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WSNs and IoT Their Challenges and applications for Healthcare and Agriculture: A Survey

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Abstract

Nowadays, the Wireless Sensor Network (WSN) has materialized its working areas, including environmental engineering, agriculture sector, industrial, business applications, military, intelligent buildings, etc. Sensor networks emerge as an attractive technology with great promise for the future. Indeed, issues remain to be resolved in the areas of coverage and deployment, scalability, service quality, size, energy consumption and security. The purpose of this paper is to present the integration of WSNs for IoT networks with the intention of exchanging information, applying security and configuration. These aspects are the challenges of network construction in which authentication, confidentiality, availability, integrity, network development. This review sheds some light on the potential integration challenges imposed by the integration of WSNs for IoT, which are reflected in the difference in traffic features.

KEYWORDS: IoT, Wireless sensor networks, Healthcare, Agricultural, Wireless Body Area Networks, Wireless Biomedical Sensors.

I. Introduction

The advancement in computer networks, wireless communication technology and microelectronic mechanical systems have allowed WSNs to be one of fastest growing technologies. WSNs have gained massive attention for their prospective applications in a different area such as surveillance, environmental monitoring, safety, health care, border and others [1]. WSNs use autonomous low-energy sensors which can monitor and track the environmental conditions surrounding them. Usually each sensor includes a power unit, a micro-controller, a wireless communication unit and a number of environmental sensors (i.e. humidity, pressure and temperature) [2]. In accordance with the latest ICT developments, WSNs for internet of things (IoT) can build ever more sophisticated, integrated infrastructure that can gathered and processed massive quantities of data [3]. These heterogeneous technologies, along with artificial intelligence technologies, could be used to set up the next generation disaster management systems. WSNs have an active role in the IoT, as they are the core building elements of the concept [4]. During this year, an approximate 50 billion devices are expected to connect to the network [5] and Most of them are fitted with sensors.

One of the primary advantages of WSNs is their ability to operate in harsh and uninhabited environments such as deserts, hills and war zones. Where deployment of sensors and human tracking of the networks in such areas is dangerous and often impossible [6]. This type of deployment increases costs or even energy consumption over all the network compared to manual deployment. This strategy needs huge numbers of sensor nodes to be deployed to cover the region required Sensor nodes have limited sensing, processing and communication capacities along with non-replaceable battery. Furthermore, in several applications, it is impossible to substitute the sensor nodes when stop functioning due to external environment or their power is totally exhausted [7],[8]. However, the imbalance in energy consumption still affects sensor performance efficiency.

The paper falls into six sections. Section one is an introductory one. The second section discusses the design challenges of WSNs. Section three discusses the security requirements in WSNs. While section four reviews hierarchical architecture of WSNs. In the fifth section, the researcher presents some potential applications and recent deployments. The last section concludes the whole paper.

II. Design Challenges of WSNs

There are different challenges facing the design of WSNs. Most WSNs have different applications and application requirements that is why still not possible to handle all of the design challenges in a single network. Now let us bring up in detail some design challenges [9],[10],[11].

Scalability: Scalability is known as the capacity to support growing numbers of network users. Based on WSN applications, the number of sensors can reach one hundred thousand and sometime there is a need to increase or decrease the number of sensors. A synchronization scheme should scale well with rising number of nodes and/or elevated network density. The system should support the addition of new sensors or devices at runtime, to adjust the system over time with increasing disabilities. Software platforms and distributed services will be needed to integrate hardware and application level seamlessly, and interoperability between them will be essential [12].

Fault tolerance: Sensor nodes are vulnerable to failure due to a variety of factors, such as environmental hazards, hardware issues, physical damage and energy loss. Therefore, WSN protocols should be able to identify errors to be corrected immediately to maintain WSNs running within the required limits.

Hardware constraints: The primary objective of the WSN designer is to produce small, active sensors that can be fitted with actuators and other components such as a global positioning system. Any additional characteristics increase the physical size of the sensor and the power usage. There needs to be a balance between hardware limitations and software development (algorithms and protocols) and the sensors need to be cheaper and more efficient. Designing and developing wearable sensors without unobtrusiveness is still a big obstacle for healthcare applications. As in the PATHS [13] sensor units, the need to integrate multiple sensors into one system makes it harder. Such wearable sensors are often heavy and highly obtrusive devices, so several publications study the integration of sensor devices with the fabric [14],[15]. In relation to the above, the sensitivity of sensor devices is especially significant when users wear sensors in harsh conditions such as fire or exercise situations. The sweat can negatively affect the action of the sensors, resulting in decreased sensitivity of the wearable sensors or requiring recalibration of the sensors. Et al.[16] proposes an automated triaxle accelerometer self-calibration algorithm.

