ENHANCED BUFFER MANAGEMENT POLICY AND PACKET PRIORITAZATION FOR WIRELESS SENSOR NETWORK

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2019

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DISSERTATION SUBMITED IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF
MASTER OF COMPUTER SCIENCE

FACULTY OF INFORMATION SCIENCE AND TECHNOLOGY
UNIVERSITI KEBANGSAAN MALAYSIA
BANGI

2019

PENAMBAHBAIKAN POLISI PENGURUSAN PENAMPAN DAN KEUTAMAAN PAKET UNTUK RANGKAIAN SENSOR TANPA WAYAR

ABDIWAHAB ABDILLAHI RABILEH

DISERTASI YANG DIKEMUKAKAN UNTUK MEMENUHI
SEBAHAGIAN DARIPADA SYARAT MEMPEROLEHI
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BANGI

2019

DECLARATION

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged.

22 January 2019

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ACKNOWLEDGEMENT

First and foremost, all I praise Almighty Allah for Bestowing His Mercy and Blessings upon me and for giving me resilient and good health throughout the period of this research.

I have taken efforts in this research. However, it would not have been possible without the kind support and help of several individuals. I would like to extend my sincere thanks to all of them.

I am highly indebted to my main Supervisor Dr. Khairul Azmi Abu Bakar for his guidance and constant supervision as well as for providing necessary information regarding the research and for his support in completing this research. I benefited greatly from having several fruitful discussions with him. I cannot forget the valuable help and motivation he offered me.

Also, I would like to express my gratitude to my co-supervisor Dr Dahlila Putri Dahnil for her motivation, important advice, constructive criticisms and valuable instructions in shaping and giving direction for completing my research.

Moreover, I am grateful for my friends, research colleagues from FTSM for their constant encouragement, inspirational support and advice throughout the time of my thesis.

Last but not the least, I express my utmost appreciation to my lovely parents for the immeasurable care, support and encouragement they've provided me throughout my life. I am grateful for their efforts in paving the way for my learning. They have always encouraged me to explore beyond the comfort zone and have believed in my potential to pursue my dreams. They helped me a lot to reach this stage of my life. Finally; I would like to thank my lovely siblings and my special cousins for their interest and support.

ABSTRACT

Wireless sensor network (WSN) is a group of small sensors spatially dispersed to monitor and sense the targeted environment such as military surveillance, healthcare applications and weather applications. As most of these applications require optimal network performance, minimizing packet drop of the network is highly significant. Packet drop is a crucial problem in wireless sensor network due to frequent link disruptions. Due to lack of continuous end to end connection; two nodes may not be able to communicate with one another. Thus, communication may be established with the help of store and forward approach between source and destination node. In that case, sensor node may not be capable of storing a chunk of data since the buffer is available in small amounts. In order to store the data packets in the buffer when the link is down, efficiency buffer management scheme is highly needed to keep the packets for a long time until the link is re-established. Buffer overflow is also the main cause of packet drop when a higher traffic load arrives and occupies the sensor node since the buffer size plays a very important role in the performance of the network. Furthermore, multiple retransmissions of same packets are done to recover lost packets as a result of buffer overflow and frequent link disconnections. In order to overcome these problems, we propose a new buffer management scheme called Packet Priority Heterogonous Queue (PPHQ) which is based on prioritizing and classifying the packets into different categories to minimize the loss of important packets. The proposed scheme is evaluated using simulation. In our proposed scheme, the MATLAB simulator was applied and benchmarked with the existing schemes in the state-of-arts. Our simulation and analysis show that PPHQ scheme can be used to save all important packets. The other results show that PPHQ improves the overall throughput by 12.39% compared to the benchmarked scheme. Furthermore, the delay of packet is reduced by 4.2% compared to the benchmarked scheme. In the meantime, PPHQ shows 0.85% improvement of packet delivery ratio compared to benchmarked scheme while maintaining optimum buffer management policy for reducing loss of important packets.

