ENHANCED DELAY-AWARE AND RELIABLE ROUTING PROTOCOL FOR WIRELESS SENSOR NETWORK

GHUFRAN ULLAH

UNIVERSITI TEKNOLOGI MALAYSIA

ENHANCED DELAY-AWARE AND RELIABLE ROUTING PROTOCOL FOR WIRELESS SENSOR NETWORK

GHUFRAN ULLAH

A thesis submitted in fulfilment of the
requirements for the award of the degree of
Doctor of Philosophy (Computer Science)

Faculty of Computing
Universiti Teknologi Malaysia

MARCH 2016

Dedicated to my Father Muhammad Haleem, Mother Khan Faroza, Brother Inayat Ullah, Wife and my Children, Munaima, Romaisa, Rabiha and Hadia without their support this thesis would have never been completed

ACKNOWLEDGEMENT

Thanks to Allah S. W. T. for giving me the strength to achieve which I was not able to achieve and for his blessings on me and my family who have supported me in every possible way.

First of all, I would like to show my sincere gratitude to my supervisor Professor Dr. Abdul Hanan Abdullah. His knowledge, experience and logical way of thinking have been great value for me. His understanding, encouraging and personal guidance have provided me a base for this thesis. His dedication, skilful guidance cooperative suggestions and constant encouragement made it possible for me to deliver a dissertation of appreciable standard and quality.

I have been very fortunate to have the love and support of my family throughout my academic career. I would like to thank and pray for my parents, who always encouraged and supported me since I was in elementary school.

I am extremely grateful and would say Special thanks to my elder brother Inayat Ullah for his constant faith in me and for always supporting my efforts and throughout my study. Without his support this study would not have been completed.

Finally, I would like to say thanks to my daughters that I had to leave them alone in Pakistan with when they needed me the most and I am heavily indebted to my wife who has been firmly believing me, supporting me, encouraging me, and caring for me all the time.

ABSTRACT

Wireless Sensor Networks (WSN) are distributed low-rate data networks, consist of small sensing nodes equipped with memory, processors and short range wireless communication. The performance of WSN is always measured by the Quality of Service (QoS) parameters that are time delay, reliability and throughput. These networks are dynamic in nature and affect the QoS parameters, especially when real time data delivery is needed. Additionally, in achieving end-to-end delay and reliability, link failures are the major causes that have not been given much attention. So, there is a demanding need of an efficient routing protocol to be developed in order to minimize the delay and provide on time delivery of data in real time WSN applications. An efficient Delay-Aware Path Selection Algorithm (DAPSA) is proposed to minimize the access end-to-end delay based on hop count, link quality and residual energy metrics considering the on time packets delivery. Furthermore, an Intelligent Service Classifier Queuing Model (ISCQM) is proposed to distinguish the real time and non-real time traffic by applying service discriminating theory to ensure delivery of real time data with acceptable delay. Moreover, an Efficient Data Delivery and Recovery Scheme (EDDRS) is proposed to achieve improved packet delivery ratio and control link failures in transmission. This will then improve the overall throughput. Based on the above mentioned approaches, an Enhanced Delay-Aware and Reliable Routing Protocol (EDARRP) is developed. Simulation experiments have been performed using NS2 simulator and multiple scenarios are considered in order to examine the performance parameters. The results are compared with the state-of-the-art routing protocols Stateless Protocol for Real-Time Communication (SPEED) and Distributed Adaptive Cooperative Routing Protocol (DACR) and found that on average the proposed protocol has improved the performance in terms of end-to-end delay (30.10%), packet delivery ratio (9.26%) and throughput (5.42%). The proposed EDARRP protocol has improved the performance of WSN.

ABSTRAK

Rangkaian Pengesan Tanpa Wayar (WSN) merupakan rangkaian data teragih berkadar rendah yang terdiri daripada nod-nod pengesan kecil yang dilengkapi dengan ingatan, pemproses dan komunikasi jarak dekat tanpa wayar. Prestasi WSN sentiasa diukur berdasarkan parameter Kualiti Perkhidmatan (QoS) iaitu masa lengahan, kebolehpercayaan dan truput. Rangkaian ini bersifat dinamik dan mempengaruhi parameter QoS, terutamanya ketika penghantaran data masa nyata diperlukan. Tambahan pula, untuk mencapai lengahan hujung-ke-hujung dan kebolehpercayaan, kegagalan penyambungan adalah penyebab utama yang tidak banyak diberi perhatian. Oleh itu, terdapat permintaan untuk membangunkan suatu protokol penghalaan yang cekap bagi meminimumkan lengahan dan menyediakan penghantaran data aplikasi tepat pada masa dalam WSN. Algoritma Pilihan Laluan Sedar Lengah (DAPSA) yang cekap dicadangkan untuk meminimumkan akses lengahan hujung-ke-hujung berdasarkan kiraan lompatan, kualiti penyambungan dan baki tenaga metrik dengan mengambil kira penghantaran paket tepat pada masanya. Tambahan pula, Model Giliran Pengelasan Perkhidmatan Pintar (ISCQM) dicadangkan untuk membezakan trafik masa nyata dan bukan masa nyata dengan mengaplikasikan teori servis diskriminasi untuk memastikan penghantaran data pada masa nyata dengan lengahan yang boleh diterima. Selain itu, Skema Mendapatkan Semula dan Penghantaran Data Efisyen (EDDRS) juga dicadangkan untuk meningkatkan nisbah penghantaran paket dan mengawal kegagalan penyambungan dalam transmisi. Ini akan menambahbaik truput keseluruhan. Berdasarkan pendekatan yang dibincangkan, Protokol Penghalaan Boleh Percaya dan Sedar Kesedaran Lengah Dipertingkatkan dan Cekap (EDARRP) juga dibangunkan. Eksperimen simulasi telah dijalankan menggunakan simulator NS2 dengan pelbagai jenis senario untuk menilai parameter prestasi. Keputusan kemudiannya dibandingkan dengan protokol penghalaan terkini Protokol Tanpa Keadaan bagi Komunikasi Masa Sebenar (SPEED) dan Protokol Pengedaran Laluan Kerjasama Yang Bersesuaian (DACR), dan didapati bahawa secara purata prestasi protokol yang dicadangkan telah memperbaiki pencapaian lengahan hujung-ke-hujung (30.10%), nisbah penghantaran paket (9.26%) dan truput (5.42%). Protokol EDARRP yang dicadangkan telah meningkatkan prestasi WSN.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ACK	-	Acknowledgment
APHD	-	Adaptive Per Hop Differentiation
ARS	-	Access Request Sequence
CAW	-	Contention Access Window
CD	-	Contention Delay
CFW	-	Contenton Free Window
CHs	-	Cluster Heads
DACR	-	Distributed Adaptive Cooperative Routing Protocol
DAPSA	-	Delay-aware Path Selection Algorithm
DTWSN	-	Delay-tolerant WSN
EDARRP	-	Efficient Delay-Aware and Reliable Routing Protocol
EDCA	-	Enhanced Distributed Channel Access
EDDRS	-	Efficient Data Delivery and Recovery Scheme
ERP		Evolutionary-based Routing Protocol
E-SLR	-	Extensive Systematic Literature Review
FBP	-	Feedback
FP-MAC	-	Fast- periodic MAC Algorithm
IFS	-	Inter Frame Space
ISCQM	-	Intellegient Service Classifier Model
NRT	-	Non-real Time
NS2	-	Network Simulator 2
QoS		Quality of Service
RT	-	Real Time
TSP	-	Traveling Salesman Problem
WSN	-	Wireless Sensor Network