Energy consumption: Energy is still the most serious design challenge for a WSN, as sensor nodes operate on a limited battery[17]. It is important that energy is used wisely and effectively to significantly extend the network's lifespan. The energy source could be replenished, in other instances, by solar and other means. Solar cells that can produce up to 15 mW / cm2 under direct sunlight, but cannot be used with wearable wireless sensors because sensors are preferred to be placed under clothing. Motion[18] and body heat[19] based energy scavenging techniques for healthcare systems should be studied for such applications. WSNs operate in harsh and uninhabited environments, making it difficult to replenish the power source, which could lead to the complete disposition of the sensor nodes [20]. The major cause of power consumption in sensor nodes can be allocated in three practical areas: sensing, communication, and processing, each requiring optimization.

III. SECURITY REQUIREMENTS IN WSNS

Data confidentiality, data integrity, data authentication, data availability and data refreshment are currently the security requirements of WSN explained below[21].

Data confidentiality: Typically, WSNs collect confidential data as required in military or healthcare applications. These deployed sensors require security aspects to keep the data secret from unauthorized parties as data confidentiality.

Data integrity: Data integrity is a fundamental requirement for accurate sensor data in WSN. Adversaries may alter the data during transmission, so that false or malicious data would result in incorrect decisions and potential financial losses. Data integrity ensures the user that the obtained data is not modified by the attacker during transit.

Data authentication: Authentication of origin and validity of data is critical in WSN. Some administrative responsibilities (e.g. modifying the network or monitoring the service cycle of sensor nodes) require authentication. The opponent may simply insert messages into the network so the receiver must be confident that the data used in every decision taking phase come from the right source. The authentication scenarios in WSN are as follows: First sensor node authentication guarantees the confidentiality and validity of the data gathered by the node. Then the user authentication ensures that only licensed users access data from the sensor node.

Data availability: WSN services should still be available all the time, especially in case of system upgrades, hardware failures, power outage disruptions or security attacks. Some research papers have proposed various solutions towards this goal. Some solutions include using additional node communication and the introduction of a central access control system to ensure efficient delivery of services to users.

Data freshness: Even in the case authentication and confidentiality are guaranteed, it is required to ensure that the data obtained is fresh and no attacker can retransmit old data. Data freshness is particularly important when using shared-keys to transmit data between WSN nodes.

IV. HIERARCHICAL ARCHITECTURE OF WSNS

WSNs consists of a number of tiny, cost-effective and low-power sensor nodes that are deployed manually or may be randomly in or very close to the phenomenon of interest. Sensor nodes continuously collect data, process and then transfer data to a base station (BS) named a sink, either through single-hop or multi-hop communications. The sensor node network configurations are done manually by network administrator or dynamically by dynamic routing protocol, depending on the route created [11]. Sensor nodes in WSNs are continually changing their locations during run time. Sensor nodes can change their positions during runtime and can leave and dynamically join the network, so it is a complex task to organize a communication scheme for them. Therefore, the clustering algorithms used to resolve the issue of organizing communication and provide organized communication methods for the unstructured WSN. It organizes the nodes into groups called as clusters, then assigns a cluster head (CH) for each group that performs data collecting and processing tasks for the whole cluster [11],[22].

In the hierarchical architecture, nodes with higher residual energy are assigned as CH, and low-energy nodes sense local data and then send it to their corresponding CH. The CH will collect, process and transmit the data directly or through another CH to the BS [23],[24]. Figure 1 shows the cluster-based WSNs architecture with single-hop and multi-hop communication between CHs and BS [22]. CHs can manage bandwidth communication to avoid data redundancy when each node collects and transmits information because only CHs can communicate with other CHs and BS [18]. Data are aggregated at the CH to discard redundant and non-correlated data this reduces the energy consumption of the network by stopping the transmission of redundant data. Clustering reduces size of the table save at the nodes, makes it much easier to handle by localizing the route set up within the CH [11],[19]. However, the CHs can die quickly because of the additional workload. However, because of extra workload, CHs may die quickly. Several researchers had suggested using specific nodes called relay or gateways nodes. They act as CHs and had the same features and can be supplied with extra energy to extend their lifetime.

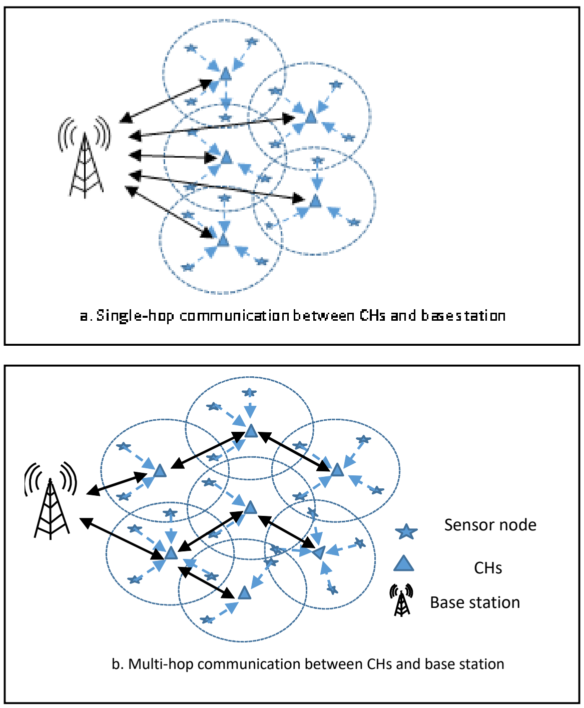

Fig. 1: Cluster-based WSNs architecture [22].

The small dashed arrows indicate the communication between the sensor nodes and their respective CHs, and the large arrows for communication between CH with CH or CHs with BS.

V. Application of Wireless Sensor Network

A. *Agricultural applications*

Technologies such as WSNs for IoT leveraged growth and introduced more robots and artificial intelligence into agriculture[25]. Advancements in wireless communication, sensor network technology and massive data analytics software have created sensors more efficient. These sensors are low-cost, low-power, multi-functional, small in size and interact at short distances used in agriculture to maximize the returns with reduced cost[11]. Sensors collect data on physical attributes such as weather, crop, temperature, humidity and soil information. The data collected give farmers detailed guidance on planting, fertilizers, irrigation, safety, and harvesting. In addition, the data collected can promote the forecasting of the future state of the land and enhance management results by correctly evaluating and reacting to variability in each field [26]. It helps minimize the usage of fertilizers, soil, pesticides and fuel and lowers the cost of production [11], [25] .

In Greenhouses: Modern Greenhouse technologies are quickly being developed and expanded. The environmental conditions of the greenhouse have a direct impact on the growth of crops and it is important to track and control this type of environment in real time [27],[28]. In modern greenhouses the active use of environmental automatic control technologies is an appropriate way of enhancing the greenhouse control technologies. A WSN is a group of small sensing devices or nodes that collect data in a given location about climate elements such as light, temperature, carbon dioxide, and humidity [29]. Then, these nodes send the data gathered to the BS, which transmits the data to a central computer that analyzes and extracts meaningful information. This system will help farmers to effectively monitor climate change changes in real time through a network monitoring platform. Most greenhouse sensors would be designed within the standard limitations [27]. Table 1 shows some examples of wireless sensors and their characteristics used in real-time greenhouse monitoring systems.

TABLE1:
Examples of sensors used in greenhouse monitoring system and their characteristics.

Sensor	Types	Features			
		Range	Accuracy	Power consumption	Operating Temperature
Humidity	Global Water WE600 [30]	0 ~100 % RH	±2% RH	30mW	-10°C ~ 50°C
	CHS series [31]	5 ~ 95% RH	±5% RH	3.15mW	0°C ~ 50°C
	Durable [32]	0 ~ 95% RH	± 5%RH in -50°C, ± 2%RH in -25°C	4mW	0°C ~ 50°C
Temperature	Global Water WE600 [30]	-50 ~ +50° C	±0.1°C	40mW	-50°C ~100°C
	Durable [32]	0°C ~ 50°C	± 0.2°C in -25°C, ± 0.5°C in 50°C	4mW	-10°C ~ 50°C

The greenhouse climate-controlling model is developed by Pahuja et al., in 2013 and deployed in India [29]. This model measures and analyzes the environmental parameters for plant growth. For improvising and developing technology, they incorporated and integrated a system that automatically monitors, analyzes and solves issues related to their problems [29]. The intelligent monitoring system established by Liu et al. in 2016 to monitor grape planting in the greenhouse [33]. They incorporated parameters which have a direct effect on grape growing. The system or process might be monitored online. Furthermore, each and every single development stage was captured by sensors using a video and image capturing technique. The data which was gathered via the sensors, provided an active database for further investigation and analysis [33],[29].

In the field: The rapid evolution of sensing and communication technologies has reduced agricultural cost considerably. Wireless sensors have been fully developed for intelligent, low power and low data rates sensors using in agriculture. Irrigation, pesticide management and fertilization are now regulated using WSNs provide real-time feedback between crops and local weather conditions to ensure secure crop growth and reduce the quantity of chemicals and water needed [34]. The sensors are inexpensive, allowing wide-ranging deployment and robust communication through redundant propagation paths for accurate information.

The Italian company Netsens has developed a new monitoring system called VineSense shown in figure 2(a) based on WSNs IoT technology [35]. The sensors deployed in the area are constantly monitoring and sending data measurements to the remote base station. Finally, end users analyze the received data through the VineSense web interface [35]. MeteoSense represents the fresh generation of professional weather stations developed by the Netsens company as shown in figure 2(b) [36]. Real-time information collected from sensors is transferred by using reliable GPRS technology. The MeteoSense is smaller, more economical, more robust, more fault-tolerant, easier to install and more energy efficient. It also uses a lithium battery that can operate up to 50 days without recharging and low power use of less than 1W while connected to GPRS [36].

a. Vinesense b. weather station (MeteoSense)

Fig. 2: weather stations for agriculture.

B. Healthcare

WSNs are used effectively in several prototypes and commercial applications for general health monitoring for the elderly, children and chronically ill. The major categories of health applications include activity monitoring, physiological monitoring, location monitoring, drug intake monitoring and medical status monitoring. Some of the existing WSNs applications and related proposals are included in Table 2.

Wireless Body Area Networks (WBANs): They are special wireless devices for healthcare systems[37]. WBANs Monitor the physical condition of the body then provide feedback via connectivity to patients or doctors. WBANs are primarily used to observe physiological parameters such as heartbeat, stress, oxygen, temperature and blood glucose monitoring [37]. A typical wireless body area network is showed in Figure 3 [38]. Health issues that may arise from diabetes include blood pressure, heart disease, stroke, blindness, kidney disease, and amputation. Wireless Biomedical Sensors (WBS) can be a more active way of treating diabetes by providing a more reliable and accurate glucose monitoring technique [37]. Wearable biosensors for IoT, are becoming highly interesting techniques that are commonly used to monitor changes in the body's biological data [39]. The main categories of biosensors are suitable for health, sport, military and other purposes. The rapid development of Wearable Biosensors offers advantages such as ease of use, low price and reliable real-time information which satisfies all clinical requirements [39]. Typically, wearable biosensors depend on wireless sensors that are included in bandage, bracelets and wearable products. The data collected by using these technologies are processed to identify occurrences predicting possible worsening of the clinical circumstances of the patient then send details to the patients or physicians through the wireless network[37],[40].

At-home Healthcare: When people age, they face a range of cognitive, physical and social changes that affect their health, independence and quality of life [41]. It is difficult to monitor and treat diseases such as diabetes, heart failure, congestive and asthma. WBANs address the social burden of aging populations and associated diseases. WSNs carried on or installed in human living areas can gather information on physiological patterns and behavioral conditions in real time and everywhere. From such living records, important conclusions can be made about the health of elderly [42].

TABLE 2:
Overview of WSNs applications for pervasive healthcare monitoring.

Category	Name	Hard ware design	Software design	GUI design	Sensing modality	Routing	Obtrusive	Context aware	machine learning	Loc. track.	RFID use
Activity monitoring	AICO[51]	Yes	Yes	Yes	Multi	Single	Low	High	Yes	yes	Passive
	Caregiver's Ast.[52]	No	Yes	Yes	Single	Single	Low	Medium	No	No	Passive
At-home Healthcare	ITALH [43]	Yes	No	Yes	Multi	Single	High	Medium	Yes	GPS	No
	HipGuard [45]	Yes	No	No	Multi	Single	High	High	No	No	No
Physiological monitoring	CodeBlue [46]	Yes	Yes	Yes	Multi	Multi	High	High	No	RF	No
	MEDiSN [47]	Yes	Yes	Yes	Multi	Multi	High	High	No	RF	No
	PATHS [13]	Yes	No	Yes	Multi	Single	High	Low	No	No	No

The IT for Home Assisted Living (ITALH) project [43] proposes the use of mobile phone-activated video camera only in emergency situations. In this system, the sensor node processor analyzes the accelerometer data in real time and identifies events such as falls or other common and abnormal events [44]. HipGuard [45] is a posture monitoring system designed for recovery durations of approximately 8 to 12 weeks after hip replacement surgery. The system has seven sensor nodes on the waist, thighs and shins edges that collect data and the processor analyzes them to monitor the condition of the hip [44].

Physiological monitoring: In physiological monitoring systems, WSN monitors and examines important human signs like respiratory rate, temperature, pulse oximetry [44]. WBANs can be deployed and applied in a variety of contexts, including disaster response, in-hospital patient surveillance and remote continuous monitoring for the elderly. Furthermore, technologies that automate clinical monitoring have the capability to enhance the healthcare quality in both the disaster and therapeutic environments [44]. Devices like the CodeBlue [46] and MEDiSN [47] target these application scenarios. Where, CodeBlue focuses on re-enhancing the process of triage during disasters with the help of WSNs comprising motes with IEEE 802.15.4 radios. CodeBlue integrated a variety of wearable health sensors such as ECG, oxygen saturation (SpO2) measurement and electromyography (EMG) pulse rate [48]. MEDIAN is used to enhance the monitoring process for hospitalized patients and disaster victims. MEDiAN has similar objectives to CodeBlue, but unlike the ad-hoc network used in Code Blue, MEDiUM utilizes a wireless backbone network of easily deployable relay points (RPs) [47]. The PATHS [13] is an ECG-measuring system that includes a wearable biosensor with two-axis accelerometer sensors, and a Bluetooth handheld device for collecting data from the wearable unit [44].

Activity Monitoring and Motion: The monitoring of activity levels and movement is another area of healthcare technology for WSNs. Wearable sensors can monitor limb movement and muscle function and are suitable for various clinical practice such as gait analysis activity classification, athletic performance [48],[42]. In the usual scenario, the patient wears up to eight gyroscopes and accelerometers (one on each limb segment) equipped with a micro-electromechanical system (MEMS) [49], [50]. The base station collects data from the network via a computer-class device in the patient's home.

The data analysis can be conducted to recover the patient's motor coordination and activity level, which is then used to monitor the patient response to treatment. In such tests, wearable sensor weight and size must be reduced to prevent encumbering the movement of a patient [53]. Lu and Fu [51]introduce an activity recognition approach with location-awareness by using various multi-modal and unobtrusive wireless sensors. Such wireless sensors are built into ambient intelligence-compliant objects (AICOs) which are ordinary household items protected by a virtual layer. Based on the data collected, AICOs generate explicit and implicit features empowered by location information and merge them generate more reliable estimates. The aim of the AICO project is to collect data naturally so they have prototyped the AICO floor, which collects data naturally in a way not altering the previous interaction [44]. The Caregiver's Assistant [52] is another behavior monitoring system which is built to monitor elderly people at home. The system works essentially by equipping different items in the user's home with RFID tags. Along with the Tag in the hand of the user, these tags help monitor what products they choose in real time. This system can be helpful for elderly with cognitive disabilities [44].

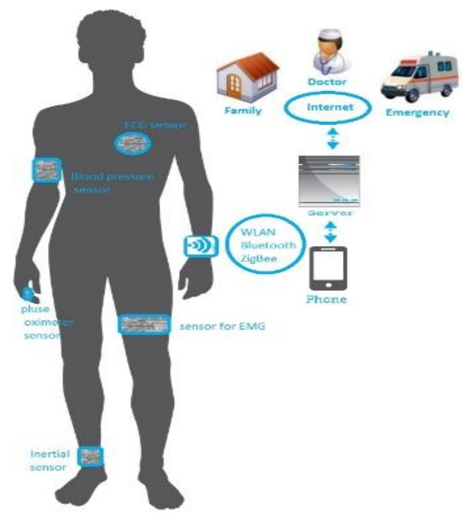

Fig. 3: Wearable Biosensors Network (WBS) architecture.

VI. CONCLUSION

The IoT smart sensors in healthcare applications allow the precise measurement, monitoring and analysis of a range of critical indicators of health status. This approach enables real-time access to patient health condition data and provides clinicians with feedback about the patient reaction to treatment. Concerning agriculture, water issues, irrigation methods and reducing the use of fertilizers, pesticides and fuel play a significant role in reducing cost of production. WSNs will help farmers by predict of the future state of the land and enhance management results by correctly evaluating and reacting to variability in each field. Despite the great promise of WSNs for the future, problems remain to be addressed in the areas of coverage and deployment, scalability, quality of service, size, energy consumption and security. This survey primarily identifies the different sides of WSNs for IoT and how IoT will be the main focus of future technologies. It also discusses the different problems which need to be resolved when using WSNs for IoT and security requirements. It also proposes a general overview of the WSNs for IoT technology and its various recent applications in agriculture and healthcare.

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