ABSTRAK

Rangkaian Sensor Tanpa Wayar (WSN) adalah didefinisikan sebagai kumpulan peralatan kecil pelbagai guna khusus untuk pemantauan persekitaran terkawal seperti pengawasan ketenteraan, penggunaan aplikasi kesihatan dan cuaca. Aplikasi berasaskan WSN memerlukan capaian rangkaian berterusan yang optimal berikutan keperluan untuk meminimumkan kadar kehilangan paket berkepentingan sewaktu penghantaran data. Kehilangan paket merupakan masalah utama aplikasi WSN berikutan berlakunya kekerapan gangguan pautan. Kegagalan hubungan komunikasi berterusan antara dua nod akan mengakibatkan masalah komunikasi yang amat ketara. Satu kaedah mengatasi masalah ini ialah dengan mewujudkan cara simpan dan hantar diantara nod pengirim (sensor) dan nod penerima sewaktu berlaku gangguan hubungan komunikasi. Namun, melalui kaedah ini, nod sensor dengan saiz penampan yang kecil berkemungkinan tidak dapat menyimpan maklumat yang banyak. Justeru, sewaktu hubungan komunikasi terputus, kecekapan skim pengurusan penampan sangat diperlukan bagi nod sensor menyimpan paket pada kadar yang lama sehingga berlaku sambungan semula. Saiz penampan memainkan peranan yang amat penting ke atas prestasi rangkaian, namun sewaktu berlaku beban lalu lintas yang tinggi akan menyebabkan berlaku limpahan penampan yang memenuhi nod sensor seterusnya mengakibatkan kehilangan paket. Selain itu, sambungan rangkaian berbilang juga akan terhasil berikutan keperluan penghantaran semula paket-paket sama yang hilang disebabkan limpahan penampan dan kekerapan gangguan pautan. Bagi menyelesaikan masalah ini, kami mencadangkan skim limpahan penampan yang baru yang dipanggil ‘Packet Priority Heterogonous Queue (PPHQ)’. Cadangan ini berdasarkan cara keutamaan dan klasifikasi paket kepada beberaoa kategori untuk meminumkan kehilangan paket-paket penting. Skim yang dicadangkan ini akan dinilai menggunakan simulasi MATLAB dengan menggunakan skim-skim sediaada sebagai penanda aras. Keputusan simulasi skim PPHQ menunjukkan peningkatan pada keseluruhan daya pemprosesan sebanyak 12.39% berbanding skim penanda aras. Tambahan juga, paket lengah dikurankan sebanyak 4.2% berbanding skim penanda aras yang lain. Pada masa yang sama, skim PPHQ menunjukkan 0.85% peningkatan secara keseluruhan berbanding skim penanda aras yang lain sambil mengekalkan polisi pengurusan penampan yang terbaik untuk menghantar paket-paket penting.

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LIST OF ABBREVIATIONS

2D	Two Dimension
3D	Three Dimension
ADC	Analog Digital Converter
BS	Base Station
CDMA	Code-division multiple access
CH	Cluster Head
CHIRON	Chain based hierarchical routing
C-LEACH	Centralized LEACH
CPU	Central Processing Unit
DAC	Digital Analog Converter
DMP	Dynamic Multilevel Priority
DOP	Drop Oldest Packet
DSM	Distributed Storage Management
DTN	Delay Tolerant Networking
E-LEACH	Energy-LEACH protocol
FIFO	First In First Out
GBR	Gradient-Based Routing Gradient Based Routing
LEACH	Low-Energy Adaptive Clustering Hierarchy
LIFO	Last In Last Out
MAC	Medium Access Control
MANET	Mobile Ad hoc Network
M-LEACH	Multi-hop LEACH
PDR	Packet Delivery Ratio
PEGASIS	Power-Efficient Gathering in Sensor Information Systems
PPHQ	Packet Priority and Heterogenous Queue

QOS	Quality of Service
RF	Radio Frequency
SN	Sensor Node
SPIN	Sensor Protocol For Information Via Negotiation
TDMA	Time Division Multiple Access
THR	Threshold
TL-LEACH	Two-Level Hierarchy LEACH
TTDD	The two-tier data dissemination
TTL	Time to live
VANET	Vehiclur Ad hoc Network
V-LEACH	Version LEACH
WMSN	Wireless Multimedia Sensor Network
WSN	Wireless Sensor Network
ZCS	Zone Cooperation at Sensors

CHAPTER I

INTRODUCTION

1.1 INTRODUCTION

Wireless sensor network (WSN) is a group of sensor nodes dispersed in a dedicated area to monitor and sense a target environment like pressure, humidity and temperature. Each sensor node comprises a radio transmission device, a small built-in microprocessor and storage unit. These component parts are equipped together and made accessible as a single functioning application. The duty of sensor node is to sense and gather the physical information from the ambient environment, the processor executes basic operational instructions as well as employs as a relay, and the radio transmitter transmits the data to the sink. Thereafter, a specific sensor node is linked to the outside world through base station.

Moreover, when the sensor node attempts to transmit a packet and the link is down or the path of the destination is not available, the node cannot hold the packet for a long time. and as a result, it will discard the packet due to limited memory. Consequently, the sensor node can only process data at low rates.

In such situations, the node must be available with larger resources on board in the conditions of storage space as well as energy to keep the packets in the buffer for a long time. One of finest sensor nodes is IMOTE2 invented by crossbow technology. Nevertheless, with no loss of generality, we can argue that sensor nodes are made to handle very low data rate as well as resource restrained nodes. Energy and storage are mostly available in extremely restricted amounts. Although sensor nodes are designed to handle low data rate, in the process of packet transfer to the sink, an intermediate node might have to send packets coming from various sources at once. These sorts of nodes could be severely burdened and due to the restricted storage space, the buffer will begin overflowing. This might further lead to loss of useful packets, and retransmission of similar data will be required. Therefore, packet retransmission may cause higher energy depletion. Furthermore, the buffer overflow could also have bad effects over the end application.

There are some other buffer management approaches introduced in the different computer networks such as Delay Tolerant networking (DTN), Mobile Ad hoc Network (MANET) and Vehicular Ad hoc Network (VANET) networks. However, it is very challenging for those methods to be implemented in a limited resource wireless sensor network. Furthermore, the wireless network varies greatly from other wired networks. When it comes to sensor network design, there is merely a single output queue which is linked with only one radio transmitter. Thus, without having a good buffer strategy, the transmitter queue will employ as first-in first-out manner.

