Integration of Wireless Sensor Networks with Cloud Towards Efficient Management in IoT: A Review

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Abstract Internet-of-things (IoT) became very popular in today's research. IoT means all devices of a particular system should be connected with each other through the internet. Cloud Computing and Wireless Sensor Networks (WSN) are integrated for efficient management in IoT. This integration is known as Sensor Cloud. This technology has a lot of applications due to the continuous development of information and communication technology. Although sensor cloud has several advantages still it has many research challenges like energy efficiency, security, QoS, etc. The wireless sensor network is the network of sensors which operate on battery. Reducing energy consumption and communication overhead are important issues of wireless sensor networks. Efficient management of WSN and cloud results in efficient management of IoT. This paper presents a survey on efficient management of IoT with sensor cloud.

Keywords IoT · Cloud computing · WSN · Sensor cloud · Virtualization

1 Introduction

IoT, cloud computing, and WSN are the latest technologies which can optimize an application with help of each other. Integration of WSN with cloud is called sensor cloud [1–3]. Figure 1 shows the architecture of sensor cloud. At lowest layer, there are physical sensors which are mapped with virtual sensors at middle layer with help of cloud. The upper layer consists of end-users who can run multiple applications at a time with same WSN. End users can also use more than one WSN at a time

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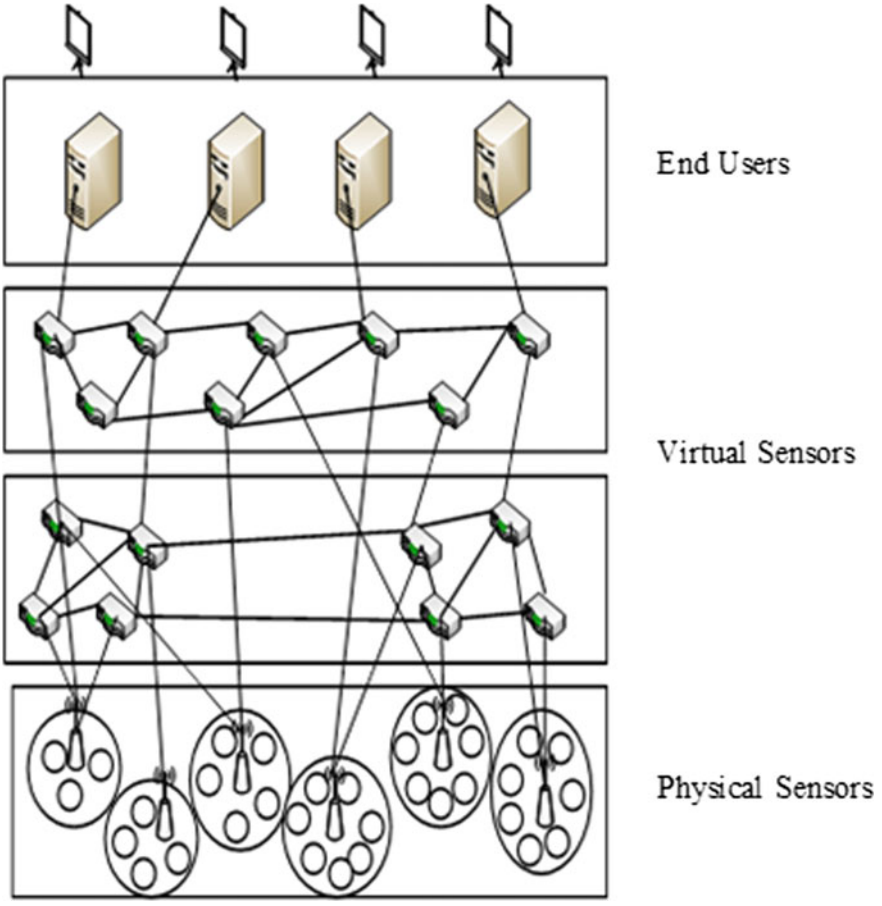

Fig. 1 Architecture of sensor cloud

within the same application with help of virtualization managed by cloud. Thus, cloud can provide sensor-as a-service. This integration helps not only the cloud but also helps WSNs [4–6] to store and effectively manage the sensor data at cloud. Other advantages of cloud include low cost of maintenance, flexibility of services, fault-tolerant communication, backup, recovery, etc. Cloud computing also enables on-demand sensor networks that can be released with minimal management efforts. Several IoT applications are based on sensors. Therefore, this integration can also help IoT for its efficient management. This integration helps a lot in real-time applications. It has several advantages and opportunities still it has some issues and challenges too, such as security [7–10], energy efficiency [11–14], load management [15], etc. Nowadays, many types of research are being carried out in this field. This paper presents a review on such researches toward efficient management of IoT.

Rest of the paper is organized as follows. Section 2 describes some basic terminologies. Various applications of IoT are discussed in Sect. 3. Section 4 focuses on related work. Finally, Sect. 5 concludes the paper with some research directions.

