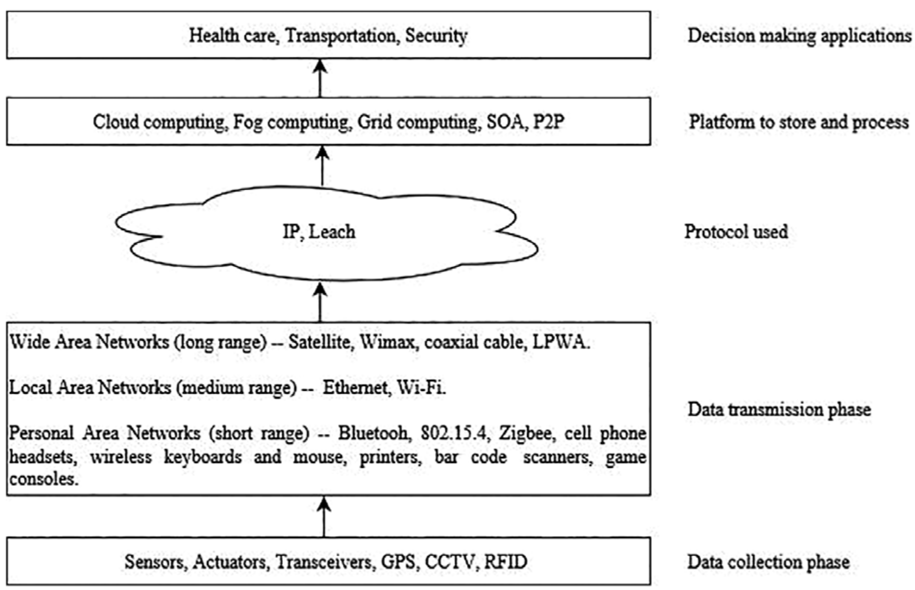

FIGURE 2 Internet of Things architecture

TABLE 1 Devices used in various Internet of Things (IoT) applications

IoT applications	Devices
Smart home/smart buildings	Amazon Echo, Google home voice controller, Nest cam indoor camera, coffee maker, Intelligent yoga mat, Navdy smart navigation system, Nest smoke and co detector, Awair smart air quality monitor, June intelligent oven, Canary home security device, Honey well smart thermostat, etc.
Environmental monitoring	Orbit B-Hyve, Rachio smart sprinkler controller 2nd Gen, IrrigationCaddy, BlueSpray, GreenIQ controller, Filament, etc.
Healthcare	AdhereTech, Breathometer mint, Samsung gear fit, etc.
Smart business/inventory and product management	Samsara sensors, UPS and emergency generators, Light emitting diodes lighting and daylight sensors
Security and surveillance	Awarepoint, iSmartAlarm, Canary flex

plant, and minerals requirement of soil and plant (Talavera et al., 2017). Healthcare IoT devices are available for monitoring, diagnosing and to perform remote surgery. These healthcare IoT devices are connected to E-Hospitals and perform its task where physical appearance of doctor is difficult (Yin, Zeng, Chen, & Fan, 2016), thus solving the problem of unavailability of doctor and analytic equipment in remote areas. Smart business is already using IoT devices for managing the productivity, employees, and to understand market behavior. Researchers develop various models to adopt IoT environment to improve the business. Some of these models are based on Business Canvas model (Dijkman, Sprenkels, Peeters, & Janssen, 2015).

Data collection phase reads/records data from digital/real environment using IoT environment and reconstructs the data to store in a common format. Therefore, data modelling in IoT is a demanding requirement to support heterogeneous applications. Physical devices in IoT environment are working on either battery or electric wired and built to minimize energy consumption/size/cost/others. Manufacturing energy efficient, low cost, long life devices is still a pressing requirement as we require thousands of devices to deploy to observe environment. Similarly, constructing energy efficient and effective algorithms to run in edge device itself (edge computing) is also a challenging task in order to make decision faster. Despite reliability of devices in IoT is guaranteed, there can be faulty nodes that behave in an imperfect way and produce wrong data. Detecting failure of nodes in IoT environment is another research problem to solve.

Every entity in IoT environment is assigned with a IP (IPv6) to connect with Internet or private network and to have identified uniquely. Firstly, IoT devices are connected to personal area network (such as Bluetooth, wireless devices, and others) used in short-range communication. Then, short-range network is connected to the local area network using Wi-Fi, Ethernet, and others. Finally, data generated in IoT devices is connected to the cloud using wide-area networks, which could be private network or Internet. These networks cover physical/virtual objects in different ranges with heterogeneous networking technologies such as wired/wireless/satellite. Moreover, not all the devices used in data collection phase produce same type of data. Such heterogeneous data require different types of protocol to digitize and move it to the target platform. Therefore, data heterogeneity demands generic protocols to support heterogeneous data.

Collected/generated data must be stored in order to process and derive insight for decision-making. Depending on the IoT environment, decision can be made either online (real-time/interactive) or off- line. These processing methods require proper infrastructure to store big data, and efficient algorithms to make decision. We have three different options to make decision based on the requirement as shown in Figure 2: cloud server, edge device, and fog device. (a) Data from IoT environment is brought into centralized servers. Such data is highly voluminous, fast, and heterogeneous. Centralized server can be a supercomputer/cluster computing/grid computing/cloud computing/others. Different computing model has been designed for different purposes. However, cloud computing has attracted businesses and research sectors with its flexible pricing strategy and scalable service feature. Cloud computing is a business model that offers everything as a service based on pay-per-use model, and suitable for IoT environment to setup virtual data center in short-time rather than deploying on-premise data center. It is expected that all industries (manufacturing, transportation, agriculture, and so on) will have IoT initiatives and 90% of all IoT data will be on cloud platform by 2020. (b) Device that generates data is called edge device, which is also called physical object in IoT environment. Sometimes, data is processed in the edge device itself with efficient and effective algorithms. However, it leads to many disadvantages: energy consumption in the device is high, decision is not global, insufficient resource availability. Therefore, it is a challenging task to support processing in edge device for decision-making on real-time. (c) Sometimes, processing can be done in gateway/router/computers/others, which are near to the edge devices. It is called fog computing. Fog computing takes cloud service functionality near to the edge devices in IoT environment. However, the disadvantages that bother edge computing are applicable to fog computing also. There are some rigid differences between cloud computing and fog computing. Cloud computing is centralized while fog computing is highly distributed. Cloud computing infrastructure is built upon racks of servers to offer everything as a service, whereas fog computing is built upon any devices such as routers, gateway, mobile, and others, which are close to the edge devices in IoT environment. These isolated devices dynamically form a computing environment and processes data as devices in fog environment can be moved anywhere in the wireless network. So, data need not be moved to cloud environment for processing. The ultimate objective of fog computing is to make use of the unused heterogeneous resources available in between edge devices and cloud servers. It also minimizes bandwidth consumption and latency of a task because time taken to move data to cloud environment and get back the result is high for some real-time applications. Fog computing eliminates such delay and processes data, and responds in real-time. Fog computing is not a replacement of cloud environment, but will co-exist with cloud computing.