In this research we investigate the various packet types which may be available within the sensor network scenarios. We are introducing a buffer management scheme that classifies these packets into various categories. Afterward, the buffer is split up into various priority queues and each packet is placed into its respective queue. The proposed buffer scheme is employed and then packets are serviced and put into the output transmitter queues.

However, when new packet arrives and there is no room space in the buffer to be inserted, then our buffer management scheme will determine whether the new arriving packets must be discarded or an old existing packet in the buffer is removed to accommodate the current arriving packet. In case the length of the arriving packets is longer, then the buffer scheme also determines how many packets must be discarded from the queue to adjust the queue size. Buffer management scheme may also determine to permit combination of the two scenarios.

Wireless sensor network is not similar to existing traditional network. From the sensor network scenarios, there could be several kinds of packets. In that case, the QoS needed for each packet type is unique. The key goal of the buffer management scheme is to provide optimum service priority to the various packet types specifically.

Our goal is to achieve optimum packet delivery rate as well as an efficient buffer management in order to keep all the packets in the buffer during network disconnection.

1.2 PROBLEM STATEMENT

In wireless sensor network, the packet drop is affected directly by the limited buffer storage of the communicating sensor nodes. However, the intermediate node needs to forward data coming from multiple sources, and due to its limited storage, the buffer of intermediate nodes could be heavily overloaded and start dropping packets. This will result in loss of valuable packets and retransmission of the same packet will be required.

Moreover, sensor nodes will also drop the packets if no attached link connection to the base station is found. Other issues that contribute to packet drop could be lack of continuous end-to-end connectivity between sensor nodes and base station because of node failure and limited lifetime of the node. In that case, the sensor node simply discards any packets that could not be forwarded as a result of poor network performance.

Due to limited amount of memory, efficient use of available buffer management policy is highly required to minimize the packet drop in WSN.

1.3 RESEARCH OBJECTIVES

This research has the following objectives:

1. To propose a buffer management scheme on limited storage space of the sensor node to ensure and reduce packet drop of Wireless Sensor Networks.

2. To evaluate and compare the proposed scheme with other buffer management schemes.

1.4 RESEARCH SCOPE

Generally, the research will be based on storage management of the sensor node. Our buffer management scheme focuses on two strategies (queueing and transmission) to achieve optimum buffer management. All incoming packets will then follow queueing strategy and transmission schedule strategy throughout the process.

However, we considered to use a routing protocol that works on finding the shortest hop path to the sink. Implementing an efficient routing protocol was not given much attention in our study, instead we stressed more on optimizing the limited storage of the sensor node.

In regard to the proposed scheme, one of the conditions we considered is that each node should have enough buffer space to hold the packet until link is available. Nodes must discard packets only when the buffer becomes full and overloaded. In our proposed approach, we have considered the following factors: storing packet and forwarding, node can only keep important packets and drop other packets if the transmitter output queue would not be able to forward packets when link is unavailable. All nodes should have enough energy and available buffer space to perform store and forward process. We also considered classifying different packet types on priority basis.

1.5 SIGNIFICANT OF THE RESEARCH

Wireless Sensor Network (WSN) has gained interest in the research field because of its easy deployment and self-configuring nature because it does not need preconfigured setup. These networks are usually utilized to transmit sensing information from source to the base station. However, this sort of packet transmission has several issues, i.e. link failure, traffic queue congestion and buffer overflow with higher dropping probability. Art of work essentially emphasizes on optimization, possibly by finding dynamic route or reducing the delay and packet drop. However, sensor storage issue is the core limitation that affects delay and loss of valuable packets. In that case, the proposed Packet Priority Heterogeneous Queue (PPHQ) scheme can result in efficient packet delivery in challenging networks in which the end to end connectivity between the source node and sink node may not be available.

To increase the chance of packet delivery, PPHQ scheme might need those nodes in the network to save and carry data packet in their local buffer and to keep the packets in the queue until the link comes back. When the small storage space is used, selecting the proper packet to discard is crucial to improve the network performance.

In our research, a PPHQ scheme is proposed to handle the small buffer and improve the packet delivery rate by prioritizing different packets according to the information and value they contain. This method is very much helpful to minimize the packet loss in WSN.

1.6 ORGANIZATION OF THE THESIS

This thesis is split up into five main chapters. Chapter 1 explains the research background on WSNs in detail, the problem statement and research gaps needed to be filled. Then the research objectives and research scope are outlined. Finally, the significance of the research is briefly described.

Chapter two describes a comprehensive literature review of this research. It begins by presenting theories, experiments, characteristics, routing protocols, and different existing buffer management policies related to WSNs. This Chapter also introduces the different packet types which are available in the sensor network scenario. This includes the proposed scheme that divides the buffer into different priority queues and different classification of packets is introduced as well. The chapter also discusses the related buffer management policies as well as ongoing projects that are closely used in this domain.

Chapter three covers the main methodology which is implemented to validate the proposed scheme. It concentrates on describing the components of proposed buffer management scheme. The proposed scheme PPHQ is extensively explained in this chapter. The simulation model applied to validate the proposed scheme is also illustrated. Finally, the network performance metrics that is utilized to characterize the quality of service are determined.