2 Basic Terminologies

Few preliminaries and basic terminologies are discussed below:

2.1 Wireless Sensor Network

Wireless sensor networks are popular because of their capability of building their own network for several environment monitoring as well as military applications [16]. They have a small size, processing capability, and memory [17, 18]. WSNs are created to sense various physical phenomenon like light, temperature, humidity, radiation, sound, etc. Wireless sensor network helps to provide a bridge between the physical and virtual world. It has a very large range of applications in industries, transportations, infrastructures, military, etc. Wireless sensor network can be explained as a self-configured framework. Its various applications monitor physical or environmental conditions to collect the sensed data. This network also has several constraints such as power, memory, processing capability, etc. Global positioning system and local positioning algorithms are used to get location and position information.

2.2 Cloud Computing

Cloud computing is the delivery of computing services such as server, storage, software, platform, database, networking, etc. It is based on pay-per-use technique [15]. This computing method provides various on-demand computer services available over the internet. Cloud computing is approaching to experience direct cost and it is expected to transform a data center from a capital-intensive set up to a variant price environment. Cloud computing modifies the equivalent traditional concepts of grid computing and distributed computing. It is a pool of abstracted, extremely scalable and control computing infrastructure capability of host-end client request and billed by a managed process [6, 19, 20].

2.3 Internet of Things

Most of the applications of IoT are based on sensors which monitor the physical and environmental conditions [1, 21, 22]. A cloud also helps to store and process bulk of data generated by an IoT application. In IoT at remote a command is given which controls the capabilities of the device. IoT devices are often mobile and can be deployed at various locations. They need to be connected to server side from a lot of different places. Internet-of-things is a network of physical devices which are based on internet. The internet is not only a network of computers it has spread into a network of device of all types and sizes such as smartphone, medical instrument, industrial system, etc. All such devices are connected, communicate, and share information based on some protocols in order to obtain smart reorganizations, positioning, tracing, safety, and control.

3 IoT Applications

IoT is the need of today's life. There can be many IoT-enabled applications such as smart parking, smart animal farming, smart waste management system, etc. Some of the applications of this technology are shown in Fig. 2 and discussed below:

3.1 Smart Home

Our life-style at home can be improved by making it smart. A smart home facilitates us in many ways. A smart house can automatically down the blinds of window or close the window as per the requirements of the seasons.

3.2 Smart Health Care

Healthcare application is gaining popularity these days where actuators and embedded sensors are implanted in the patients to receive the health related data of the patients. This data is analyzed automatically and doctors can provide facilities and health related services to the patients accordingly [4]. Thus, suitable actions can be taken for the betterment of the patients by the healthcare system.

Fig. 2 Major applications of IoT

3.3 Smart City

Good quality of life in the smart city is improved by providing comfort and ease to the residents. Interest for information is received according to people's necessary different interconnect systems that understand and offer the suitable services (like transport, utilizes health, etc.) to people.

3.4 Smart Grid

Smart grid is techniques that provides electricity from supplier to consumer through digital technology for saving energy and reduces cost and increase reliability. The network operator is all about the extension of grid observation, improved reliability,

wide measurement, and self-healing properties. The system integrated it all about integration of it and automation application.

3.5 Smart Transportation

The smart transportation systems are generally developed by the government or transportation authority. This system controls the traffic with help of smart traffic signal system. Various progressive programs regulate transportation. The advancement of electric vehicles, charging facility and dedicated short range communication helps the development of smart vehicular system.

3.6 Smart Agriculture

Smart agriculture is a computing-based agriculture that helps to change and reorient the agriculture systems. It efficiently supports the development and guarantees of food security during and ever-changing climate. The main focus of smart agriculture is to enhance agriculture productivity and incomes.

3.7 Smart Animal Farming

Smart animal farming became very popular these days. It provides proper diet care and environment required for animals. Smart farming is required to monitor animal farms remotely. This intelligent system should also do surveillance of the entire farm. Good care of animals is very important.

3.8 Environmental Monitoring

Use of cloud and IoT can change the development of high-speed information system between the entities. Sensors are deployed in any monitoring area to sense some environmental conditions such as temperature, pressure, movement of objects, etc. [5]. Some monitoring can be continuous and long term such as level of water, gas concentration in air, soil humidity and other characteristics, inclination for static structures, position changes, lighting condition of infrared radiation for fire and animal detection. A cloud-based data access is able to structure the potential energy requirements of low energy communicative segments and presents fast access to the data for end user. It accepts to manage and process the complex events given by the real-time data flow of sensors.

Table 1 IoT area, utilization, requirements and challenges

IoT area	Utilization and requirements	Challenges
Smart home	Industrial consolidation, Development of multi-power saving and cross-application	The core component, security, private protection
Smart healthcare	Medicine, treatment of remote virtual, the sharing and management and information of patient for treatment and drug	The industrial clear are no planning, limited manufactured abilities sensor, medical and biomedical largest scalability of data
Smart city	Efficient delivery of public utilities such as water, electricity as well as associated government service	It requires smart people
Smart grid	The power generated in sensor monitoring, the power supply in automatically management	The core lack of technology, communication including reliable, electromagnetic security, and capabilities
Smart transportation	The RFID technology in development of intelligent transport system	The transportation management from various administration department
Smart agriculture	Real-time access and information sharing of agricultural resources, intelligent management of products circulation and safety	Lack of low-cost sensing technology and devices, lack of communication infrastructure in countryside
Smart animal farming	This smart system will operate remotely for monitoring the animal farms	It will detect any misshaping and protection or such type of like fire
Environmental monitoring	Environment monitoring includes population, impressive sciences, geographic research, monitoring of flood and fire	Less number for monitoring station and least develop management platform, less in developed on manufacturing the high accuracy sensor chips, the unified industry standard

Table 1 shows the comparative study of various areas of IoT, their utilization, requirements, and challenges.

4 Related Work

In this section, a survey on various techniques for efficient management of IoT with sensor cloud is presented. The analysis is discussed as follows.

Madden et al. [23] described the industrial vision correctly. Sensors have limited constraints such as intermittent connectivity, energy and memory constraints etc.

Maintaining record of historical information is difficult for sensor data streams. These limitations show that the traditional database instrumentation is unsuitable for queries over sensor. They presented the Fjords architecture for query management over sensor data streams and limiting the resource demands. This architecture also helps to maintain the high query throughput.

Gnawali et al. [24] discussed CTP report, which is a variable rating protocol from the wireless sensor networks. CTP usually uses three techniques to give effective, robust, and reliability routing for high-equilibrium network condition. CTP's link estimator has accurate platform-independent interface. Second, CTP usually uses the algorithm to time to manage traffic, sending few visual signals in stability topology yet quickly adaptive to changes. Finally, CTP activates the technology with data traffic quickly to discover and fix routing failures.

Sudarshan et al. [25] demonstrated that the mobile sensor is a rising technology which is being researched in large in the past decade. This research survey paper studies the concept of mobile sensor integrated with the cloud service. It informs the different mobile sensor availability and their classification. It studies the necessary and limited mobile sensor network in terms of store computed power efficiency and scalable.

Estrin Deborah et al. [26] explained that sensed data can be stored at cloud so that it can be retrieved by any handheld devices like mobile phones anytime and from anywhere to analyze the system. Any user can fetch the data using his mobile phone or computer as per the permissions granted to him by the IoT system. Thus it helps to many expectations of daily lives. Present data capture leveraged data processing and personal data overleaps are the essential components for these emerging systems.

Alessio et al. [27] described that IoT has now become part of our life. They explained that cloud and IoT are merged together to serve a varied number of application scenarios.

Nair [28] explained that WSNs are used broadly in different areas. They discussed a model for power-aware scheme.

Dash et al. [29] presented wide range of critical applications that get and process data of remote sensor systems from the real world.

Dinh et al. [30] told that a volatile increase of the mobile application and environment communication in mobile computing is the cause of the evolution of sensor cloud.

Dash et al. [31] explained that there is an expanding pattern of utilizing distributed computing circumstance for the capacity of information process. Cloud computing gives applications, platforms, and foundation over the internet. It is another mechanism to get the shared assets. Remote sensors have been viewed as the most fundamental innovation for the twenty-first century which is spatially distributed in the sensor network for information transmission. Secure and easygoing access of information in distributed computing is very expansive.

A comparative study of the literature survey of related work is shown in Table 2.

Table 2 Comparative study

Authors	Year	Contribution	Remarks
Madden et al. [23]	2016	Explained the industrial vision correctly	Architecture from the decision multiple queries over many sensors and should be limited sensor resources demand get through maintaining high query throughout
Gnawali et al. [24]	2009	CTP reports a variable rating protocol from the wireless sensor networks	The technology with data traffic is quick
Sudarshan et al. [25]	2010	Survey of Mobile sensor is a rising technology	Mobile sensor power efficiency and scalable
Deborah et al. [26]	2016	Mobile phone and cloud service collective and analyse system systematically data	Present data capture leveraged data processing and personal data overleap are the essential components for these emerging system
Alessio et al. [27]	2016	Technology that is both already part of our life	Where cloud and IoT are merged together is predicted as disruptively
Nair et al. [28]	2011	Environment monitoring surveillance and military applications	Management circumstance management, data conglomerations, connect management
Dash et al. [29]	2012	Distributed resources sharing	Real-time traffic accumulation, real-time environment data monitoring
Dinh et al. [30]	2013	Integrated cloud computing into the mobile environment	Performs environment communication in mobile computing
Dash et al. [31]	2010	Utilizing distributed computing circumstance	Expanding pattern of utilizing distributed computing

5 Conclusions and Future Directions

Today, IoT has become part of human life. Many IoT-enabled devices are available in market and still, in future, there is a large scope for researches related to IoT. Several IoT applications are based on sensors and cloud. Therefore, for efficient management of IoT, sensors, and cloud should also be efficiently managed. This paper provides a review on efficient management of IoT using sensor cloud which is the result of integration of WSNs and cloud.

There are several other research issues and challenges to work upon such as security, QoS, cost control, pricing, etc. These challenges provide future directions to the research.

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