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Introduction

The recent advancements and continuous increase in number of applications for Wireless Sensor Networks (WSN) have brought more and more challenges for existing systems and researchers. WSN is a kind of network which contains a large number of nodes, connected with each other, that communicate and transmit data to the sensor network (Younis *et al.*, 2014). These sensors are spread in the specific area to monitor physical or environmental conditions such as temperature, sound, pressure etc. These nodes have the capability of sensing the surrounding environment and transfer the data collected from the observed field over wireless links (Aslan *et al.*, 2012). The sensed data is forwarded through single or multi-hops transmissions to a sink node (Sumathi and Srinivas, 2012) as shown in Figure 1.1. The sink node can be the final destination or may further relay the data to other connected networks (such as Internet). The deployment of these sensor nodes can be mobile or fixed which are placed either planned or random way.

The WSN was initially used in the military environment for monitoring the battlefields (Pejanovi and Tafa, 2012). These networks were bi-directional which also enable control of the sensor activities. Now a day the WSN is commonly used in many other important areas such as air pollution monitoring, forest fire detection and industrial appliances.

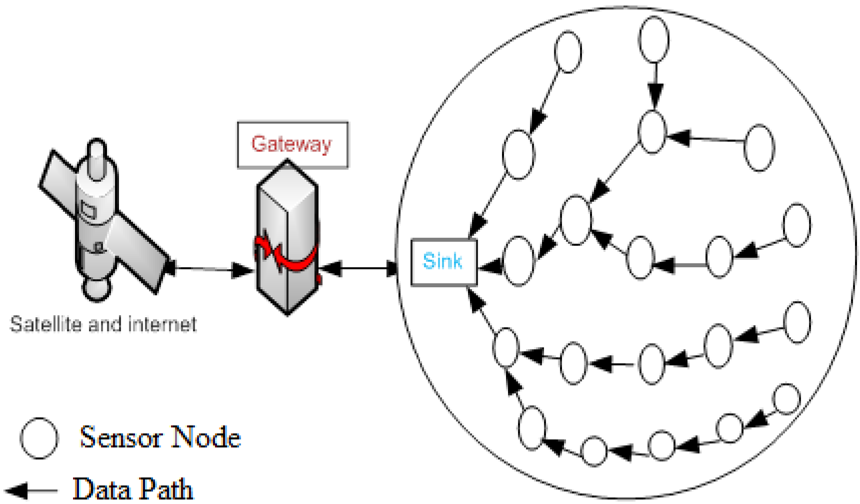

Figure 1.1 A typical multi-hop WSN (Mainwaring *et al.*, 2008)

WSN can be deployed in smaller areas having very less number of sensor nodes and on the other hand, it can also have larger scale deployment with thousands of sensors (Doherty *et al.*, 2012). The sensor node contains different number of units such as processing, transmission, sensing, position locater, power and mobilizer. The number of these units in a sensor can vary based on the nature of application and deployment requirements such as mobilizer is required only in the applications that have mobility factor (Dong and Dargie, 2013).

Sensor nodes communicate with the sink node directly or in hop-to-hop manner. The sink node can be a sensor inside the WSN or can be a gateway connecting the WSN to some external network. The WSN works in both distributed and centralized approaches. In a centralized approach, there always exists a base station or a cluster head (CH) that controls the working of the clusters or the network in terms of decisions regarding routing (Nikolidakis *et al.*, 2013) and resource allocation (He *et al.*, 2011). However, in distributed approach, the decisions of routing and resource allocations are made locally by the sensor nodes based on local measurements (Tunca *et al.*, 2014).

Most of the recent routing protocols are designed to satisfy the specific requirements of applications. The network designers and developers have achieved some improvements in Quality of Service (QoS) parameters; however, there is a trade-off between the parameters due to their conflicting nature. For example, some data collection schemes reduce energy consumption but with the increasing delays. Furthermore, some routing protocols are aimed to improve one or two of the parameters and leave the rest such as energy (Yan *et al.,* 2013), delay (Cheng *et al.,* 2011) and reliability (Srinivas *et al.,* 2013). Different WSN applications enforce different kind of requirements on routing protocols and techniques in terms of QoS parameters such as reliability, delay and scalability. Therefore, further research is needed in order to improve QoS provision in routing protocols of WSN.

1.2 Problem Background

WSN has gained the attention of researchers and industry in the last few years due to its practical applications in almost all walks of life (Zhu *et al.,* 2012; Conti and Giordano, 2014). WSN requires guaranteed QoS parameters, especially in real time applications. A number of techniques and models have been suggested by the researchers which solved the routing issues up to some extent. Still, it is the area of research which needs more focus for better provision of QoS parameters. A real time application must be reliable and delay-sensitive because QoS parameters are critical and have decisive effect on the performance of WSN. However, these QoS parameters have varying impact with respect to specific type of applications (Hammoudeh and Newman, 2013). For a reliable WSN, it is essential to have the guaranteed minimum end-to-end delay, high throughput for both real time and non-real time applications. However, some applications such as multimedia have additional requirement like low jitter and latency (Sumathi and Srinivas, 2012).