Finally, algorithms used for processing huge stored data or streaming data must be efficient and effective as classical algorithms are not suitable for processing big data for IoT applications (Stackowiak, Mantha, & Nagode, 2015). Algorithms designed for edge computing tend to be lightweight and run in polynomial time. Similarly, on-line and off-line algorithms are completely different in nature and designed for different purposes. Therefore, algorithms for IoT environment (edge device/fog device/centralized server) should be able to provide knowledge in polynomial time and help for decision-making in applications such as health care, transportation, security, and so on.

4 | IoT DATA PROCESSING INFRASTRUCTURE

Exploiting heterogeneities in each level of IoT framework opens up many challenges to work on. Heterogeneity is the characteristics of containing dissimilar elements/entities. Devices in fog computing and servers in cloud data center are becoming more heterogeneous as advanced hardware is deployed every time. Each device has different configuration and capacity. Therefore, latency of a task varies device to device. In cloud data center, either cluster of physical servers or cluster of virtual machines (VMs) is hired for IoT applications to store big data and process. As shown in Figure 2, between edge devices and scalable algorithms, there are many levels of heterogeneities to consider: hardware heterogeneity, VM heterogeneity, performance heterogeneity, and workload heterogeneity.

- Hardware heterogeneity: Nodes in cloud and fog environment are not of same in configuration and performance.
- VM heterogeneity: Virtual cluster of VMs for allocated for big data processing framework such as Hadoop, Spark, Strom, and so on. are not of same flavor over period of time due to horizontally scalable service nature. For instance, Figure 3 shows the heterogeneity levels for MapReduce processing framework.
- Performance heterogeneity: VM performance varies dynamically due to hardware heterogeneity and co-located VM's interference.
- Workload heterogeneity: It indicates jobs of different size, length, resource requirement, amount of data to process, and others.

Therefore, big data frameworks deployed in cloud environment should consider the devices that are part of fog computing for scheduling tasks to exploit more parallelism. To try hands-on experience on IoT concept and demonstrate the methods for setting up IoT environment over Internet, Pfister (2011) sails through step-by-step process using .NET micro framework and Netduino Plus Board with some examples. For instance, to simulate data forwarding among nodes in IoT environment, it requires high level of interoperability (physical/virtual entities interacting each other) and demands hardware-software usability to accomplish linking resources and synchronization of events (Li, Da Xu, & Zhao, 2018; Shahid & Aneja, 2017; Talavera et al., 2017; Yin, Zeng, Chen, & Fan, 2016). For example, Figure 4 contains 10 elements, which are interconnected. If node 1 observes some data that must be sent to node 9, data is forwarded through intermediate nodes by communicating neighbor nodes. Therefore, each node has to communicate each other to move data from source destination without cycling in the network. Any graph can be represented as a matrix or adjacency list for computer programs to process. When a graph is

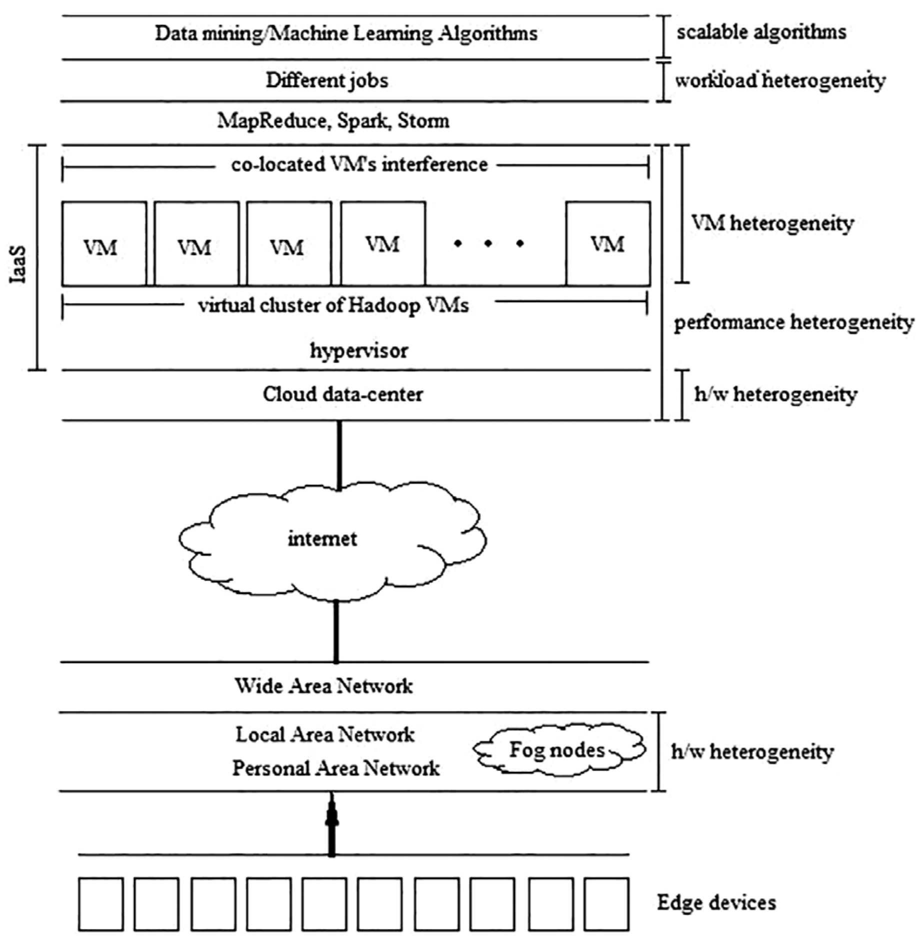

FIGURE 3 Heterogeneity in Internet of Things data processing infrastructure

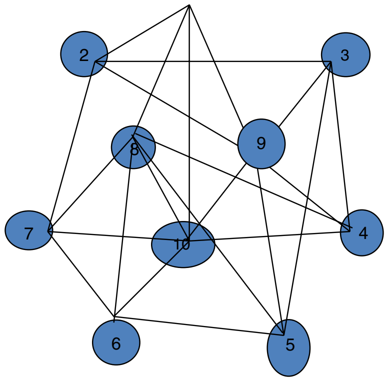

FIGURE 4 Connected things with in a network

modelled as a matrix (e.g., see Figure 5), sometimes it may not be able to load a huge matrix in memory as matrix size (*nxn*) is huge. By using matrix manipulations, we can derive meaningful information.

