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Wireless Sensor Network: A Bibliographical Survey

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Abstract

Objectives: To provide more organized literature on wireless sensor network. **Method:** In this paper, the bibliographical survey has been conducted on the types of wireless sensor network, the real application of wireless sensor network, and the performance metrics that are often used by researchers in evaluating the performance of wireless sensor network. The latest information and references have been further analysed in order to extract key information and mapped into respective subsections. **Results:** This bibliographical survey contains 450 references related to wireless sensor network that covers type of wireless sensor network, applications and most popular performance metrics used by researchers in solving common problems in wireless sensor network. The list of references covers related research works from 2005 until 2016 and grouped into several subsections based on types, applications and performance metrics. **Conclusion:** This bibliographical survey covers brief information and criteria related to wireless sensor network that includes types, real applications, and the most popular performance metrics that have been widely used. Ultimately, it can be as source of references to the other researchers in finding literatures that are relevant to their research area in wireless sensor network.

Keywords: Performance Metrics, Real Applications, Types of Wireless Sensor Network, Wireless Sensor Network

1. Introduction

Wireless Sensor Network (WSN) has become the next step in information revolution and important research area in computer networking. It allows real time monitoring, lightweight information exchange and processing, simple calculation, temporary data storage, and many more. Due to dynamic nature of distributed environment, there are a lot of aspects that need to be considered such as packet routing, load balancing, sensor node localization, sensor node energy efficiency, time synchronization, and security issues. However, there are still a lot of improvements that can be explored to further extend its capabilities.

WSN consists of a collection of sensor nodes that communicate with each other to forward submitted packets to destination node in a large scale networking area[1,2,3]. WSN has been applied in many critical applications such as military, health, habitat, environment, and industrial[4,5,6]. The application of WSN system mainly depends on its type, functions, and characteristics.

One of the most common challenges faced by researchers in determining key problems and designing their experiments is to identify the research area and performance metrics that need to be used in solving the problems[7]. Often, this is caused by unorganized and large number of available literatures[8]. Thus, it is essential to come up with a bibliographical survey that covers the most critical problems and performance metrics that have been used in the area including other important information. This bibliographical survey covers the types of WSN, real applications in WSN, and the most popular performance metrics that have been used in WSN.

2. Types of Wireless Sensor Network

Depending on the situation, WSN can be deployed on land, underwater, and underground[9,10].There are many types of WSN such as terrestrial WSN, underground

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WSN, underwater WSN, multimedia WSN, and mobile WSN[11,12].

2.1 Terrestrial Wireless Sensor Network

Terrestrial WSN consists of sensor nodes that are deployed in a certain area by using either ad hoc (unstructured) or pre-planned (structured) technique[13-15]. In ad hoc networks, sensor nodes will be dropped randomly into targeted area[16-29]. In pre-planned, sensor nodes can be organized by optimal placement[30-34], grid placement[35-37], or 2D[38-40] and 3D[41-45] placement models.

2.2 Underground Wireless Sensor Network

Underground WSN consists of many buried sensor nodes that are used to monitor underground conditions[46,47]. Management of underground WSN is complicated due to limited battery power of sensor nodes which is difficult to replace or recharge. Wireless communication is also very critical due to high potential of signal losses[48]. Thus, efficient routing algorithms are needed to manage critical limitations of underground WSN as well as increase reliability and accuracy of routing process[21,46,49-70].

2.3 Underwater Wireless Sensor Network

Underwater WSN involves a number of expensive sensor nodes that are deployed to monitor underwater conditions. Sensor nodes must have the ability to self-configure and adapt to underwater environment[71]. Special underwater vehicles are used to explore the underwater environment and gather data from available sensor nodes[72]. Acoustic waves are used to establish the wireless communication in underwater WSN with consideration of delay, limited bandwidth and signal fading problem[14,73]. Therefore, critical issues in underwater WSN such as delay, energy efficiency, throughput, packet loss, and hotspot problem must be handled by effective routing algorithms[21,74- 97].

2.4 Multimedia Wireless Sensor Network

Tracking events in multimedia such as audio[98-100], video[101,102] and image[103,104] can be easily performed with multimedia WSN approach[105,106]. Low cost sensor nodes in multimedia WSN connect to each other for data retrieval, process, correlation and compression using wireless communication[107,108]. Like terrestrial WSN, sensor nodes in multimedia WSN are distributed in pre-planned manner in order to guarantee the coverage. High amount of bandwidth are used by many multimedia contents such as video stream will affect the energy consumption of sensor nodes[109]. Efficient routing algorithm is crucial to handle common issues in multimedia WSN such as high energy consumption, delay, high bandwidth demand and QoS provisioning as well as to ensure the quality of multimedia WSN[110- 129].