Chapter 4 presents and discusses the simulation results using different performance metrics. The simulation results are obtained by running various simulations and comparing them with the existing scheme in the state-of-the-art.

Finally, Chapter 5 summarizes the results of the study and provides recommendations for future works.

CHAPTER II

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter presents an overview of the related works on the topic: buffer management of Wireless Sensor Network. Moreover, this chapter discovers different issues and challenges that exist in the current state-of-art. Furthermore, this chapter highlights the importance of this research in contributing and extending the current state-of-art in this domain.

The rest of this chapter is organized as follows; Section 2.2, gives the overview of WSN Sections 2.3 talks about the architecture of WSN. In Section 2.4, characteristics of WSN is discussed. Section 2.5 presents classification of routing protocols, which is divided into five subsections focusing on the types of routing protocols (i.e. flat routing, hierarchical routing, and location routing). Section 2.6 presents related research work on buffer management, while Section 2.8 provides a conclusion to this chapter

2.2 An Overview of WSN Technology

WSN are ad-hoc in nature and composed of scattered devices with sensor nodes to cooperatively monitor environmental or physical conditions at various locations. Due to the quick evolution of wireless technologies and substantial progress of wireless network services, WSNs have become the ideal choice of all for information shipping throughout a variety of domains. To the framework of WSN, there's huge potential in which a WSN could be set up to support several applications.

WSNs have attracted the researchers due to their mixed uses in addition to its special challenges. One of the important operations of WSNs is collecting and transmitting the information needed by various applications having adjustable demands on reliability as well as data delivery at the base station. Node redundancy, an inherent function in WSNs, raises the fault tolerance but there is little or no assurance on reliability levels in the existing methods. Scheme for modeling reliability of information transmission protocols in WSNs is currently absent.

In information aggregation WSNs, information loss regularly occurs because of faults like accidental link disconnections as well as hazard node faults because sensor nodes (SNs) have limited resources and are usually used within hardly accessible and inhospitable places. Node failure often alters the topology of the network causing divided communication routes and data loss, ultimately cutting back on network reliability. WSNs have been categorized as wireless networks comprising of various small, low priced, power constrained, autonomous nodes which are dispersed within a location of target for the objective of observing and sensing the environmental factors, for instance, light, temperature, humidity and motion ((Katiyar, Mamta, H.P. Sinha, Gupta, & Dushyant, November 2012). Communication or transmission of information usually happens through wireless multi-hop transmission. As seen in Figure 2.1, most of the WSN protocols show an (source node, sink node) architecture, which can include multiple source nodes to produce packet, typically by utilizing sensor nodes for measuring environmental elements, for example, temperature, humidity or radiation, and sink nodes for gathering information collected from source nodes and the intermediate nodes which aids in communication from source node to the base station.

The data generation might happen both proactively and perhaps in reactive method depending on certain demands. Base stations (BS), might be highly energetic and also have much more resources compared to some member nodes in the network. In general, WSN nodes are battery equipped in which the energy consumption level and capabilities to perform transmission is determined by the size of the node. This is because sensor node is designed to be small in size and the battery capacity is not likely to extend network lifetime. Node's energy exhaustion is among the crucial issues in increasing network lifetime and dealing with early battery draining, especially when each node consumes more energy in every task. In that case, there should be other ways to cope energy problems to prolong network lifetime.

Besides that, it is tough to properly characterize the actual abilities of WSNs, especially as a result of the growing number of scenarios making use of technology (Pantazis, Nikolidakis, & Vergados, 2013). Some theories argue that normal WSN are depending applications and thus it is not possible to produce a structure that could be utilized in most (Shah, Patel, Patel, Patel, & Jhaveri, 08 November 2017). Wireless technology continues to be traditionally used to link individuals to one another or even to applications. Wireless local area networks (WLAN), mobile networks as well as wireless broadband target to offer voice as well as data networks. On the contrary, a WSN network provides to utilize applications such as health monitoring, security and surveillance monitoring etc. The advancement of sensor networks has made it possible for the prevalent organization of nodes comprising of tiny sensor nodes having the capabilities of detection, computation and transmission. Sensor node collects data from the factors affecting the environment, does the computations locally and finally transfers the effects and output to the base station through a wireless transmission and takes response action later. This is because each node delivers just minimal data since these types of network is utilized to monitor a huge area.

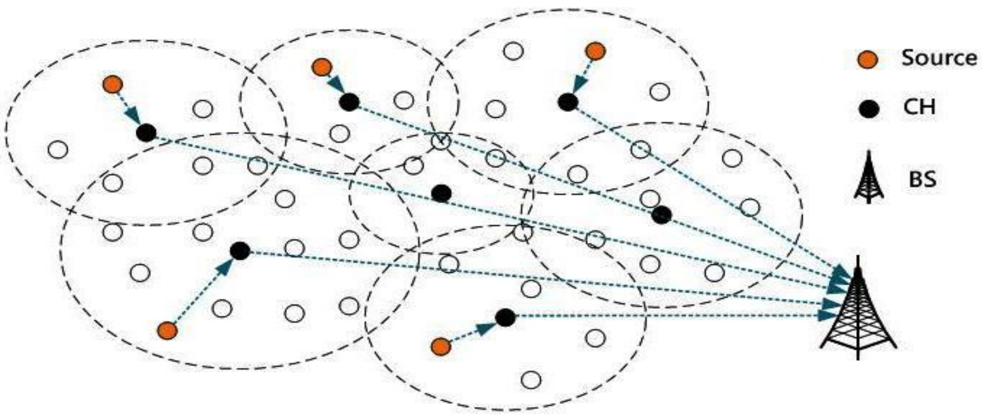

Figure 2.1 WSN Design and Architecture (Yang, and Chen, 2011)