5 | A SURVEY ON IoT APPLICATIONS

In this section, some significant IoT applications are investigated based on the model, algorithm, and security aspect. Bedi, Venayagamoorthy, Singh, Brooks, and Wang (2018) discuss the issues and challenges present in current electric power and energy systems (EPES). Limitations of present EPES and the role of IoT in converting the traditional electric power network into modern one are discussed in this paper. Moreover, an extensive review on EPES based on IoT is presented along with networking and security for these systems. Supervisory control and data acquisition (SCADA) systems are already deficient in proper security actions, but with the addition of new architectures of IoT based on future Internet, mobile wireless sensor network (WSN), cloud computing, and so on, there are more issues at stakes in the security and deployment of these classical systems. The

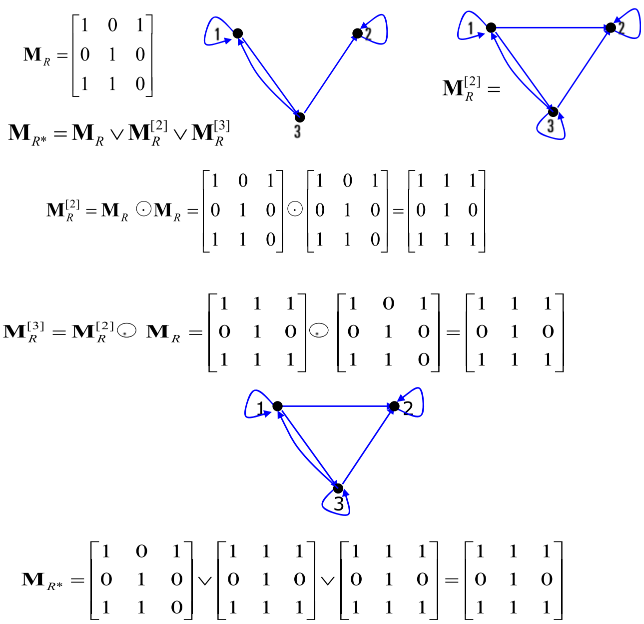

FIGURE 5 Representing connecting entities

main focus of the paper (Sajid, Abbas, & Saleem, 2016) is to acme the security challenges that are in the industrial SCADA-based systems in an IoT-cloud environment. They described present work going on SCADA systems in IoT and cloud environment. They also provided number of works that can be used for securing the system.

IoT is connecting many devices with the help of WSN. These devices are embedded devices, which are very low power, and consist less memory and resources. The work described by Javed, Afzal, Sharif, and Kim (2018) is a detailed comparison of operating systems (OS) used in IoT devices based on architecture, programming models, memory management, and power. Authors compared their work with other survey papers and addressed the major constraints of OS with respect to hardware components. The growth of sensor technology, communication systems, and processing techniques rise in the expansion of smart sensor for the adaptive and advanced applications. A hierarchical taxonomy, localization techniques, and their applications in the different situation are discussed by Shit, Sharma, Puthal, and Zomaya (2018). Taxonomy of localization technique is prepared based on offline training in localization, like training dependent and self-determining approaches. They also compared, various open issues related to localization schemes for IoT and various directions for future research are discussed.

25w?>In health care, IoT applications are prevalent with power-constrained devices such as power aware wearable devices. Baali, Djelouat, Amira, and Bensaali (2018) survey some of the past milestones related to these subsystems of wearable healthcare IoT devises and deliberate promising research directions by addressing their restrictions. They organized their work in accordance to the broadly adopted structure of IoT connected with health wearable devices. Fernández-Caramés and Fraga-Lamas (2018) reviewed Industry 4.0, smart labels and provided details about latest technologies used, their applications, the most applicable academic and commercial applications, and their interior architecture and design necessities, providing researchers with the essential basics for evolving the next cohort of human-cantered smart label applications. This paper is the revision of the basic features of the most current smart label systems for industrial applications. It delivers a detailed comparison on the newest communication technologies in this regard. It also provides many information about the cases where these smart labels can be used. They also proposed a strategy of making smart label system following the principles of the Industry 4.0.

The state-of-the art analytics and network practices for real-time IoT analytics are discussed by Verma, Kawamoto, Fadlullah, Nishiyama, and Kato (2017). Authors first designated the fundamentals of the software platforms, IoT analytics and use cases, and then clarify the shortcomings of the network methodologies to provision them. To discourse those deficiencies, they discussed the pertinent network practices, which may provision IoT analytics and they also presented many future research problems and upcoming research instructions. It is a monotonous task to efficiently pursue and select an appropriate device and/or its data between a large number of existing devices for a specific application. A revision of the many search methods for the IoT, categorizing them according to their strategy principle and also on their search approaches is presented by Pattar, Buyya, Venugopal, Iyengar, and Patnaik (2018). Authors described their advantages and disadvantages, the method adopted, challenges, and a number of future research directions.

6 | RESULTS OF IoT USE CASE: SENSOR AND CLOUD COMBINATION FOR SMART CITY

Currently, in the global information and communications technology (ICT) situation, more and more powerful (usable) devices (such as smart phones, sensors, home appliances, RFID devices, and others) are connected to the Internet, and the amount of traffic in the whole world is large It shows signs of the world of "things" from the perspective of smart appliances or Internet of Things (IoT) by affecting (data sharing, voice, multimedia, and others). Different resources can be aggregated (as in Figure 6) and extracted based on the semantics of customized resources, so it enables something like service paradigm or better "Cloud of Things."