1.2.1 Routing Protocols in WSN

There are three types of routing protocols in WSN: flat, hierarchical and location based routing (Al-karaki and Kamal, 2003). In flat routing, every sensor node in the network has the same functions and roles. Contrary to flat routing, the nodes play diverse functions in the hierarchical routing. The location based routing uses nodes' locations to send data in the network. A routing protocol can be called adaptive when it is able to adjust according to the changes in network situations (Hammoudeh and Newman, 2013) considering specific performance parameters. A routing protocol should have the capability to establish performance metrics which are utilized to compute links/paths quality in order to minimize packet loss and to fulfil the requirements of applications. It should also be able to re-compute the paths in case of dynamic changes in the network (Carballido *et al.,* 2012).

Different routing protocols have been proposed in the last few years but the performance of these protocols varies with the nature of different type of applications and network architectures. A solution is to be sought for clustering in wireless and ad-hoc networks since these methods are mostly tempting for dense and large scale applications. In hierarchical routing, there are two or more tiers: the sensor nodes which placed in upper tier work as backbones and are known as Cluster Heads (CHs). The sensor nodes located in lower tiers are responsible for sensing and forwarding of data to base stations through CHs (Attea and Khalil, 2012). Nie *et al.* (2010) stated that multi-tier WSN networks are more scalable and provide greater benefits over single tier networks in terms of enhanced reliability, low cost and improved coverage. Numerous routing algorithms have been explored independently and also in context of clustering.

LEACH protocol suggested by Heinzelman *et al.* (2002) is a cluster based routing protocol that utilizes randomized variation of CHs role by equally dividing the energy capacity among the network nodes (Attea and Khalil, 2012). LEACH works very well for both constant and periodic monitoring applications that gathers and relays the data to a centralized station (Mendes and Rodrigues, 2011). LEACH is based on certain assumptions that limit its efficiency in different applications, such as single hop communication.

Attea and Khalil (2012) have suggested a new evolutionary based routing protocol to improve the unwanted actions of Evolutionary Algorithms in order to handle clustering routing problems in WSN. A novel fitness function is defined which integrates two clustering features: separation error and cohesion. Its main purpose is to save energy of the network while requiring more modifications in awareness of node heterogeneity. Another research work has been done on the QoS parameters in WSN but still it is a critical problem to provide guaranteed solutions to all QoS parameters (Liu *et al*., 2012). Therefore, it is an open issue for the researchers to propose some techniques or mechanisms. These standards do not provide any specific and satisfactory level of techniques to provide minimum end-to-end delay with high throughput. The real-time routing problem, specifically in the delay-constrained point to point network, is also discussed by Xu *et al*. (2009).

End-to-end delay has been a serious and challenging issue for the researchers in the last few years. The reasons for higher delay are heterogeneous network traffic, changing of network topology, burden on the network and the applications on demand. The situation becomes more complicated due to various causes, for example the obtainable synthesis of various changed and unusual network channels. To come up with a solution in order to handle such situations, end-to-end delay must be managed properly. Wang *et al.* (2012) presented that for heterogeneous traffic (real time and non-real time) the complexity of wireless sensor network increases while providing data delivery with lower delay. Additionally, the dynamic changes in the network can also affect different QoS parameters.

In order to achieve QoS for various types of applications, a generic system should be designed that can handle almost any kind of traffic. The performance of WSN can be measured by the QoS parameters such as achieving minimum end-to-end delay, more reliability, higher throughput, lower duty cycles and jitter (Yigitel *et al.,* 2011).

1.2.2 End-to-end Delay

In wireless sensor networks, minimizing end-to-end delay from sensor nodes to the sink node is a critical issue. To come up with a solution for this issue, routing layer performance should also be taken into account (Yigitel *et al.,* 2011). Similarly, the minimization of medium access delay at MAC layer of the sensor devices can also ensure end-to-end delay requirements.

A multiple path selection technique has been suggested by Huang and Fang (2007) to provide guaranteed QoS parameters performance. The authors proposed a multi-constraint multi-path routing algorithm based on hop count metric to enhance both reliability and delay parameters. QoS provision is improved based on local information that is mapped on path links. The inaccurate approximation of link quality and estimation of path can cause the performance degradation in WSN. In this approach, to find a better solution of the problem the optimization issue is mapped into a linear programming problem by applying certain approximation approaches. However, many of the possible discoverable paths are ignored, which lacks the routing algorithm performance and can affect reliability and end-to-end delay of the network. Furthermore, the authors have not considered the data delivery schemes that can significantly reduce packet redundancy.

All the aforementioned QoS-aware routing protocols consider different parameters such as delay and reliability with the aim of achieving the increased WSN performance. These routing protocols either ignore the unique constraints of the real time delay-sensitive applications or consider only a single issue. In the available literature, Distributed Adaptive Cooperative Routing Protocol (DACR) is the latest QoS-aware protocol that considers both parameters of delay and reliability. DACR is a lightweight reinforcement method that provides the best relay node with least overhead. Comparatively, the DACR performs better than other state-of-the-art approaches (Liang *et al.*, 2009). However, DACR ignored the differentiation of real time and non-real time network traffic to avoid traffic overloading. Xue *et al*. (2011) have highlighted the fact that real time applications are more delay-sensitive and therefore needs to be prioritized in routing the data. While in Stateless Protocol for Real-Time Communication in Sensor Networks (SPEED), He *et al*. (2003) have considered this differentiation of traffic types only for low congested networks. The performance of SPEED decreases in heavily congested network. However, its performance gradually decreases due to link failure which affects the reliability and causes excessive delays in data delivery.

1.2.3 Data Reliability

Lack of reliability is also an open research issue and requires special attention for the betterment of QoS in WSN. For data reliability, standard CSMA/CA protocol is also used which works better in light traffic mode. However, in a heavy traffic load scenarios, the performance of CSMA/CA degrades quickly and hampers the communication in terms of low throughput and high delays (Nefzi and Song, 2012). In order to address these issues on time and to identify the packet losses, acknowledgement mechanisms can be utilized accordingly. Huang and Fang (2007) have suggested path diversity based routing mechanism to improve the reliable packet delivery.