2.2 ARCHITECTURE OF WSN

Wireless Sensor Networks evolved through many generations starting from simple sensors deployed in fields for military applications to hazardous industrial applications. Now, the sensor networks are mainly classified into three fields based on their applications i.e. in WSN, energy consumption is a major issue and in MANET's mobility of nodes is considered as the major challenge for various mobile applications. Furthermore, in VANET's, a crucial challenge is to minimize the path length (Xu, Shen, & Wang, 2014).

Current WSN can be placed underwater and underground. Sensor network faces various challenges and limitations depending upon the atmosphere. Thus, wireless sensor network can be categorized as underwater WSN, WSN terrestrial, multi-media WSN, mobile and underground WSN (H, Wang, & Toh, Dec-2005). Most Terrestrial WSNs commonly include lots of wireless sensing nodes settled in a given space, either pre-planned or in ad hoc manner (Chandrashekar & Manvi, july-2014). In unexpected placements, sensing nodes may be dropped from aircraft and notably located into the geographic region. In pre-planned placement, you will find optimum position, 3-D and 2-D placement models (Maraiya, Kant, & Gupta, 2011). In extremely terrestrial Wireless sensing networks, dependable communication in associate atmosphere is essential to communicate back to the base station (Cheng, Yong, & Wei-xin, April.2014).

Terrestrial sensing nodes have secondary battery for power supply, because primary source of battery can be prohibited and reversible. In wireless sensor networks, there are several approaches that could help to save energy. Some approaches are multi-hop fastened routing, network knowledge aggregation, eliminating knowledge redundancy, minimizing delays etc. Underground Wireless sensing networks involve a range of sensing nodes buried in caves to monitor underground conditions (Meshram, Bobate, & Chaturvedi, 2013). Additionally, sink nodes can be placed within ground to send knowledge from sensor nodes to the sink.

These sensing nodes are expensive as a result of acceptable instrument components that are opted to make sure the reliable communication via water, soil, rocks, and alternative mineral substances (Aghaei, Rahman, Rahman, & W. Gueaieb, 2008). The atmosphere creates a challenge for wireless communication because of signal losses and high levels of transmission loss. Hence a regular sensor node ought to have communication, processing, and sensing capabilities for observation. A node consists of a radio frequency (RF) transceiver, microcontroller as well as power generator along with ADC/DAC component. Figure 2.2 illustrates the Architecture and component of a Sensor Nodes (Manshahia, 2016).

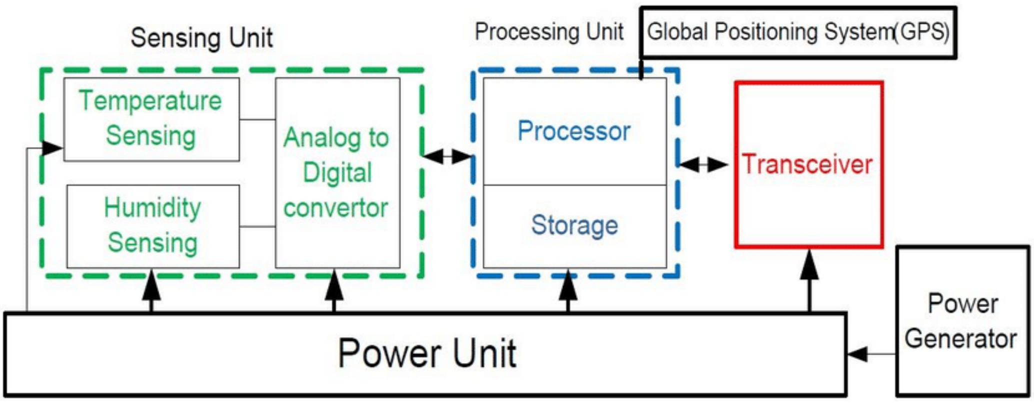

Figure 2.2 Main Components of WSN (Manshahia, 2016)

Underwater Wireless sensing networks involve a range of vehicles and sensing nodes placed underwater (Saleem, et al., 2010). These sensing nodes are expensive as compared to terrestrial WSNs. The autonomous underwater vehicle had been used for exploration or collection of knowledge from sensing nodes. A normal underwater wireless communication may be started by transmission of the acoustic waves. The challenges in underwater acoustic communication are restricted information measure, long propagation delay and signal deterioration.

Multi-media Wireless sensing networks are enabled to see as well as track activities in the variety of multimedia system like video data, imaging and audio. Multi-media Wireless sensing networks include sensing nodes which have in-built microphones and cameras. These sensing nodes can be connected with other nodes in the network. To be able to get coverage, these nodes are located in a planned manner.

The major challenges in WSN are high energy dissipation, quality of the service provision, compression techniques, processing as well as cross-layer style. Multimedia content like video streaming requires excessive information measure for the information to be delivered (Raha, Naskar, Paul, Chakraborty, & Karmakar, 2013). High data rate can cause high energy consumption. Transmission technique can support low energy consumption and high information measure.

Mobile Wireless sensing networks involve the sensing nodes which can move and connect with their physical atmosphere. Mobile nodes can sense their environment and communicate similar information to stationary nodes. Mobile node has the capability of preparing and repositioning itself within a network. Information gathered by the mobile nodes could also be forwarded to alternative mobile nodes. Mobile WSN faces various issues like deployment, localization, navigation, self-organization and coverage, management, maintenance and energy (Verma & Mittal, 2014).

2.3 CHARACTERISTICS OF WIRELESS SENSOR NETWORK

WSN is now utilized to observe many real-life aspects to evaluate various parameters. Thus, considering characteristics of WSN effectively is essential in terms of network topology and deployment (Buratti, Conti, R, & Verdone, 2009). The major characteristics of WSNs are defined as following:

a. Low Cost Node

In general, in WSN topology, thousands of sensor nodes are positioned to sense the specified target. To be able to minimize the entire budget of the complete network, the total cost of the sensors must be maintained as small as they can.

Besides, power efficiency is utilized for different purposes like computations, storage and transmissions. Sensor node dissipates much more energy in terms of data transmission as well as reception. In case the sensor node runs out of energy, sensor node becomes malfunctioned as no other choice to recharge again but to dispose. Therefore, an efficiency energy protocol and better algorithm development should be taken into account to manage the energy consumption in the system. In terms of energy consumption of computations, usually the sensor node has very low capability to perform any computations since the cost and power needs to be taken into consideration.

b. Communication Capability of The Sensor Node

In general, sensor node establishes communication via radio waves and transmits data through a wireless channel. Thus, sensor node has the capability of directly communicating within a boundless range with narrow bandwidth. The transmission medium could be unidirectional at times or bidirectional. When combined these sensor nodes together and deployed in a hostile place, the operation of WSN is tough to jog easily.

Thus, the communicating hardware as well as software program needs to take into account keeping the robustness of the sensor node as well as its resilience and security. Privacy and security in every node need adequate protection system to stop unauthorized access, hits, plus unintentional harm of the data held by the sensor node. Moreover, extra security measures should also be considered. Disseminating sensed data as well as processing the big amount is done by every node randomly. In WSN, each node can collect, process, sort data, as well as aggregate the information and finally send them to the sink. Consequently, the distribution of sensed data supplies the robustness of the network.

c. Dynamic Network Topology

Generally, WSN works dynamically even though the sensor node might fail to be coherent for certain conditions such as battery exhaustion. Communication network may be disrupted when extra sensor node is added and put into the network which could cause frequent topology shifts in the network. Therefore, the WSN node needs to get lodged with self-configuration and self-organization performance.

d. Self-Organization

In WSN, each sensor node should have the ability of establishing self-collaboration as soon as the sensor nodes are positioned in an undistributed manner and left in a hostile and unattended area. The sensor nodes have to organize together and cooperate in order to alter with the distributed algorithm and create network immediately.

e. Multi-hop Transmission

A lot of sensor nodes are positioned around WSN. So, the achievable method to connect with the sink node is taking the assistance of an intermediate node by selecting the best transmission route. If a single device tries to send data to the base stations that is outside its radio range, then the only way to communicate is to send data through multi-hop transmission with the help of intermediate nodes.

f. Application Oriented

WSN differs from the traditional network because of the nature of resource constraint. It is greatly influenced by the application choices from health applications, and ecological in addition to overall military applications. The nodes are set up uniformly or arbitrarily and covered based on the application category.

g. Robust Operations

From the time when most sensor nodes are set up in a great hard environment, the need for having a fault tolerant sensor node that is also capable of handling any errors is highly crucial. Therefore, sensor nodes are required to have the capability to self-configure, self-organize, as well as self-collaborate.

h. Small Physical Size of The Node

Sensor nodes are tiny in dimension with limited communication range. Because of its small size and the restricted power, they make the communication capability very low.

2.4 ROUTING PROTOCOLS IN WSN

Routing protocols have a broad scope in the research field once applied in WSN. These routing protocols could be characterized on the foundation of network types (made for the applications), establishment of transmission paths, and traffic in network management and establishment of network connection. Figure 2.3 demonstrates the classification of routing protocols that are subsequently separated into subclasses (Khurana & Aulakh, 2013). In the following sections, different routing protocols for WSNs are all presented.

2.4.1 Network Structure Based Routing Protocols

Routing protocols based on network structure performs efficiently in regard to the system limitations provided for the network layout or capacity. These protocols are consequently characterized as flat routing (Data Centric based), hierarchical routing (Cluster based) and Location (Geographic based) routing as seen in Figure 2.3.

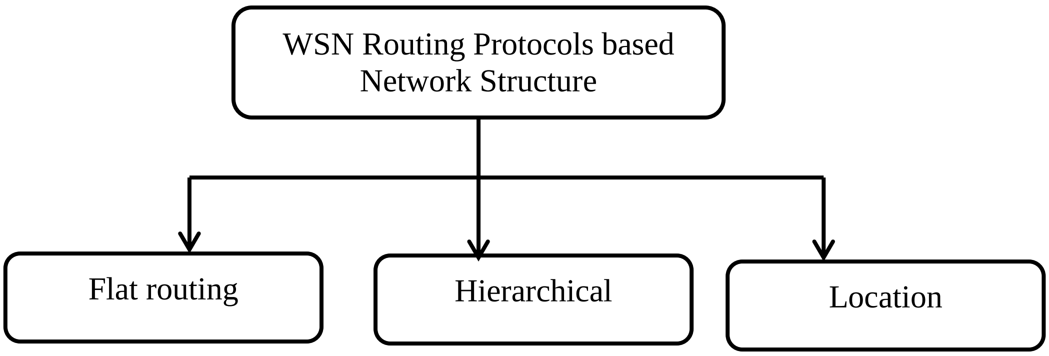

Figure 2.3 Classification of Routing Protocols in WSN

2.4.2 Flat Routing (Data Centric)

In flat routing protocol, whole nodes have equal and similar operation roles to collaborate together and accomplish sensing duty (Park, 2010). This protocol is based on being data centric as the base station transmits query messages requesting data from other nodes as shown in Figure 2.4. Upon receiving those messages, the sensor nodes send data back as requested by the base station. Some of the benefits of flat routing protocol include, it is free routing loop and can maintain less routing table. But the problem is that if certain nodes acknowledge at the same time, it may cause congestion in network as a result of significant packets loss. In that case, it is not suitable for wide range networks.

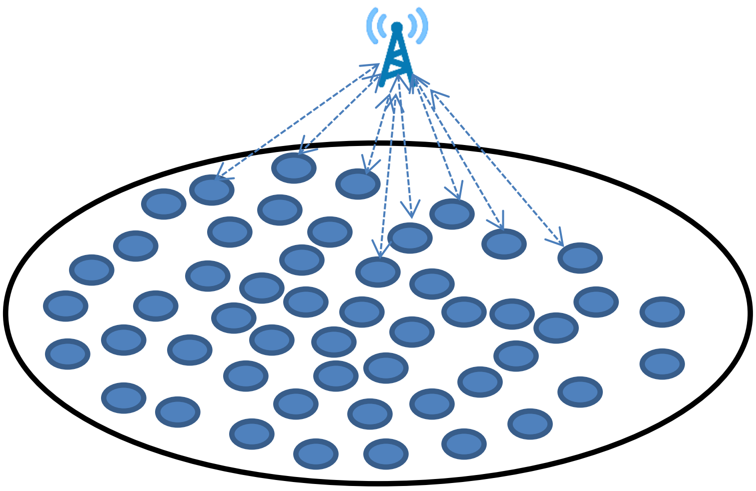

Figure 2.4 Flat Routing Protocol

a. Flooding and Gossiping Routing Protocol

Flooding and gossiping are probably the typical conventional network routing protocols (Kulik, Balakrishnan, & Heinzelman, 1999). In flooding protocol, every sensor node gets the data and forwards those data to each of the adjacent nodes. The moment the packet is received by the base station or the highest number of hops is reached, the transmission operation ends. Even though, flooding is not difficult, it has got numerous disadvantages such as overlap, implosion problem and resource exhaustion. The issue of implosion is avoided through gossiping, in comparison to classical broadcasting that transmits messages to other nearby nodes. It forwards data to a random node. Due to this, the chosen nodes will only transmit the message to the sink. Moreover, no longer routing tables and topology is required for further maintenance.

b. Sensor Protocol for Information via Negotiation (SPIN)

SPIN is an elastic data centric transmission protocol which broadcasts data from sensor nodes in a power restricted WSN (Kulik, Balakrishnan, & Heinzelman, 1999). It also deals with the implosion and overlap issues of traditional flooding. In WSN, sensor nodes communicate with each other and send hello messages in advance before sending the real packet i.e. sensor nodes exchange request messages among themselves to ensure the removal of duplicate data as well as transmission of important data to take place smoothly. Therefore, these nodes must track their power level and avoid excessive consumption of their resources. Furthermore, when transmitting the data to the targeted SPIN, it is not certain whether the data would be received successfully which may lead to its disadvantage. It might also not work well in high-dense nodes.

The other disadvantage to SPIN (Heinzelman, 2002) is the fact that if the sensor node interested to get certain data that is distant from the sender node and the nodes between sender and destination are not concerned with that information, then data packet might not be sent to the destination node. Thus, SPIN is not the best option for communication devices.

c. Rumor Routing

Rumor routing protocol is presented by (Estrin, 2002), which lets query messages to be sent to sensor value in the network. It is mostly intended for situations where geographic routing conditions is not appropriate. Rumor routing is a rational negotiation among flooding events and flooding queries advertisement.

Rumor routing is flexible and makes it possible for exchange negotiation between setting up reliability of packet delivery and overhead. In general, directed diffusion protocol, the query messages are flooded across the whole network and packets are sent via several path routes at a lower bit rate, but rumor routing protocol sustains only a single communication path between source node and destination node. In this routing protocol, transmission routes are established for queries to be transported and when the query is created, it is transmitted for arbitrary way till an appropriate route is found, rather than flooding messages all over the network. After the best route is found by the query, it may be transmitted straight to the route.

When events are flooded over the network, node senses the event, keeps its event table as well as an agent is created to discover paths. The table records contain the history and information regarding sensor source node, events and recent hop node. The key role of the agent is to spread messages regarding local events to the farthermost nodes.

d. Flooding and Directed Diffusion

Intanagonwiwat et al. presented a common data collection model for WSN named directed diffusion. This protocol is one of data-centric routing protocols in which most nodes within network are application-aware. The process of diffusion enables to minimize power consumption by choosing expediently appropriate routes as well as processing and caching aggregated data in the network.

Directed diffusion protocol is made up of a few fundamentals which include: interests of information, query messages, gradients, and reinforcements. The interest information is a query message which identifies the kind of data a user needs to obtain, and it holds a summary of sensing information which is reinforced by a sensor network for getting that information. Typically, data packet in sensor networks is the accumulated data sensed from the environment. Such sensed readings may be an event that contains a brief report of the sensed information. In this protocol, data packet is entitled with attribute-value pairs.

SPIN routing protocol enables each sensor node to broadcast an advertisement message about the availability of data, and the sensor nodes which are keen can query that data but in Directed Diffusion protocol the sink node query the nodes only if a particular information is available by flooding.

The key benefits of directed diffusion routing protocol are:

I. As directed diffusion is data centric, the communication happens at the neighboring nodes first with no demand for identifying the node address process. Each node will perform data gathering and storing, as well as sensing. Caching sensed data is the most crucial benefit in terms of power saving and data delay.

II. Direct Diffusion is also considered to be a highly powerful and efficient protocol as it is based on demand routing protocol, also global knowledge maintenance of network topology is necessary.

Directed Diffusion is not a better option for such applications, environment monitoring system due to continuous packet delivery to the base station is highly needed which in turn may not work effectively on query driven models.

2.4.3 **Hierarchical Routing (Clustering)**

In hierarchical routing protocol (Zhang Z. M., 2008), the network area of WSN is grouped into different layers of clusters. Each cluster organizes itself and elects a CH among the member nodes which is then in charge of data gathering and forwarding it to the upper layer or base station. Figure 2.5 depicts the hierarchical routing protocol using multi-hop communication within clusters to maintain packet delivery and energy consumption.

Employing hierarchical cluster scheme can contribute to better packet delivery performance by allowing sensor nodes to forward data only to their corresponding CH instead of direct transmission to the base station (Ghosh A. H., 2008). In this way, nodes collaborate by sending packets to one another using hop by hop till data is delivered to the base station. However, the role of CH is to aggregate and relay a large load of data collected from the member nodes to maintain an efficient packet routing and minimum energy consumption.

In flat routing, broadcasting information often causes poor network performance and results in congestion of the entire network. The hierarchical clustering routing protocol is considered to be most appropriate protocol to WSN environment (Bagci & Yazici, 2013).

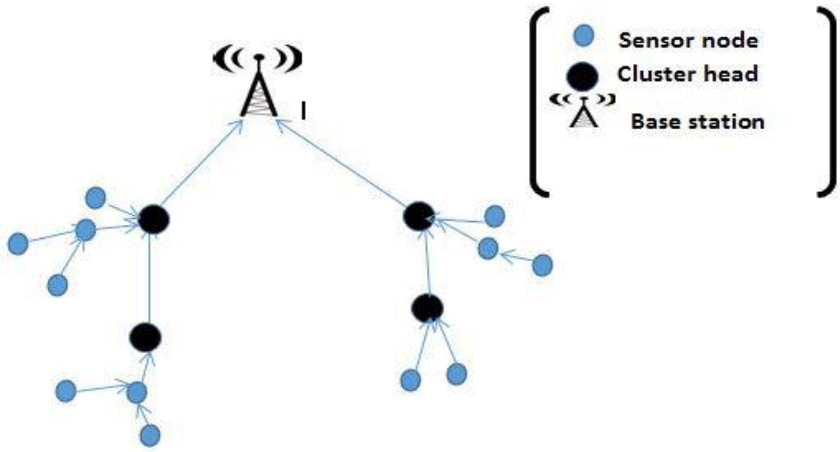

Figure 2.5 Hierarchical Routing Protocol

a. LEACH Routing Protocol

Low-Energy Adaptive Clustering Hierarchy is a routing protocol which is based on TDMA mechanism and employs clustering mechanism to reduce the transmission cost (Joshi & Priya.M, 2013). If one of the nodes in the network drains its battery power or dies, then LEACH protocol is applied to sustain network lifetime. Leach is a self-configuring, and self-collaborating dynamic protocol in which a cluster head (CH) is selected from a group of local clusters dynamically at a time interval to check excessive consumption of energy, and to combine data collection, consequently reducing the duplicate data sent to the sink and increasing network lifetime, thereby making this algorithm effective for energy saving.

Data is collected by the CH from its cluster members periodically and this LEACH algorithm makes use of TMDA/CMDA in the reduction of intra/inters cluster collisions. For each round that a node is chosen as CH, it disseminates information to the other sensor nodes within the network. Cluster heads are shifted randomly after a while to balance out the node's energy consumption (Akkaya et al. 2005). The sensor node can make this choice by selecting a random number, either 0 or 1.