With future Internet plans, the sensor network plays a particularly important role in making hot, smart cities. Smart sensor will be in the world of ICT. However, due to differences in home appliances using sensors, smart sensors are likely to be highly diversified in terms of communication technology, detection function, and sophistication function. This paper aims to contribute to the design of social infrastructure where a new generation of services interact with surrounding environments and to create opportunities for connection or geographical recognition. The architecture proposal is based on the Sensor Web Enablement standard specification and uses IoT's Contiki OS. Smart City is considered a reference scenario.

6.1 | Background

As presented in the current ICT trend (as in Figure 7), sensing and operational resources can participate in the cloud, not simply a simple endpoint, but computing and traditional cloud stacks (abstraction, virtualization, grouping), do not treat it as a stored resource. Additionally, we add opportunities for connecting and geographically recognizing by adding sensors and actuators. Based on the naming convention of virtualized computing resources ("Infrastructure as a Service") and stored resources ("Data as a Service"), using the phrase "Sensing and a Service as Service" (SAaaS). In addition to making a fixed infrastructure, the resulting scenario is very dynamic, as it can include mobile devices with rapid variations. Therefore, we rely on the contribution model of volunteers by the approach under the plan which can solve these problems adequately.

Significant interactions in both the detection environment and the cloud are IoT parts that the actual physical item can abstract based on the semantics of the resource. The actual outline social infrastructure can be made such that such abstraction is performed and discovered and allocated. Things can communicate and save information in the surrounding environment. It can also interact with our environment. According to recent reports by Gartner, by 2020 30 billion devices will be connected. In this way, we can assume scenarios such as a group of extra systems, ecosystems, general equipment, and sensor networks interconnected on the Internet. Therefore it is commonplace to think about possible ways and solutions that can face the