Packet loss refers to the packets that have been transmitted by the source node but have not been received at the destination node (Dong *et al.*, 2014). These packets are usually dropped due to either high interference on the communication link or Cyclic Redundancy Check (CRC) failures at the receiving unit of the destination node (Sumathi and Srinivas, 2012). WSN can get dynamic behaviour, where the sensor nodes can be disconnected from the network and links can be changed due to battery depletion, environmental conditions and topological changes. These changes are caused by the network scalability where the sensor nodes may be increased or decreased. Similarly, connections between nodes may change due to mobility of nodes (Abbasi *et al.*, 2013). These aforementioned issues lead to packet loss and ultimately degrade the performance of the network. All of the above issues are the causes that affect QoS in WSN. Traffic load is based on the events occurred in the specific area. Therefore, in order to control the above mentioned changes, adaptive actions need to be taken by the MAC protocols according to the network dynamics. For example, for real time systems, in case of high-rate data transmission traffic, the sensor nodes must continue with a high duty cycle. However, in case of low-rate traffic streams, most of the sensor nodes could be reserved as passive to conserve energy.

The above mentioned discussion leads to the conclusion that most of the existing routing protocols are aimed to address only a single QoS parameters issue such as end-to-end delay, reliability issue or trade-off between the both. None of these routing protocols consider the real time and non-real time network traffics, reliability and the link failure issues of WSN.

1.3 Problem Statement

In WSN, QoS is affected by a number of parameters such as end-to-end delay, reliability and topology changes. The real time WSN has unique challenges and constraints of QoS parameters such as, delay-sensitivity and reliable data delivery. Different mechanisms have been suggested in literature (He *et al.*, 2003; Al-anbagi *et al.*, 2013) that consider end-to-end delay as the critical issue which needs to be enhanced in order to get efficiency. Furthermore, the issues of reliability also need to be enhanced to address the issue which occur due to dynamic network topology. Therefore, the QoS requirements of routing protocols are mainly determined by the features served in WSN applications. Most of the existing routing protocols are based on the specific application. Therefore, further enhancement is required in these protocols to make them adaptive that can satisfy the dynamic requirements of different applications. The recent advancement of WSN applications has introduced the multiplicity of nodes which increases challenges for designers to develop new protocols and improve the performance. In this research work, adaptive techniques are proposed by enhancing existing techniques for obtaining better results and improvements in terms of QoS parameters. Through an extensive literature review, it is found that no one has worked on this research theme. Hence, a protocol which alleviates the mentioned features is required.

1.4 Research Questions

The following research questions will be addressed:

i. How to reduce end-to-end delay in order to deliver real time data in a certain time threshold.
ii. How to distinguish real time and non-real time data packets to improve overall throughput of wireless sensor network.
iii. How to improve packet delivery ratio, to guarantee quick recovery from link failures and to ensure reliability of data transmission with acceptable delay.

1.5 Research Aim

The aim of this research is to come up with a new routing protocol which will be able to improve the medium access and to provide low end-to-end delay to get the high level efficiency in the wireless sensor networks. The aim of designing a queuing model is to distinguish the real time and non-real time traffic of the network and forward the traffic accordingly. Furthermore, an efficient data delivery and recovery scheme is also aimed at improving packet delivery and recovering the lost data packets due to links or transmission failures. So, the development of a routing protocol which will facilitate the aforementioned requirements is the main aim of this research oriented work

1.6 Research Objectives

The following research objectives are to be achieved during the research work. These objectives are in the perspective of the research questions mentioned above.

i. To design and develop an efficient delay aware routing algorithm based on hop count metric using multi-path selection to achieve minimum end-to-end delay.
ii. To design and develop an intelligent Queuing model that identifies and distinguishes the real time and non-real time traffic and forwards the traffic efficiently.

iii. To design and develop an efficient data delivery and recovery scheme that ensures packet delivery and recovery caused by broken links and transmissions failures during the data transmissions.

1.7 Research Scope

To know and understand the scope of the proposed research, one needs to know issues related to the QoS parameters in depth. The scope of this research work covers the issues related to QoS parameters in WSN. The real time data delivery and reliability are both the desired aspects of this research work. This research work enhances QoS required for both real time and non-real time applications which provides reliable and time bound data delivery to the users. The scope of this research work is as follows.

i. In WSN, the network traffic can be of both real time and non-real time nature. These types of traffic have their own delay-constraints which need to be considered accordingly. This research work focuses on routing mechanism for both real time and non-real time communication.

ii. The deployment of sensor networks can be planned or random which is based on the type of applications. The proposed work is applicable for both types of deployment as for as the sensors are in the communication range of each other.

iii. The topology of WSN is sometimes affected by the movement of sensors which may have decisive effect on routing. Therefore, this research does not consider sensors' mobility. However, sometimes static topologies are also affected by node failures and lead to link failure which are considered in this research work.

1.8 Significance of the Study

The use of this research work can be substantial in different real life applications such air control system, industrial applications where on time data delivery is required. The routing is a key factor which degrades or improves the overall performance of the network. In this work, the delay and reliability features of real time traffic and non-real time are quantified on the basis of hop-count, residual energy and link quality. This research provides both delay-tolerant and delay-sensitive data delivery depending upon the type of application. The proposed research provides the reliable data delivery with reduced delay in WSN. The traffic load is classified by distinguishing the type of traffic which reduces the link failure and improves the performance of WSN.

1.9 Organization of Thesis

The remaining of the thesis is organized as follows: Chapter 2 provides a detailed literature review about the latest work in the field of WSN with respect to routing issues and their existing solutions. Different techniques used for improving reliability, minimizing delay and maintainability of the quality of services classes are elaborated. Chapter 3 presents the research methodology, including the operational framework for the design and development of an enhanced delay-aware and reliable routing protocol (EDARRP) for WSN. It consists of three components namely DAPSA, ISCQM and EDDRS. Chapter 4 provides discussion on the first component that is designing and development of the Delay-Aware Path Selection Algorithm (DAPSA).

Chapter 5 presents the second and third components that are designing and development of an Intelligence Service Classifier Queuing Model (ISCQM) and an Efficient Data Delivery and Recovery Scheme (EDDRS). Chapter 6 is the detailed description of the evaluation and results of the proposed routing protocol and its comparison with state-of-the-art protocols. Chapter 7 concludes and describes the contributions of this research with possible future directions.

REFERENCES

Abbasi, A. A., Younis, M. F., and Baroudi, U.A. (2013). Recovering From a Node Failure in Wireless Sensor-Actor Networks with Minimal Topology Changes. *IEEE Transactions on Vehicular Technology*. 62(1), 256–271.

Abreu, C., Ricardo, M., and Mendes, P. M. (2014). Energy-aware routing for biomedical wireless sensor networks. *Journal of Network and Computer Applications.* 40(1), 270–278.

Akbari, J.T. (2012). An adaptive backbone formation algorithm for wireless sensor networks. *Computer Communications*. 35(11), 1333–1344.