2.5 Mobile Wireless Sensor Network

Mobile WSN consists of sensor nodes that have the ability to move on their own, reposition and interact with the environment[130,131]. Like static sensor nodes, mobile sensor nodes have the ability to sense, communicate and compute. However, mobile sensor nodes have additional ability to organize themselves and reposition in the WSN system[132]. Mobile sensor nodes can explore large coverage area to gather information and also communicate with other mobile sensor nodes. A reliable dynamic routing algorithm for mobile WSN should focus on sensor nodes localization, coverage area, navigation and reposition of nodes, data process and maintenance[133- 161].

3. Applications in WSN

WSN is considered a high potential technology that has successfully been deployed and tested in real environment as well as applied in many applications. Its capabilities have been proven to be able to improve many critical applications in various sectors such as in military, habitat, business, industrial, health and environment[162]. Thus, it is essential to understand main problems in each of these sectors and how WSN can effectively solve these problems. In addition to that, it is also important to identify challenges in deploying WSN in each sector so that required solutions or mitigations can be applied accordingly.

3.1 Military

WSN technology was first applied in military application called Sound Surveillance System (SOSUS) which was introduced by United States Military in 1950s[163]. The system was proposed to detect and track Soviet Submarines[164]. Nowadays, WSN is still being applied in military applications to detect and track personnel and moving vehicles as substitution for human personnel during surveillance missions. In military applications,

sensor nodes must collect confidence and precision information from the targeted area and submit to the base station. Reliable and secure WSN routing algorithms are needed to improve the quality of military applications in order to apply in real environment[165- 184].

3.2 Habitat

Monitoring the habitat with a presence of human can give the impact to the sensitive population where it could reduce breeding success, increase stress, encourage predation or may shift the animal population to inappropriate habitats[185]. This problem can be prevented with WSN where sensor nodes interact with physical environment to provide information and localized measurements. Collaboration of many small sensor nodes can provide long term data collections that are difficult to be done by manual observation. There are a lot of researches done in monitoring the habitat such as wildlife animal, sea animal, and plant without affecting the natural behaviour of population[186- 209].

3.3 Industrial and Business

Nowadays, industrial applications such as data-logging, supervisory control machine monitoring and fault diagnosis use WSN technology to improve the services and product development[210-233]. Sensor nodes that are used in industrial applications can monitor, control and process the data such as pressure, vibration, temperature and viscosity[234]. All information collected by sensor nodes is wirelessly submitted to the control system for the purpose of operation and management. However, there are still challenges that need to be considered when involving WSN in industrial applications such as their robustness, reliability, and ability to execute the operation along with industrial process[235,236]. WSN has also been applied in business applications to establish the business value by improving existing business processes or enabling new business processes[237-247]. A good WSN routing technique that provides long lifetime, easy to use system and low-cost devices is needed to improve its usage in industrial application and business application.

3.4 Health

WSN technology is also applied in healthcare applications through advance medical sensors to improve the quality of care on different population[248]. There are several health applications that already used WSN to monitor special diseases like Parkinson[249-251], Alzheimer[252,253] and heart attack[254,255]. An efficiency WSN routing algorithm in health application should provide high level of trustworthiness and also ensure the security and privacy of the data[248,256-286].

3.5 Environment

WSN is widely used in environment applications such as air pollution monitoring[287-291], forest fire detection[292-297], landslide detection[298-302], flood detection[303-306], water quality monitoring[307-314] and natural disaster prevention[315-323]. This technology is inspired from automated loggers where data is recorded and downloaded manually at specific intervals. In order to get accurate and relevant data, WSN is used where sensor nodes in environment application are responsible to monitor the natural environment and at the same time measure certain parameters with the purpose of providing vital hazard warnings[324]. Many explorations have been done in optimizing the usage of WSN in environment application and at the same time to face the challenges such as standardization, data quality, security, and power management[325-339].

4. Performance Metrics

In computer network, performance metrics are used to evaluate and quantify the performance of any system[340]. This bibliography covers nine popular performance metrics that have been used in evaluating the performance of routing process in WSN which includes throughput, delay, success rate, packet loss, path length, energy consumption, energy efficiency, network lifetime, and load capacities. The selection of each performance metric is solely based on the objective of a particular WSN application.