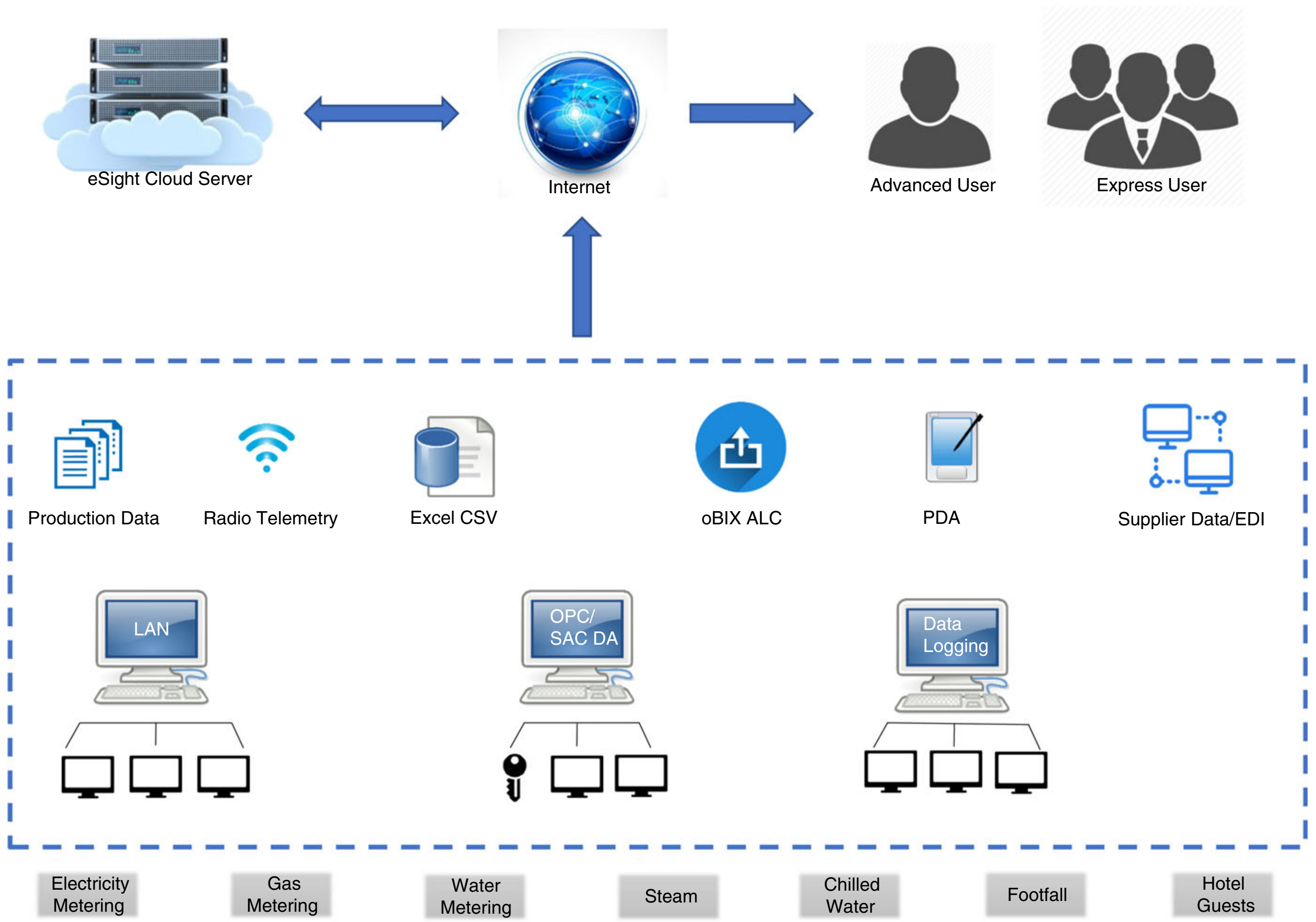

FIGURE 6 City wide data aggregation

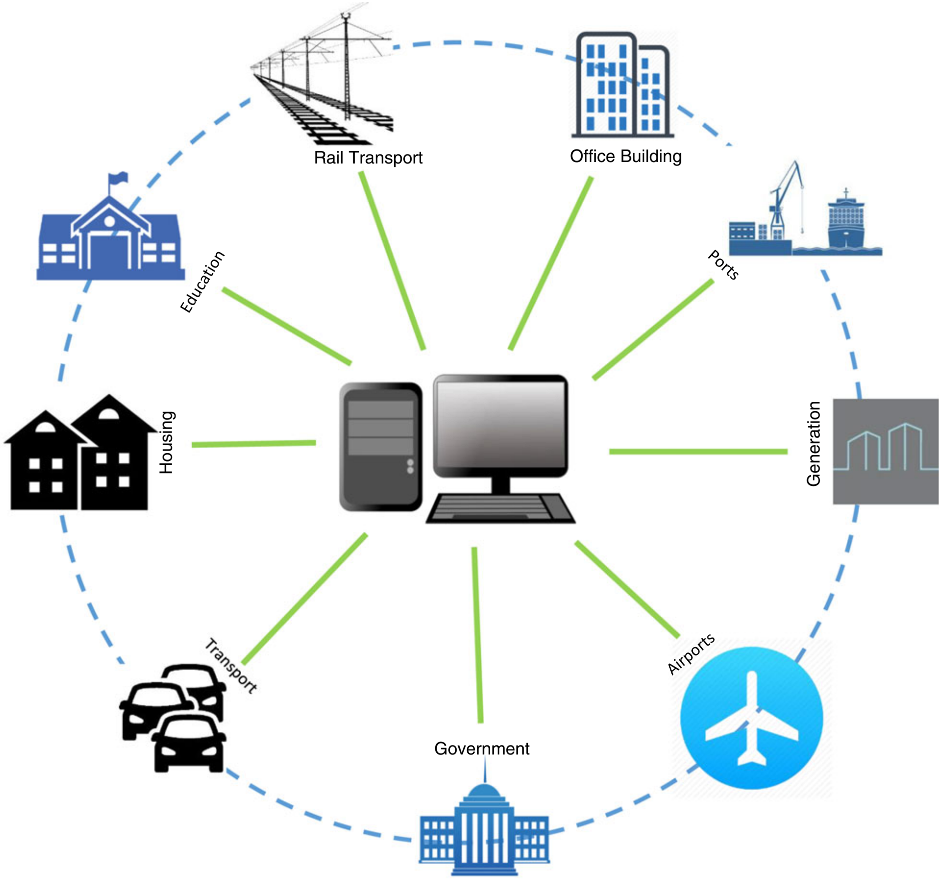

FIGURE 7 City energy management center

task of inclusive of all things selected according to the functions they offer and to cooperate to pursue specific goals.

In this scenario, topics such as strategic issues that institutions and governments already confirmed with great effort have been predicted in many other viewpoints through many research trends (Future Internet, IoT). This is consistent with technology trends to identify individuals and mobile clouds in 2012's most popular cloud theme. Computing preservation and detection interacts with the surrounding environment because complementing little aspects are supplemented with large images and adjoining muscles are required comprehensively from the detection/operation point of view in order to optimally adjust the interaction a popular infrastructure is created.

A recent category of devices at the edge of the Internet is consumer-centric mobile detection and computing devices such as smartphones and automotive sensors. These devices fuel the evolution of IoT and supply sensor data to the Internet on a social scale. Individuals with detection and computing devices will share the data, extract information to measure, and confirm common phenomenon phenomena.

The ability of people today to create and share the content recorded as being written via the Internet is getting bigger and bigger. By aggregating and analyzing information using mobile devices and web services and using sensors (e.g., cameras, motion sensors, and GPS), people can detect aspects of life that were not seen before. New features that can participate in analyzing are appearing. This trend of participatory sensing or mobile crowdsensing is mainly related to data collection, processing, and analysis. It inherently guides participation of users and community groups at sensor networks (SNSs) and documents many aspects of life.

In this context, it is necessary to have mechanisms to make it possible to efficiently discover and select sensors and actions based on specific conditions and devices and SNs that take energy efficiency into consideration. Other problems to be solved relate to various resource combinations, that is, how to coordinate the search, manipulation, computing, storage resources of existing public/secret computing and storage cloud, and volunteer-based sensing clouds that exist. The above objective brings two independent solutions. In order to provide standalone services voluntarily provided by SAaaS Cloud, union providers can combine resources, not including volunteers SAaaS Cloud.

6.2 | Motivate/Object

In this way, our vision moves to Cloud of Things (CoT) compared to IoT and Web of Paradigms. CoT means more than just interconnecting and hyperlinking. CoT uses certain service-level agreement contracts/procedures to provide services that abstract, virtualize, and manage things according to the requirements and requirements of the users negotiated and agreed by the parties. The objective is to implement a service that provides an index and query method applied to things. Detected information is generally acquired by an independent administrative agency that possesses its own monitoring infrastructure and software architecture.

The concept of data sharing on these huge scales is a system concept of a system aimed at providing a new dimension efficiency by mission-critical integration of various “systems” provided by independent public and private organizations It is done.

An example of an application is a concrete realistic world-wide smart cities initiatives, which includes many administrations. According to the idea of system integration, IoT enables high-level interoperability and some flexibility. It enables seamless communication flow between various devices and hides communication services and end-to-end complexity. However, due to the complexity of the technology and the excess of the interconnection network, the integration strategy is limited. Therefore, much research by the scientific community is still necessary.

For example, IBM India recently supported funds for new research activities, taking Sensor Mitton and others into account. This article presents a new architecture that provides Internet users with the ability to get all types of data derived from different detection infrastructures. Data provisioning is very flexible and meets user's requirements. This result is achieved by achieving high-level abstraction of detection technology and detected data. This architecture was designed taking into account the following main objectives: Data provisioning needs to be performed for high reactivity and high-level extensibility.

The system needs to quickly install deployed sensors and easily integrate new sensors into the sensing environment.

A specific design strategy was developed to partized these requirements. Since the upper-level intelligence can be individually managed, especially in the hierarchical configuration of the components of the architecture, the data abstraction and the client's request, the strong interaction of the system and the sensor, the detected information was analyzed, filtered, and aggregated by surrounding decision-makers. The data abstraction layer of our architect was developed based on the sensor web enablement (SWE) standard defined by the Open Geospatial Consortium.

Nonetheless, our solution is limited to using SWE's sensors to overcome the limitations of SWE. The layer that interacts with system integration (SI) uses Contiki, which is an OS designed for sensors and embedded systems. It provides a unified platform for communicating with various sensors. The remaining papers are organized as follows. First of all, background information on related ideas is provided in the next section. The proposed complete framework and its components are described in the section “Reference Scenario and Proposed Architecture”. Finally, in this research we will conclude as a proposal for future research.

6.3 | Related work

In the area of sensor technology, virtualization has been proposed as a goal of ensuring seamless interoperability and scalability of sensor node platforms from other vendors through uniform management by inserting an abstraction layer between the application logic and the sensor driver. By configuring a virtual sensor network to perform virtualization, it enables versatile collaboration and efficient use of resources on the physical infrastructure that can contain a dynamic subset of sensors. The software abstraction layer deals with interoperability and manageability issues and is used to allow dynamic reconfiguration of sensor nodes within a WSN, a combination of some purpose and sensor data.

With regard to the description and implementation of the framework for efficient representation, annotation, and processing of sensor data, the goal of the Open Geospatial Consortium SWE plan is to define the web service interface and data encoding to enable the search and execution of sensors in the WWW, to be received. On the other hand, the W3C Semantic Sensor Network Incubator Group aims to extend the syntactic level of interoperability to the semantic level.

Important research on sensing, operation, and IoT aims at efficient semantic annotation of sensor data and proposed a way to store sensor data and metadata in a Linked Open Data Cloud for public access. Similarly, the infrastructure called SensorMasher provides non-technical users with the ability to access and manipulate sensor data from the web, and for sensor data representations such as SUMO, Ontosensor, and LENS. other ontologies and semantic models are presented. A detailed survey of existing sensor ontologies can be found. In order to address these issues, SENSEla, the European FP7 project, was launched in 2008–2010. Some great industries like Ericsson place themselves in smart cities and present it as their next challenge.

A promising research area is the IoT aiming at meshing network environments where nodes can be designated as semantically physical items. While resources in the cloud can be useful in overcoming certain limitations of smart devices in IoT scenarios, there is no flow awareness in the cloud, which widens the gap between elastic resources and mobile devices. There are various bridging approaches, but as described, the binding must handle the mapping between the physical environment of the IoT and the virtual environment of the cloud. The cloud formation of sensors and other mobile devices is similar to the existing technology developed in the dynamic services field. The service registry must act as a repository for the metadata associated with the service. They can be structurally centralized or distributed for information retrieval, keyword based, signature based, semantic based, flow based, and quality based. Service monitoring and tracking facilities are devised in order to deal with the unreliable nature of services. And the availability of some services may swing steadily in a unpredictable way.

For example in literature, some works deal extensively related to smart cities. The authors highlight how cities of the future will need to collect data such as smart water, electric meter, and so on.

Many of them are low-cost sensors with a high level of noise and unreliable communication equipment.

6.4 | Some kind of database and proposed database

In smart cities, a site can be a building, a factory, or also a whole city. Each site is an automatic system, which clients and services interact each other.

The automatic system has its own data producers and clients interested in sensed data. Data producers could be a single sensor or possibly WSNs, and they are possibly mobile and therefore connect at different points of the cloud along time. Data gathered by data producers into a site are stored through a database manager in a local relational database, in order to offer an efficient retrieval of data to internal clients. This database distribute in order to share and store information in a smart way. It could even include sensors themselves. To offer a service to clients, the database manager publishes sensed data on a global distributed column-based database. Whenever a client requests data, the database manager checks if the client requests can be satisfied within a site or if it needs external information. This allows many sites to cooperate with each other, sharing data and services.

In order to build such database, we introduce three main components: Hypervisor, Autonomic Enforcer, and VolunteerCloud Manager.

The Hypervisor abstracts away embedded sensors available on a personal device belonging to a network. The adapter enables the communication directly with sensing devices and keeps track of resources connectivity. It translates application commands and forwards them to the underlying physical resources, using the native communication protocol of the resources.

The Autonomic Enforcer and a VolunteerCloud Manager deal with issues related to the interaction among nodes, belonging to a single Cloud, for generating a Cloud of Sensors.

Such a model requires fundamentally novel algorithms for the data collection and composition of different services. And also, it entails novel application-level mechanisms in order to enable those who request or provide services to share data, while respecting the privacy of those involved.

Cloud-based services can be any heavy type of services that needs more resources and infrastructure in order to function properly. All these services have several and usually intensive requirements in resources.

Cloud-based services can use traditional publish–subscribe model into Cloud environment in order to be used by other users or services. However, use advanced features of Cloud environment to allow elastic services scalability and global delivery on-demand.

On the other hand, mobile-based services include mobile nodes that are moving in a nonstructural way and provide any type of services and information from their current location. A user can provide various types of location-based information depending on the application. The advantage of these kinds of services is that they exchange content, and such database provides information to the user in a flexible and fast way.

6.5 | Smart cities data handling

We expect that in smart cities, smart sensors with high processing power and multitier capabilities will be deployed. Sensors are deployed in street to measure the traffic, and deployed in everywhere. Two major OSs are: Contiki and TinyOS.

Contiki is an open source, highly portable, multitasking OS and designed for microcontrollers with small amounts of memory. Contiki has been used in many projects, such as road tunnel fire monitoring. An area of application of such idea could be the IoT. To this purpose, it is necessary to deal with things, exploiting the well-known ontologies and semantic approaches shared and adopted by users and customers.

6.6 | Proposed idea

Our proposing idea is to predict patient number due to air quality, especially problem of fine dust in the air. The reason we choose this idea is currently China's dust comes to Korea very harshly. We found that air quality has correlation to lung-related illness. We collect data from Korea government open data site and healthcare big data hub (opendata.hira.or.kr). Data was placed in patient per month and fine dust per month.

```
xx = numpy.loadtxt("data_pgi.txt", d

x = xx[:,0]
y = xx[:,1]

xm = numpy.mean(x)
ym = numpy.mean(y)

xs = numpy.std(x)
ys = numpy.std(y)
```

FIGURE 8 Load data to program

6.7 | Algorithm

We use python language to plot data, and calculate correlation coefficient. Data was in space segmented format with two variables: *x*-axis is find dust and *y*-axis is patient average number of month in hospital. First data was read from space segmented text file and using numpy python module, *x*- and *y*-axis is assigned to fine dust of month and patient number of month, respectively. Second, we calculate mean and *SD* of *x*- and *y*-axis. As in Figures 8 and 9, we finally calculate correlation coefficient of *x*- and *y*-axis, then plot graph of *x*- and *y*-axis, and print correlation coefficient.

6.8 | Flow

Data is read from space segmented file and assigned to variables *x* and *y*, then plotted to graph.

6.9 | Experimental results

We experiment four lung-related illness. First emphysema has high correlation coefficient value of 0.658 with fine dust. And the pneumothorax that strongly related with emphysema also has high correlation coefficient value of 0.678. Our experiment result shows that pneumonia has the highest correlation with dust. On the other hand, result shows that tuberculosis has nothing to do with fine dust, correlation coefficient value of −0.134. Figures 10–13 gives the distribution of various conditions with respect to fine dust.

6.10 | Conclusion

The area where this idea can be applied is likely to be IoT. For this purpose, we must use the data by combining the supplier's and

```
xmymsum=0
for a,b in zip(x,y):
    xmymsum+= (a-xm)*(b-ym)

#covariance
cov = xmymsum/60

#correlation
cor = cov / (xs*ys)
```

FIGURE 9 Calculate correlation coefficient

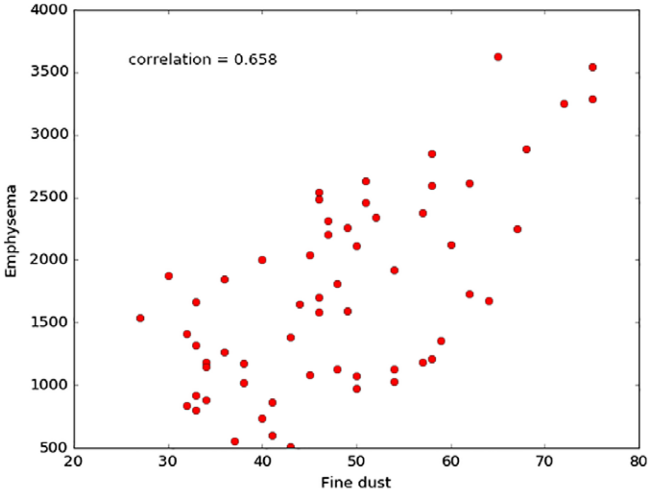

FIGURE 10 Emphysema/fine dust graph

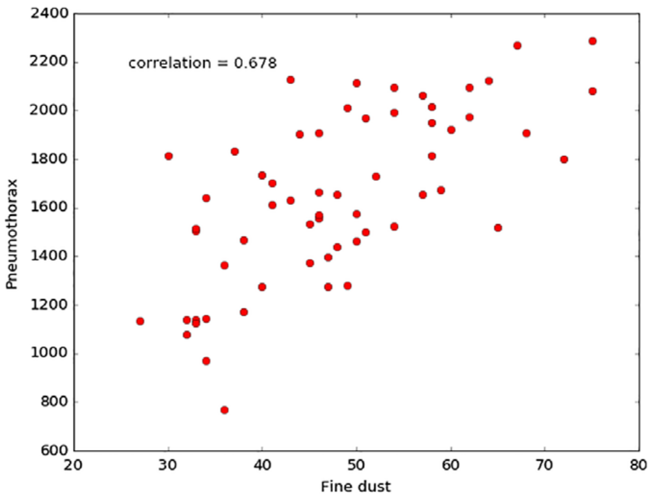

FIGURE 11 Pneumothorax/fine dust graph

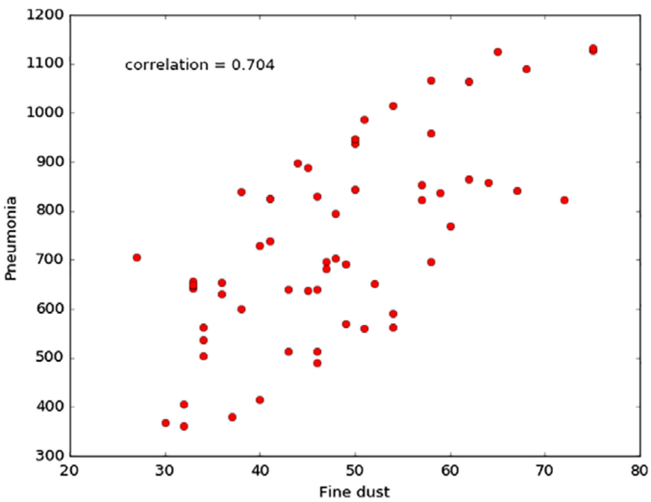

FIGURE 12 Pneumonia/fine dust graph

customer's sensor data. This article deals with some sensing devices and clouds to implement this clever urban idea. An architecture is defined to handle all the issues described here.

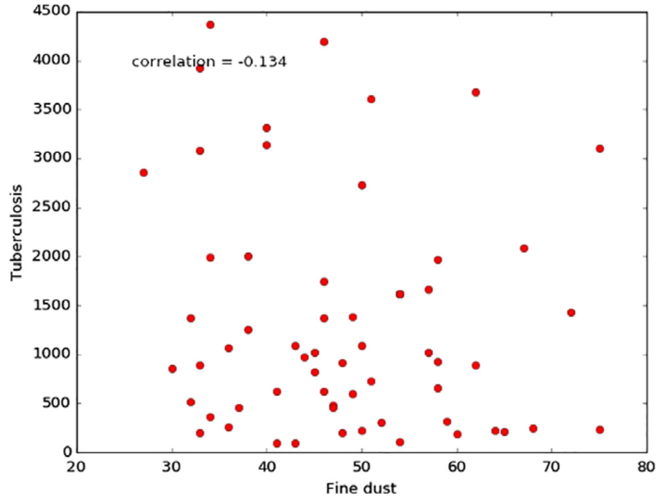

FIGURE 13 Tuberculosis/fine dust graph

These architectures use abstract layers designed according to the SWE standard specification to provide data collected from many heterogeneous SIs to Internet clients in a consistent manner.

Many items are still outstanding issues and challenges, and are important for future work. Specifically, we aim to develop advanced services for filtering and integrating data to apply to specific use cases in smart city.

And lastly, we conduct experiment to find the relationship between fine dust density and lung-related illness occurrence. Now many sensors are around us in this city. We tried to point that air quality sensors are especially necessary for our health in smart city, because of the experimental result and also WHO designates fine dust as serious carcinogen. Not only air quality sensors, but also smart city is capable to adopt numerous cloud sensors to protect our health in this city.

7 | CONCLUSION

Applications of IoT have been increasing to automate the environment for minimizing human effort. There are many open issues and challenges in various levels from data acquisition till decision-making to address. In this paper, we have reviewed the concept of IoT, basic IoT architecture, IoT data processing architecture, a survey on IoT applications, and results of some IoT use cases.

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REFERENCES

Alaa, M., Zaidan, A. A., Zaidan, B. B., Talal, M., & Kiah, M. L. M. (2017). A review of smart home applications based on Internet of Things. *Journal of Network and Computer Applications*, *97*, 48–65. https://doi.org/10.1016/j.jnca.2017.08.017

Allhoff, F., & Henschke, A. (2018). The Internet of Things: Foundational ethical issues. *Intenet of Things*, *1–2*, 55–66.

Baali, H., Djelouat, H., Amira, A., & Bensaali, F. (2018). Empowering technology enabled care using IoT and smart devices: A review. *IEEE Sensors Journal*, *18*(5), 1790–1809.

Bedi, G., Venayagamoorthy, G. K., Singh, R., Brooks, R. R., & Wang, K. C. (2018). Review of Internet of Things (IoT) in electric power and energy systems. *IEEE Internet of Things Journal*, *5*(2), 847–870.

Chernyshev, M., Baig, Z., Bello, O., & Zeadally, S. (2018). Internet of Things (IoT): Research, simulators, and testbeds. *IEEE IoT Journal*, *5*(3), 1637–1647.

Di Martino, B., Rak, M., Ficco, M., Esposito, A., Maisto, S. A., & Nacchia, S. (2018). Internet of things reference architectures, security and interoperability: A survey. *Internet of Things*, *1–2*, 99–112.

Dijkman, R. M., Sprenkels, B., Peeters, T., & Janssen, A. (2015). Business models for the Internet of Things. *International Journal of Information Management*, *2015*, 672–678. https://doi.org/10.1016/j.ijinfomgt.2015.07.008

Fernández-Caramés, T. M., & Fraga-Lamas, P. A. (2018). Review on human-centered IoT-connected smart labels for the industry 4.0. *IEEE Access*, *6*, 25939–25957.

Javed, F., Afzal, M. K., Sharif, M., & Kim, B. S. (2018). Internet of Things (IoTs) operating systems support, networking technologies, applications, and challenges: A comparative review. *IEEE Communications Surveys & Tutorials*, *20*, 2062–2100.

Li, S., Da Xu, L., & Zhao, S. (2018). 5G Internet of Things: A survey. *Journal of Industrial Information Integration*, *10*, 1–9. https://doi.org/10.1016/j.jii.2018.01.005

Lin, J., Yu, W., Zhang, N., Yang, X., Zhang, H., & Zhao, W. (2015). A survey on Internet of Things: Architecture, enabling technologies, security and privacy, and applications. *IEEE IoT Journal*, *4*(5), 1125–1142.

Lunardi, G. M., Al Machot, F., Shekhovtsov, V. A., Maran, V., Machado, G. M., Machado, A., … de Oliveira, J. P. M. (2018). IoT-based human action prediction and support. *Internet of Things*, *3–4*, 52–68.

Pattar, S., Buyya, R., Venugopal, K. R., Iyengar, S. S., & Patnaik, L. M. (2018). Searching for the IoT resources: Fundamentals, requirements, comprehensive review and future directions. *IEEE Communications Surveys & Tutorials*, *20*, 2101–2132.

Paul, A. (2013). Graph based M2M optimization in an IoT environment. *Proceedings of the 2013 Research in Adaptive and Convergent Systems*, 45–46.

Paul, A., Ahmad, A., Rathore, M. M., & Jabbar, S. (2016). Smartbuddy: Defining human behaviors using big data analytics in social internet of things. *IEEE Wireless Communications*, *23*(5), 68–74.

Paul, A., Daniel, A., Ahmad, A., & Rho, S. (2017). Cooperative cognitive intelligence for internet of vehicles. *IEEE Systems Journal*, *11*(3), 1249–1258.

Pfister, C. (2011). *Getting started with the internet of things: Connecting sensors and microcontrollers to the cloud*. ISBN: 978-1-4493-9357-1. O'Reilly Media, Inc.

Rathore, M. M., Ahmad, A., Paul, A., & Rho, S. (2016). Urban planning and building smart cities based on the internet of things using big data analytics. *Computer Networks*, *101*, 63–80.

Sajid, A., Abbas, H., & Saleem, K. (2016). Cloud-assisted IoT-based SCADA systems security: A review of the state of the art and future challenges. *IEEE Access*, *4*, 1375–1384.

Shahid, N., & Aneja, S. (2017). Internet of Things: Vision, application areas and research challenges. Paper presented at the Proceedings of the International Conference on IoT in Social, Mobile, Analytics and Cloud, I-SMAC 2017. https://doi.org/10.1109/I-SMAC.2017.8058246

Shit, R. C., Sharma, S., Puthal, D., & Zomaya, A. Y. (2018). Location of Things (LoT): A review and taxonomy of sensors localization in IoT infrastructure. *IEEE Communications Surveys & Tutorials*, *20*, 2028–2061.

Stackowiak, R., Mantha, V., & Nagode, L. (2015). *Big data and the Internet of Things*. ISBN 978-1-4842-0986-8. Apress.

Stankovic, J. A. (2014). Research directions for the Internet of Things. *IEEE IoT Journal*, *1*(1), 3–9.

Talavera, J. M., Tobón, L. E., Gómez, J. A., Culman, M. A., Aranda, J. M., Parra, D. T., … Garreta, L. E. (2017). Review of IoT applications in agro-industrial and environmental fields. *Computers and Electronics in Agriculture*, *142*, 283–297. https://doi.org/10.1016/j.compag.2017.09.015

Verma, S., Kawamoto, Y., Fadlullah, Z. M., Nishiyama, H., & Kato, N. (2017). A survey on network methodologies for real-time analytics of massive IoT data and open research issues. *IEEE Communications Surveys & Tutorials*, *19*(3), 1457–1477.

Yin, Y., Zeng, Y., Chen, X., & Fan, Y. (2016). The internet of things in healthcare: An overview. *Journal of Industrial Information Integration*, *1*, 3–13. https://doi.org/10.1016/j.jii.2016.03.004

Zanella, A., Bui, N., Castellani, A., Vangelista, L., & Zorzi, M. (2014). Internet of Things for smart cities. *IEEE IoT Journal*, *1*(1), 22–32.

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