Akyildiz, I. F., Melodia, T., and Chowdhury, K. R. (2007).A survey on wireless multimedia sensor networks. *Computer Network.* 51(4), 921–960.

Al-anbagi, I., Erol-kantarci, M., and Mouftah, H. T. (2013). Priority- and Delay-Aware Medium Access for Wireless Sensor Networks in the Smart Grid, *IEEE Systems Journal*. 8(2), 101–111.

Al-karaki, J. N., and Kamal, A. E. (2004). Routing Techniques in Wireless Sensor Networks, *IEEE Wireless Communications.* 11(6), 270 – 298.

Alonso, J. M., Ocaña, M., Hernandez, N., Herranz, F., Llamazares, A., Sotelo, M. A. Magdalena, L. (2011). Enhanced WiFi localization system based on Soft Computing techniques to deal with small-scale variations in wireless sensors. *Applied Soft Computing*, 11(8), 4677–4691.

Anitha, R. U., and Kamalakkannan, P. (2013). Enhanced cluster based routing protocol for mobile nodes in wireless sensor network. In *the International Conference on Pattern Recognition, Informatics and Mobile Engineering*, 21-22 February. Massachusetts, USA: IEEE, 187–193.

Aslan, Y. E., Korpeoglu, I., and Ulusoy, O. (2012). A framework for use of wireless sensor networks in forest fire detection and monitoring. *Computers, Environment and Urban Systems*, 36(6), 614-625.

Attea, B. A., and Khalil, E. A. (2012). A new evolutionary based routing protocol for clustered heterogeneous wireless sensor networks. *Applied Soft Computing*, 12(7), 1950–1957.

Ayaz, M., Baig, I., Abdullah, A., and Faye, I. (2011). A survey on routing techniques in underwater wireless sensor networks. *Journal of Network and Computer Applications*, 34(6), 1908–1927.

Babbitt, T. A., Morrell, C., Szymanski, B. K., and Branch, J. W. (2008). Self-selecting reliable paths for wireless sensor network routing. *Computer Communications*. 31(16), 3799–3809.

Balamurugana, S., Saraswathi, S. and Mullaivendhanc, A. (2012). Delay Sensitive Optimal Anycast Technique to Maximize Lifetime in Asynchronous WSN's. *Procedia Engineering* 38(1): 3351-3361.

Bangash, J. I., Abdullah, A. H., Anisi, M. H., & Khan, A. W. (2014). A survey of routing protocols in wireless body sensor networks. *Sensors* (Basel, Switzerland), 14(1), 1322–57.

Banimelhem, O., and Khasawneh, S. (2012). GMCAR: Grid-based multipath with congestion avoidance routing protocol in wireless sensor networks. *Ad Hoc Networks*, 10(7), 1346–1361.

Barontib, P., Pillaia, C.P., Chooka, V.W.C, Chessab,S.C., Gottab, A. and Hua Y.F.(2007). Wireless sensor networks: A survey on the state of the art and the 802.15.4 and ZigBee standards. *Computer Communications* 30(7): 1655-1695.

Beaubruna, R., Ruizb,J.F.L., Poirierc, B. and Quinterob A. (2012). A middleware architecture for disseminating delay-constrained information in wireless sensor networks. *Journal of Network and Computer Applications* 35(1): 403-411.

Boulis, A. (2007). Demo Abstract : Castalia : Revealing Pitfalls in Designing Distributed Algorithms in WSN, 407–408. In *the Proceedings of the 5th international conference on embedded networked sensor system*, 4-9 November. New York, USA: ACM, 407-408

Buratti, C., Conti, A., Dardari D., and Verdone R., (2009).An overview on wireless sensor networks technology and evolution. *Sensors* 9(9), 6869-6896.

Canete, E., Diaz, M., Llopis, L., and Rubio, B. (2012). HERO: A hierarchical, efficient and reliable routing protocol for wireless sensor and actor networks. *Computer Communications*, 35(11), 1392–1409.

Carballido, B. V., Rea, S., and Pesch, D. (2012). InRout – A QoS aware route selection algorithm for industrial wireless sensor networks. *Ad Hoc Networks*, 10(3), 458–478.

Carli, M., Panzieri, S., and Pascucci, F. (2014). A joint routing and localization algorithm for emergency scenario. *Ad Hoc Networks*, 13(A), 19-33.

Challal, Y., Ouadjaout, A., Lasla, N., Bagaa, M., and Hadjidj, a. (2011). Secure and efficient disjoint multipath construction for fault tolerant routing in wireless sensor networks. *Journal of Network and Computer Applications*, 34(4), 1380–1397.

Chehri, A., Fortier, P., and Tardif, P.-M.(2009). Cross-layer link adaptation design for UWB-based sensor networks. *Computer Communications*, 32(13-14), 1568–1575.

Chen, H., and Lou, W. (2014). On protecting end-to-end location privacy against local eavesdropper in Wireless Sensor Networks. *Pervasive and Mobile Computing*,16(A), 36–50.

Chen, M., Leung, V. C. M., Mao, S., and Yuan, Y. (2007). Directional geographical routing for real-time video communications in wireless sensor networks. *Computer Communications*, 30(17), 3368–3383.

Chena, I.R., Wanga, Y., Wangb, D.C. (2010). Reliability of wireless sensors with code attestation for intrusion detection. *Information Processing Letters* 110(17), 778-786.

Cheng, C., Tse, C. K. and Lau, F. C. M. (2011). A Delay-Aware Data Collection Network Structure for Wireless Sensor Networks, *IEEE Sensors Journal*, 11(3), 699–710.

Chiang, C., Liao, W., and Liu, T. (2007). Adaptive Downlink / Uplink Bandwidth Allocation in IEEE 802.16 (WiMAX) Wireless Networks : A Cross-Layer

Approach, In *the Global Telecommunications Conference,* 25-27 November. Washington, DC: IEEE, 4775–4779.

Choe, H. J., Ghosh, P., and Das, S. K. (2010). QoS-aware data reporting control in cluster-based wireless sensor networks. *Computer Communications*, 33(11), 1244–1254.

Chunlin, L. and Layuan, L. (2008). Cross-layer optimization policy for QoS scheduling in computational grid. *Journal of Network and Computer Applications* 31(3): 258-284.

Cobo, L., Quintero, A., and Pierre, S. (2010). Ant-based routing for wireless multimedia sensor networks using multiple QoS metrics. *Computer Networks*, 54(17), 2991–3010.

Conti, M., and National, I. (2014). Mobile Ad Hoc Networking : Milestones , Challenges , and New Research Directions, *IEEE Communications Magazine*, 52(1), 85–96.

Demirkol, I. and C. Ersoy (2009). Energy and delay optimized contention for wireless sensor networks. *Computer Networks*, 53(12), 2106-2119.

Djenouri, D. and I. Balasingham (2011).Traffic-differentiation-based modular QoS localized routing for wireless sensor networks. *IEEE Transactions on Mobile Computing*, 10(6), 797-809.

Doherty, L., Simon, J., and Watteyne, T. (2012). Wireless Sensor Network Challenges and Solutions, *Microwave Journal*, 34(1), 147-155.

Dong, Q., and Dargie, W. (2013). A Survey on Mobility and Mobility-Aware MAC Protocols in Wireless Sensor Networks. *IEEE Communications Surveys and Tutorials*, 15(1), 88–100.

Dong, W., Liu, Y., He, Y., and Zhu, T. (2014). Measurement and Analysis on the Packet Delivery Performance in a Large-Scale Sensor Network, *IEEE/ACM Transactions on Networking*, 22(6), 1952–1963.

Dunbabin, M., Corke, P., Vasilescu, I., Rus, D. Data Muling Over Underwater Wireless Sensor Networks Using An Autonomous Underwater Vehicle (2006). In *the Proceedings of the IEEE International Conference on Robotics and Automation*, 25-28 June. Luoyang, Henan: IEEE 2091– 2098.

Fotouhi, H., Zúñiga, M., and Alves, M. (2012). Smart-HOP: a reliable handoff mechanism for mobile wireless sensor networks. *Sensor Networks*, 7158(1), 131–146.

Gadallah, Y., and Serhani, M. A. (2011). A WSN-driven service discovery technique for disaster recovery using mobile ad hoc networks. *Wireless Days (IFIP 11)*, Niagara Falls, Canada: IEEE, 412–416.

Gragopoulos, I., Tsetsinas, I., Karapistoli, E., and Pavlidou, F.-N. (2008). FP-MAC: A distributed MAC algorithm for 802.15.4-like wireless sensor networks. *Ad Hoc Networks*, 6(6), 953–969.

Guermazi, A., and Abid, M. (2011). An Efficient Key Distribution Scheme to Secure Data-Centric Routing Protocols in Hierarchical Wireless Sensor Networks. *Procedia Computer Science*, 5(1), 208–215.

Guo, W., and Zhang, W. (2014).A survey on intelligent routing protocols in wireless sensor networks. *Journal of Network and Computer Applications*, 38(1), 185–201.

Ha, R., Ho, P.H., Shen, X.S. (2006). Cross-layer application-specific wireless sensor network design with single-channel CSMA MAC over sense-sleep trees. *Computer Communications*, 29(17), 3425-3444.

Halder, S., and Das, S.B. (2014). Enhancement of wireless sensor network lifetime by deploying heterogeneous nodes. *Journal of Network and Computer Applications*, 38(1), 106–124.

Hammoudeh, M., and Newman, R. (2013b). Adaptive routing in wireless sensor networks: QoS optimization for enhanced application performance. *Information Fusion*, 22(1), 235–247.

Han, S.-W., Jeong, I.-S., and Kang, S.-H.(2013). Low latency and energy efficient routing tree for wireless sensor networks with multiple mobile sinks. *Journal of Network and Computer Applications*, 36(1), 156–166

Hassan, A. I., Elsabrouty, M., and El-Ramly, S. (2011). Energy-efficient reliable packet delivery in variable-power wireless sensor networks. *Ain Shams Engineering Journal*, 2(2), 87–98.

Haule, J., and Michael, K. (2014). Deployment of wireless sensor networks (WSN) in automated irrigation management and scheduling systems: a review. In *the Proceedings of the 2nd Pan African International Conference on Science, Computing and Telecommunications, 27-29 July*. Arusha, Tanzania: IEEE 86–91.

He, T., Stankovic, J. A., Lu, C., and Abdelzaher, T. (2003). SPEED : A Stateless Protocol for Real-Time Communication in Sensor Networks. In *the Proceedings of 23rd International Conference on Distributed Computing Systems, Providence*, 19-22 May. RI, USA: IEEE, 46-55

He, Y., Zhu, W., and Guan, L. (2011). Optimal Resource Allocation for Pervasive Health Monitoring Systems with Body Sensor Networks. *IEEE Transactions on Mobile Computing*, 10(11), 1558–1575.

Heinzelman W., Chandrakasan A., Balakrishnan, H. (2002) An application-specific protocol architecture for wireless micro sensor networks, *IEEE Transactions on Wireless Communications*, 1(4), 660–670.

Hortos, W. S. (2010). Cross-layer protocol design for QoS optimization in real-time wireless sensor networks, In *the Prec. of Wireless Sensing, Localization, and Processing*, 28 April, Orlando, FL: SPIE, 21-31.

Huang, X., and Fang, Y. (2007). Multi-constrained QoS multipath routing in wireless sensor networks. *Wireless Networks*, 14(4), 465–478.

Hussain, S. A., Razzak, M. I., Minhas, A. A., Sher, M., and Tahir, G. R. (2009). Energy Efficient Image Compression in Wireless Sensor Networks. *International Journal*, 2(1), 623–628.

Isik, S., Donmez, M.Y., Ersoy, C. (2011). Cross Layer Load Balanced Forwarding Schemes for Video Sensor Networks, *Ad Hoc Networks* 9(3): 265-284.

Javaid, N., Abbas, Z., Fareed, M. S., Khan, Z. A., and Alrajeh, N. (2013). M-ATTEMPT: A New Energy-Efficient Routing Protocol for Wireless Body Area Sensor Networks. *Procedia Computer Science*, 19(A), 224 - 231

Kandris, D., Tsagkaropoulos, M., Politis, I., Tzes, A., and Kotsopoulos, S. (2011). Energy efficient and perceived QoS aware video routing over Wireless Multimedia Sensor Networks. *Ad Hoc Networks*, 9(4), 591–607.

Karaboga, D., Okdem, S., and Ozturk, C. (2012). Cluster based wireless sensor network routing using artificial bee colony algorithm. *Wireless Networks*, 18(7), 847–860.

Khan, R., Madani, S. A., Hayat, K., and Khan, S. U. (2012). Clustering-based power-controlled routing for mobile wireless sensor networks, *International Journal of Communication Systems*, 25(4), 529–542.

Kumar, H., Arora, H., and Singla, R. K. (2013).*Energy-Aware Fisheye Routing (EA-FSR) algorithm for wireless mobile sensor networks*. Egyptian Informatics Journal, 14(3), 235–238.

Lang, X., and Chin, K.-W.(2014). Algorithms for bounding end-to-end delays in Wireless Sensor Networks. *Wireless Networks*, 20(7), 2131 - 2146

Le, T., Hu, W., Corke, P., and Jha, S. (2009). ERTP: Energy-efficient and Reliable Transport Protocol for data streaming in Wireless Sensor Networks. *Computer Communications*, 32(7-10), 1154–1171.

Levendovszky, J., Tran-Thanh, L., Treplan, G., and Kiss, G. (2010). Fading-aware reliable and energy efficient routing in wireless sensor networks. *Computer Communications*, 33(1), S102–S109.

Li, B., and Kim, K.-I. (2013). A novel real-time scheme for (m,k)-firm streams in wireless sensor networks. *Wireless Networks*, 20(4), 719–731.

Li,J., Li, Z., Mohapatra P. (2009). Adaptive per hop differentiation for end-to-end delay assurance in multi-hop wireless networks. *Ad Hoc Networks* 7(6), 1169-1182.

Li, Y., and Bartos, R. (2014). A survey of protocols for Intermittently Connected Delay-Tolerant Wireless Sensor Networks. *Journal of Network and Computer Applications*, 41, 411–423.

Liang, X., Chen, M., Xiao, Y., Balasingham, I. (2009). A novel cooperative communication protocol for QoS provisioning in wireless sensor networks, in *the 5th International Conference on Test beds and Research Infrastructures for the Development of Networks & Communities and Workshops*, 6-8 April. Washington DC, USA: IEEE 115–120

Lin, F. Y.-S., Yen, H.-H., and Lin, S.-P.(2009). Delay QoS and MAC Aware Energy-Efficient Data-Aggregation Routing in Wireless Sensor Networks. *Sensors*, 9(10), 7711–7732.

Liu, Q., Chang, Y., and Jia, X. (2013). A hybrid method of CSMA/CA and TDMA for real-time data aggregation in wireless sensor networks. *Computer Communications*, 36(3), 269–278.

Liu, T., Li, Q., and Liang, P. (2012). An energy-balancing clustering approach for gradient-based routing in wireless sensor networks. *Computer Communications*, 35(17), 2150–2161.

Lu, G., and Krishnamachari, B. (2007). Minimum latency joint scheduling and routing in wireless sensor networks. *Ad Hoc Networks*, 5(6), 832–843.

Mainwaring, Polastre, Szewczyk, Culler, Anderson, Wireless Sensor Networks for Habitat Monitoring
Available at: http://www.cs.usfca.edu/~srollins/courses/cs686-f08/web/notes/wsnoverview.html
Accessed on: 25-October, 2013

Mascarenas, D., Flynn, E., Rosing, T., Lee, B., Musiani, D., Dasgupta, S., Kpotufe, S. (2007). A different approach to sensor networking for SHM: Remote powering and interrogation with unmanned aerial vehicles. In *the Proceedings of the 6th International workshop on Structural Health Monitoring*, *11-13 September, Stanford, CA: DEStech, 45-54.*

Maadani, M., Motamedi, S. A., and Safdarkhani, H. (2011). Delay-Reliability Trade-off in MIMO-Enabled IEEE 802.11-Based Wireless Sensor and Actuator Networks. *Procedia Computer Science*, 5(1), 945–950.

Macit, M., Gungor, V. C., and Tuna, G. (2014). Comparison of QoS-aware single-path vs. multi-path routing protocols for image transmission in wireless multimedia sensor networks. *Ad Hoc Networks*, 19, 132–141.

Mendes, L. D. P., and Rodrigues, J.P.C.(2011). A survey on cross-layer solutions for wireless sensor networks. *Journal of Network and Computer Applications,* 34(2), 523–534.

Misra, S., and Dias, P.T (2010).A simple, least-time, and energy-efficient routing protocol with one-level data aggregation for wireless sensor networks. *Journal of Systems and Software,* 83(5), 852– 863

Moazzez-Estanjini, R. and Paschalidis,I.C (2012). On delay-minimized data harvesting with mobile elements in wireless sensor networks. *Ad Hoc Networks*, 10(7), 1191-1203.

Mohaghegh, M., Masseyacnz, E., and Manford, C. (2011).Cross-layer Optimization for Quality of Service Support in Wireless Sensor Networks. Structure, *UNITEC*, 528–533.

Nadu, T., Deepa, C., and Latha, B. (2014). HHCS : Hybrid Hierarchical Cluster Based Secure Routing Protocol for Wireless Sensor Networks, In *the International Conference on Information Communication and Embedded Systems (ICICES 14)*, Chennai, India: IEEE, 1022-1026.

National Instruments, What is a Wireless Sensor Network ?(2011). National Instruments. Available at: http://www.ni.com/white-paper/11529/en/
Accessed on: 17/09/2013.

Nayebi, A. Sarbazi H.A., Karlsson G. (2010). Performance analysis of opportunistic broadcast for delay-tolerant wireless sensor networks. *Journal of Systems and Software,* 83(8): 1310-1317.

Nazir, B., and Hasbullah, H. (2013). Energy efficient and QoS aware routing protocol for Clustered Wireless Sensor Network. *Computers and Electrical Engineering*, 39(8), 2425–2441.

Nefzi, B. and Y.-Q.Song (2012). QoS for wireless sensor networks: Enabling service differentiation at the MAC sub-layer using CoSenS. *Ad Hoc Networks* 10(4), 680-695.

Ngai, E., Zhou, Y., Lyu, M. R., and Liu, J. (2010). A delay-aware reliable event reporting framework for wireless sensor–actuator networks. *Ad Hoc Networks*, 8(7), 694–707.

Nie, P., Jin, Z., and Gong, Y. (2010). Mires ++ : A Reliable , Energy-aware Clustering Algorithm for Wireless Sensor Networks, In *the Proceedings of the 13th*

International conference on Modeling, analysis, and simulation of wireless and mobile systems, 17-21 October. NY, USA: ACM, 178-186.

Nikolidakis, S., Kandris, D., Vergados, D., and Douligeris, C. (2013). Energy Efficient Routing in Wireless Sensor Networks Through Balanced Clustering. *Algorithms*, 6(1), 29–42.

Ozdemir, S. (2008). Functional reputation based reliable data aggregation and transmission for wireless sensor networks. *Computer Communications,* 31(17), 3941-3953.

Pejanovi, M., and Tafa, Z. (2012). A Survey of Military Applications of Wireless Sensor Networks. In *the Mediterranean Conference on Embedded Computing,* 19-21 June. Barcelona, Spain: IEEE, 196 - 199

Petrioli, C., Member, S., Nati, M., Casari, P., Zorzi, M., Basagni, S., and Member, S. (2014). ALBA-R : Load-Balancing Geographic Routing Around Connectivity Holes in Wireless Sensor Networks, *IEEE Transactions on Parallel and Distributed Systems*, 25(3), 529–539.

Prathap, U., Shenoy, P. D., Venugopal, K. R., and Patnaik, L. M. (2012). Wireless Sensor Networks Applications and Routing Protocols: Survey and Research Challenges. In *the International Symposium on Cloud and Services Computing*,17-18 Dec, Mangalore: IEEE, 49–56.

Raayatpanah, M. A., SalehiFathabadi, H., Khalaj, B. H., Khodayifar, S., and Pardalos, P. M. (2014). Bounds on end-to-end statistical delay and jitter in multiple multicast coded packet networks. *Journal of Network and Computer Applications*, 41(1), 217–227.

Razzaque, M. A., Ahmed, M. H. U., Hong, C. S., and Lee, S. (2014). QoS-aware distributed adaptive cooperative routing in wireless sensor networks. *Ad Hoc Networks*. 19(1), 28-42.

Salameh, H.B. Shu, T. Krunz M. (2007). Adaptive cross-layer MAC design for improved energy-efficiency in multi-channel wireless sensor networks. *Ad Hoc Networks,* 5(6), 844-854.

Shakshuki, E. M., Malik, H., and Sheltami, T. R. (2011). A comparative study on simulation vs. real time deployment in wireless sensor networks. *Journal of Systems and Software*, 84(1), 45–54.

Silva, I., Guedes, L. A., Portugal, P., and Vasques, F. (2012). Reliability and availability evaluation of Wireless Sensor Networks for industrial applications. *Sensors*, 12(1), 806–38.

Sobeih, A. (2006). J-SIM : A Simulation and Emulation Environment for Wireless Sensor Networks Hung - Ying Tyan, *National Suny At-Sen University*, 104–119.

Srinivas, E., Ekamabaram, M.N. (2013). An Efficient and Protected Routing Practice for High Reliability Sensor Networks, *International Journal of Computer and Electronics Research*, 2(4), 514–517.

Sumathi, R., and Srinivas, M. G. (2012). A Survey of QoS Based Routing Protocols for Wireless Sensor Networks. *Journal of Information Processing Systems*, 8(4), 589–602.

Tacconi, D., Miorandi, D., Carreras, I., Chiti, F., Fantacci R. (2010). Using wireless sensor networks to support intelligent transportation systems. *Ad Hoc Networks*, 8(5), 462-473.

Tang, S. and Li, W. (2006). QoS supporting and optimal energy allocation for a cluster based wireless sensor network. *Computer Communications*, 29(14), 2569-2577.

Torres, C. and Glosekotter, P. (2011). Reliable and energy optimized WSN design for a train application. *Journal of Systems Architecture*, 57(10): 896-904.

Tunca, C., Isik, S., Donmez, M. Y., Ersoy, C., and Member, S. (2014). Distributed Mobile Sink Routing for Wireless Sensor Networks : A Survey. *IEEE Communications Surveys and Tutorials*, 16(2), 877–897.

Tyagi, S., and Kumar, N. (2013). A systematic review on clustering and routing techniques based upon LEACH protocol for wireless sensor networks. *Journal of Network and Computer Applications*, 36(2), 623–645.

Vajdi, S. V., Hilal, A. R., Abeer, S. A., and Basir, O. a. (2012). Multi-hop Interference-Aware Routing Protocol for Wireless Sensor Networks. *Procedia Computer Science*, 10, 933–938.

Varga, A., and Hornig, R. (2008). An Overview of the OMNET++ Simulation Environment. In *the Proceedings of the First International ICST Conference on Simulation Tools and Techniques for Communications Networks and Systems*.24–26 August, Belgium: ACM, 60

Zhao, W. Ammar, M., Zegura, E. (2004). A message ferrying approach for data delivery in sparse mobile ad hoc networks, In *the Proceedings of the 5th ACM international symposium on mobile ad hoc networking and computing*, 24-26 May, New York, USA: ACM, 187–198.

Zhao, W., Ammar, M., Ferrying M. (2003). Proactive Routing In Highly- Partitioned Wireless Ad Hoc Networks, In *the Proceedings of the 9th IEEE workshop on future trends of distributed computing systems,* 28-30 May, Barcelona: IEEE, 308–314.

Wang, D., and Wang, P. (2014). Understanding security failures of two-factor authentication schemes for real-time applications in hierarchical wireless sensor networks. *Ad Hoc Networks*, 20(1), 71–85.

Wang, Y., Vuran, M. C., and Goddard, S. (2009). Cross-Layer Analysis of the End-to-End Delay Distribution in Wireless Sensor Networks. In *the 30th Real-Time Systems Symposium*, 1-4 Dec, NJ, USA: IEEE, 138–147.

Wang, Y., Vuran, M.C., Goddard S. (2012). Cross-layer analysis of the end-to-end delay distribution in wireless sensor networks. *IEEE/ACM Transactions on Networking,* 20(1), 305-318.

Watteyne, T., Molinaro, A., Richichi, M. G. and Dohler, M., (2011). From MANET To IETF ROLL Standardization : A Paradigm Shift in WSN Routing Protocols, *IEEE Communications Surveys and Tutorials*, 13(4), 688–707.

Wen, Y., Tom, A. F., and Powers, D. M. W. (2014). On energy-efficient aggregation routing and scheduling in IEEE 802.15.4-based wireless sensor networks, *Wireless Communications and Mobile Computing*, 14(2), 232-253

Wu, D., Bao, L., and Li, R. (2010). A holistic approach to wireless sensor network routing in underground tunnel environments. *Computer Communications*, 33(13), 1566–1573.

Xian, X., Shi, W., and Huang, H. (2008). