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FUTURE TRENDS OF WIRELESS SENSOR NETWORK

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Abstract—A wireless sensor network (WSN) is a network formed by a large number of sensor nodes, each equipped with sensor(s) to detect physical phenomena such as heat, light, temperature, pressure, motion or sound etc. This paper focuses on the historical background of how the wireless sensor network has come into the existence, it's types, and the current trends. It also presents the applications of WSNs in various fields like agriculture, environmental monitoring, military, health, automation, industrial monitoring, public utilities, assets management and many more. This research paper has also pinpointed the various challenges and issues which are being faced in Wireless Sensor Network and the future possibilities of Wireless Sensor Network.

***Keywords* —** Wireless Sensor Network, Types of WSN, History of WSN, Trends of WSN, Issues and challenges of WSN, Applications of WSN

I. INTRODUCTION

With the change in time and technological advancement, there has been seen the drastic changes in each and every aspects of human life. Similarly, the recent advances in hardware, sensor, and wireless networking technologies have benefited not only in the large-scale industrial and managerial areas but also even in the day to day human activities.

Not just like the traditional sensors that sense physical parameters in a passive manner, but the microsensors in a sensor network are a part of a full-fledged computer called a sensor node and have capability to process the sensor readings or share them with their neighbors. Each sensor node consists of a variety of different sensors, an embedded processor, memory, a low power radio, and a tiny battery [4].

Wireless sensor network is a modern information technology which integrates sensors, wireless communication, low-power embedded components and distributed data processing. WSN's network, which is able to implement real-time perceiving, monitoring as well as obtaining information of the specified target in certain regions, is composed of a large quantity of static or dynamic sensor nodes. WSN relies on embedded technology to fuse the acquired data. Finally, wireless communication technology is employed to transmit data to the terminal [1,2]. The Figure I give the simple overview of Wireless Sensor Network.

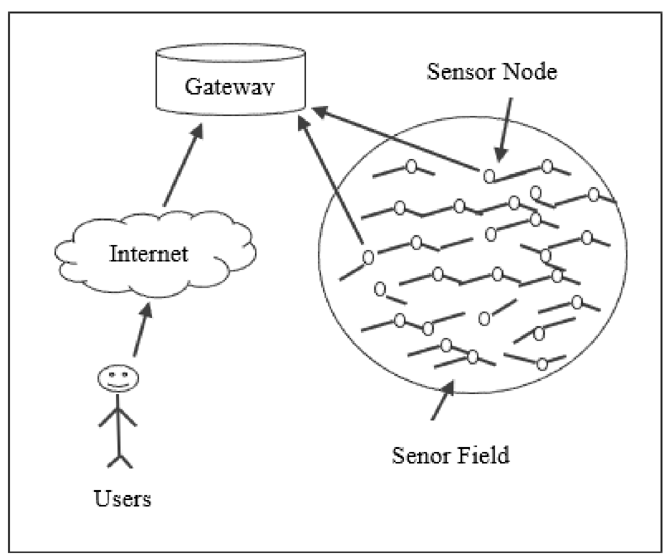

Figure I: A Simple Overview of Wireless Sensor Network [34]

The wireless sensor network is applied in the various field for the ease and the basic working of WSN application is dependent on the following equation [11]:

Sensor + CPU + Radio waves = Various WSN Application

which is shown in the Figure II.

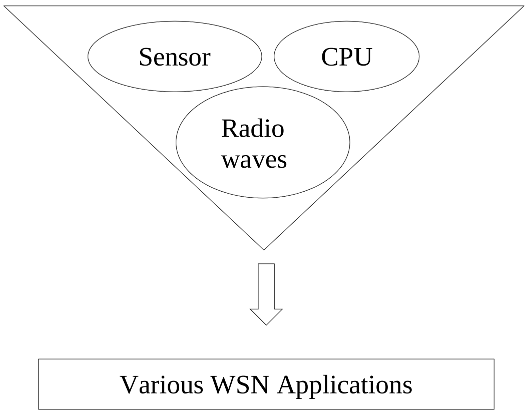

Figure II: Dependent of Wireless Sensor Network Application [11]

One of the biggest advantages of WSN over other wireless, battery-powered environments is that they consist of tens or hundreds of autonomous nodes that operate without human interaction for weeks or months at a time. Furthermore, sensor networks are also often embedded into some possibly remote physical environment so that they can monitor and collect data in a proper way [5].

Depending on the various environment, the sensor networks that can be deployed are also different types such as underwater, underground, on land, and so on. Some of the different types of WSNs include [12]:

i. Terrestrial WSNs
ii. Underground WSNs
iii. Underwater WSNs
iv. Multimedia WSNs
v. Mobile WSNs

i. Terrestrial WSNs

Terrestrial WSNs are located easily on the land area which are capable of communicating base stations efficiently. It consists of hundreds to thousands of wireless sensor nodes that can be deployed either in unstructured (ad hoc) or structured (Preplanned) manner. The battery is equipped with solar cells as a backup power source [12].

ii. Underground WSNs

As the deployment, maintenance, equipment cost is high in comparison to other types of WSNs, the underground wireless sensor networks seem to be more expensive than the terrestrial WSNs. These sensor network consist of a number of sensor nodes that are hidden in the ground to monitor underground conditions whereas the additional sink nodes are located above the ground so that the underground sensor relay information from the sensor nodes to the base station.

The underground wireless sensor networks deployed under the ground are difficult to recharge as it is not possible to have back-up energy source like solar power in terrestrial WSNs. Also, the underground environment makes wireless communication a challenge due to high level of attenuation and signal loss [12].

iii. Underwater WSNs

The underwater networks consist of a number of sensor nodes and vehicles deployed under water.

A challenge of underwater communication is a long propagation delay, bandwidth and sensor failures and energy back-up. The Underwater WSNs also face the problem in underwater communication and networking techniques [12].

iv. Multimedia WSNs

Multimedia WSNs mainly consist of low-cost sensor nodes equipped with microphones and cameras. The main purpose of Multimedia WSN is to enable tracking and monitoring of events in the form of multimedia, such as imaging, video, and audio. These nodes are interconnected with each other over a wireless connection for Data compression and Data retrieval.

High energy consumption, High bandwidth requirements, Data processing and Compressing techniques are some of the challenges of multimedia WSNs [12].

v. Mobile WSNs

The Mobile WSNs is a network having the collection of sensor nodes that can be moved on their own and can be interacted with the physical environment. The sensor nodes attached to unmanned aerial vehicles (UAVs) for surveillance, environment monitoring is also categorized under the mobile WSNs. Because of having the ability to compute, move, sense and communicate, wireless sensor networks are much more versatile than the static sensor networks. The advantages of Mobile Wireless Sensor Network over the static wireless sensor networks include better and improved coverage, better energy efficiency, superior channel capacity, and so on [12].

In this paper, we concentrate on the evolution of wireless sensor network, it's applications, current research status, technical difficulties, issues, and future developing tendency. The section II presents the historical trends of wireless sensor network, section III presents the current trends of wireless sensor network, section IV shows its future possibilities. The section V covers the issues and challenges it should face for the further development of wireless sensor network and the section VI concludes the paper.

II. HISTORICAL TRENDS

To understand the tradeoffs in today's WSNs, it is necessary to briefly examine their history. Like many advanced technologies, the origin of WSNs can also be seen in military and heavy industrial applications which are also prevalent today. The first wireless network that have been developed is the Sound Surveillance System (SOSUS), developed by the United States Military in the 1950s to detect and track Soviet submarines. This network used submerged acoustic sensors i.e. hydrophones which are distributed in the Atlantic and Pacific oceans [13].

Echoing the investments made in the 1960s and 1970s to develop the hardware for today's Internet, the United States Defense Advanced Research Projects Agency (DARPA) started the Distributed Sensor Silicon Laboratories, Inc [13].

Later on, with the evolution of Network program in 1980 to formally explore the challenges in implementing distributed/wireless sensor networks, Governments and universities also eventually began using WSNs in applications such as air quality monitoring, forest fire detection, natural disaster prevention, weather stations and structural monitoring. Then, the engineering students made their way into the corporate world of technology giants of the day, such as IBM and Bell Labs. Later, they also began promoting the use of WSNs in heavy industrial applications such as power distribution, waste-water treatment and specialized factory automation [13].

In this way, WSN were started to be developed in diverse platforms for control and monitoring many applications varied from natural environment to ambient awareness, from military to surveillance and from industrial plants to domestic home environments and volcano monitoring [6,7, 10]. So, WSN has been an exciting area of research used in many applications such as environmental monitoring, target tracing, medical fields and many more [8, 9]. Due to its multiple usage in various fields, the focus was on the multidisciplinary research area where collaboration of user's domain experts, hardware designer and software developers were essential components for efficient implementation.

Even the market demand for WSNs was strong, moving, WSN was proved to be a challenge because the military, science/technology and heavy industrial applications of those times were all based on bulky, expensive sensors and proprietary networking protocols. WSNs had surely placed a premium on functionality and performance, while other factors such as hardware and deployment costs, networking standards, power consumption and scalability were the reasons for WSN to fall the way side [13].

As a solution, the design of WSN for minimum consumption of energy was started to explore where cluster routing was found to be an effective solution in reducing energy consumption and provided network stability; sensor nodes were divided into groups to form a cluster and each cluster had a leader known as cluster head [14].

In addition to this, the security was also started giving priority thereafter. Key Cryptography (PKC) based solution for security services such as key-distribution and authentication were used. To have a strong cryptography and less power, elliptical curve cryptography (ECC) was proposed for implementation using custom hardware approach as the distributed sensor networks (DSNs) system generates huge amount of data which is a very challenging task for the detection system [11].

A multi-objective immune co-evolutionary algorithm (MOICEA) was proposed for target coverage as it was known that the target coverage is an important aspect in WSN. A tree-clustered data gathering protocol (TCDGP) to improve upon the LEACH (Low Energy Adaptive Clustering Hierarchy) and TREEPSI (Tree Based Energy Efficient Protocol for sensor Information) methods was proposed [15]. This protocol could help to reduce the power consumption as it could preserve the advantages of the LEACH methods. Automated process for the wireless sensor and actor network application were discussed that eliminates human intervention [16]. The positioning of an actor can be determined by the sensor through the cluster head as representative.

This is how the wireless sensor network have been developing and various research works are still in the way of progressing for further advancements.

III. RECENT TRENDS WITH APPLICATIONS

After the improvement in hardware, routing protocols, the security issues, in the today's time, we can see that the WSN have been successfully implemented into the various fields where in some cases, the human interaction is also not needed. So, the development of advanced features in wireless sensor network shows that it has a very wide scope and applications. It also seems like there would be barely any fields to be left where the wireless sensor network cannot be applied. The various application areas of Wireless Sensor Network in current trends with its usages are as follows:

i. Military

In today's time, new and emerging technologies, such as networks, support military operations by delivering critical information rapidly and dependably to the right individual or organization at the right time is a very challenging task. This improves the efficiency of combat operations. The new technologies must be integrated quickly into a comprehensive architecture to meet the requirements of present time. Improvement in situation awareness is must requirement [17]. Detection of enemy unit's movements on land or sea, sensing intruders on bases, chemical or biological threats and offering logistics in urban warfare are also some of the very important applications in Military sectors [18].

ii. Biomedical/Medical

There have been seen the lot of improvements by uses of WSNs in biomedical and medical field and are still in growing phase. Biomedical wireless sensor networks (BWSNs) show the future opportunities for supporting mobility which monitor vital body functions in hospital and home care. So, there is requirement for BWSN to develop in order to cover security handling, improved signal integration and visualization [27].

As the Internet usage has become one of the daily human activities, eservices for the healthcare which is commonly known as eHealth have recently attracted significant attention within both the research society and industry. Followings are several ongoing projects for healthcare using WSN:

- CodeBlue – an architecture proposed for tracking and monitoring of patients [23]
- ALARMNET – a WSN built for assisted living and residential monitoring [24]
- AMON – a Wireless Body Area Sensor Network System [25]
- GlucoWatch G2 – use WSN to research wearable personal health system that will monitor and evaluate human vital signs [26].

iii. Agriculture

[20] has stated that agriculture can be benefited by the deployment of WSN to get the information regarding the health of plant, soil degradation and water scarcity. With help of WSNs we can also check what type of water is consumed in irrigation.

iv. Structure Monitoring

Structures like: Heavy Duty Bridges, Skyscraper etc. must be inspected at regular time intervals while repairing or replacing based on the time of use and on their working conditions. The sensors embedded into structures enable condition-based maintenance of these assets has been explained in [21]. Wireless sensing allows assets to be inspected when the sensors indicate that there may be a problem. This will reduce the cost of maintenance by preventing harmful failure. These applications include sensors mounted on heavy duty bridges, within concrete and composite materials, and big buildings [22].

v. Industrial & Commercial

Since the long-time wireless transmission of data is being used in industrial applications, but recently it has gained importance. Successful use of wireless sensors in systems such as supervisory control and data acquisition has proved that WSNs could effectively address the needs of industrial applications. The critical process applications of WSNs in industry are monitoring temperature, flow-level, and pressure, humidity parameters which can also be implemented in the smart water and smart gas pipe systems [27].

vi. Smart Home/Smart Office

The research on smart homes is going on full pace after the successful installment of smart bed in developed country like Korea. It is very obvious that Smart home can provide custom behaviors for a given individual. And it will definitely take a considerable amount of work and planning to create a smart home. There are many examples of products currently on the market which can perform individual functions that are considered to be part of a smart home like: Smart Dustbin, Smart Meter [28].

vii. Traffic Management and Monitoring

Traffic congestion has become a burning problem as most of the big cities is suffering from traffic congestion around the world. For the solution, A real-time automatic traffic data collection must be employed for efficient management of rush hour traffic. [29] explained ITS (Intelligent Transport System) to be the application of the computers, communications, and sensor technology to surface transportation. The vehicle tracking application is to locate a specific vehicle or moving object and monitor its movement and make sure to improve the flow of vehicle traffic and improve safety.

viii. Topology and Coverage Control

Topology and Coverage control plays great role for prolong lifetime, reducing radio interference, increasing the efficiency of media access control protocols and routing protocols. It also ensures the quality of connectivity & coverage and increase in the network service as well [30].

ix. Quality of Service (QoS) Provision

Because of severe energy and computational resource constrains of wireless sensors, QoS Support is a very challenging task. There can also be the various service issues such as the delay, reliability, network lifetime, and quality of data may conflict. In this case, multipath routing can improve the reliability despite of increase in the energy consumption. Thus, modeling such relationships, measuring the provided quality, and providing means to control the balance is essential for QoS support.

This type of research analyzes and enhances the performance of a WSN by deploying a simple max-min fairness bandwidth allocation technique [31].

x. Mobility management

For the future internet and next generation, mobility stands out to be an important issue. It is crucial to study new models for supporting and managing mobility of WSN nodes as WSN are becoming part of future internet. Creating a standard mobility scenario is tedious for WSNs because of its applicability in variety of cases. The most common scenario in WSNs architecture is intra WSN device movement where each sensor node has the ability to change from its local position at run time without losing the connectivity with the sensor router (SR). In inter WSN device movement, sensor nodes move between different sensor networks, each one with its SR responsible to manage and configure all the devices aggregated [27].

An example of WSN movement is described in RFC3963 [32], a research project of IETF working group NEMO where sensor network deployed in a moving bus is a real scenario of this type.

Thus, these are some of the remarkable progresses in some of the various fields of the human life. All the current advances have also been tabulated in the Table I.

Table I: Recent Advances in WSNs [27]

Area	Applications
Military	Military situation awareness, Battlefield surveillance, Sensing intruders, detection of enemy units
Biomedical/Medical	CodeBlue, ALARMNET, AMON, GlucoWatch G2
Agriculture	Soil degradation, plant's health and water quantity information
Structure Monitoring	Condition based maintenance, concrete and composite materials
Industrial and Commercial	Monitoring and control of industrial equipment
Smart Home/Smart Office	Safety and Security, Lighting, air and water control
Traffic Management and Monitoring	Traffic congestion control
Topology and Coverage Control	prolong lifetime, reducing radio interference, increasing the efficiency, graph models of topology control
Quality of Service Provision	Tradeoff between reliability and energy consumption, delay energy consumption and delay
Mobility Management	Study of mobility of nodes

IV. Future Trends

As there is advancement in technology, the future developments in sensor nodes must produce very powerful and cost-effective devices. In the future, sensor node may be used in applications like underwater acoustic sensor systems, sensing based cyber physical systems, time critical applications, cognitive sensing and spectrum management, security and privacy management [27]. This section elaborates the various possibilities of further development in WSN applications.

i. Cognitive Sensing

Cognitive sensor networks operate on principle of deployment of large sensors intelligently and autonomically to acquire localized and situated information of the sensing environment. To manage a large number of wireless sensors is a complex task. As described by [35], a significant research interest can be seen in bioinspired sensing and networking. Swarm intelligence and quorum sensing are two examples of cognitive sensing:

Swarm intelligence is for studying the collective behavior of decentralized, self-organized systems and is developed in artificial intelligence [35].

Quorum sensing is also an example of bioinspired sensing and networking. Quorum sensing is the ability of bacteria to coordinate and communicate behavior through signaling molecules [35].

ii. Spectrum Management

We can envision a future in which wireless devices, such as wireless keyboards, power-point presenters, cell phone headsets, and health monitoring sensors to be ubiquitous as application and demands of low power wireless protocols is growing. However, the pervasiveness of these devices leads to increase congestion and interference within themselves as well as between networks because of overlapping physical frequencies [36].

Cognitive radio is one of the approaches developed to utilize multiple frequencies for parallel communication. A generic solution is provided by [36] as SAS: Self-Adaptive Spectrum Management middleware for WSNs can be easily integrated with an existing single frequency.

V. CHALLENEGS OF WSN

As mentioned in future trends, the advancement and features in WSN can still be levelled up in various aspects. Besides, these there are various challenges and issues to be tackled for the succession. Some of them are:

i. Cost: Producing a low cost and tiny sensor node is one of the major challenges. Low cost of sensor nodes can be achieved through recent and future progress in most of the fields. Because of cost constraint, it was not able to be used effectively.

ii. Security: Security is another most concerned challenges in WSNs. There is leakage of user's information through the attacks on WSN. It causes adverse effect in the wealth as well as in the health of the individuals.

iii. Unified System and Network Architecture: Even if the researches in the field of WSN has been going on rigorously around the world from the 1950s there is no availability of unified system and network architecture on the top of which different application can be built.

iv. Energy or Power: WSN is the field where there is continuous consumption of power. So, either the development of prolong lifetime power or the design of the energy efficient algorithms and hardware that uses power intelligently can be the best solution for the issue of energy.

These are some of the main complications which would be very helpful to improve the Wireless Sensor Network prominently. Similarly, other shortcomings of WSN are time synchronization problem, communication gap between sensor nodes and lack of real-world protocols to be implemented in WSN.

VI. Conclusion

WSNs have the capacity to be installed everywhere, on the road, underground, underwater, forests, battlefields, disaster prone area, work area, etc. WSN is one of the demanding needs in the today's time due to its ubiquitous nature. In the near future, WSNs can be deployed as underwater acoustic sensor systems, cognitive sensing and spectrum management, and security and privacy management.

Thus, this paper presents a brief review of WSNs history, its types, trends and challenges from inception to the future. This review paper would be very useful to study the history of WSN, it's trends, various issues and challenges of WSNs. WSNs have been emerging day by day and we can foresee that it could not be remain segregated from any of the fields in the near future.

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