4.1 Throughput

In WSN, throughput is an important performance metric used to validate the performance of WSN routing because it can show the number of successful packets per second arrived at the destination node from source node[341]. Number of available sensor nodes can influence the throughput value of submitted packets where the larger

the amount of sensor nodes used can eventually increase the throughput. Throughput has been used by many researchers as metric in validating the performance of their proposed system or algorithm[21,50,78,104,114,116,117,174,342-356].

4.2 Delay

Delay in WSN is measured by the average end-to end delay of packet submission. Delay is the average time taken between packets initially submits from the source node and the time of successfully arrived at the destination node[357]. Propagation delay and queuing are also taken into considerations when measuring the delay. Value of delay indicates the quality of the packet submission where low delay shows a good packet submission. Many researchers have considered delay as a performance metric in their research work[50,51,59,78,88,90,91,93,114-116,120,124,134,158,167,184,231,259,313,343,346,347,350,351,356,358-376].

4.3 Success Rate

The total number of packets received at destination node per packet sent from source node is measured as success rate. Success rate is an important performance metric that needs to be considered in routing process because it shows the quality of routing technique and robustness of transmission path in ensuring the successful packet submission. Often, this metric is used in fault tolerance research area to measure the performance of the proposed workflow or algorithm[59,88,90,91,93,134,161,355,370,376-393.]

4.4 Packet loss

Packet loss is an opposite value of success rate where it measures the total number of packets that do not arrive at the destination node out of all packets sent from source node. The quality of transmission path can be measured by the number of packet loss per packet transmission where high number of packet loss indicates low quality of transmission path. Packet loss always is an important performance metric that used by many researchers in measuring the quality of WSN routing technique[46,50,53,93,120,174,351,365,382,384,386,394-396].

4.5 Path length

Packets in WSN system are transmitted by multi-hop technique from source node to destination node. The number of hops taken by packet indicates the path length of packet transmission. Many research work focused on reducing the path length which will eventually lead to reduction of forwarding time of packet transmission[53,174,366,367,377,397-405].

4.6 Energy Consumption and Energy Efficiency

Another important performance metric in evaluating a WSN routing technique is the measurement of energy consumption used by sensor nodes. Energy consumption is the sum of energy used by all sensor nodes in transferring and processing the submitted packet[406]. An efficient routing algorithm that can reduce energy consumption of sensor nodes will increase the network lifetime. Most of the researchers focused on reducing the energy consumption of sensor nodes without degrading the quality of WSN system[21,90,93-95,104,112,117,167,313,338,342,344,348,352,359,360,363,364,367,369,376,377,381,384,407-420]. There are researches that used energy efficiency to evaluate routing performance but the term is also similar to evaluating energy consumption[1,91,140,159,161,353,356,381,384,385,390,414,421- 432].

4.7 Load Capacities

Load capacities are the total number of packet received of each sensor nodes at the time. Load must be distributed fairly in order to prevent hotspot or load balancing problem[433-434]. Hotspot occurs when certain sensor nodes are under heavy traffic load which will eventually consume more energy. Fair distribution of packets to available sensor nodes can improve the network lifetime of WSN[21,349,350,354,378,379,397,407,411,415].

4.8 Network Lifetime

Network lifetime is measured on the total time taken of network until the first sensor node is died[435]. An efficient routing technique will prolong the lifetime of WSN system by reducing the number of path length, delay, energy consumption and packet loss as well as distributing the packets fairly to all sensor nodes[112,151,342,355,360,362,365,369,373,374,390,391,402,411, 417,432,435-450].

5. Conclusion

Based on this bibliographic survey that consists of the last 11 years of works, it can be concluded that WSN is possibly one of the most reliable solutions in health, habitat

monitoring, environment monitoring and many more real world applications due to its capability to provide real time monitoring and ability to incorporate with distributed environment. Out of all performance metrics that have been listed, the most popular and critical performance metrics in evaluating the performance of WSN are energy consumption, delay and throughput where a good WSN system should have low energy consumption, low delay and high throughput. This bibliography survey is hoped to be able to assist fellow researchers in finding the most recent, critical and important information of WSN. In addition to that, it may simplify the process of finding relevant literatures that can be used for specific research scope in WSN.

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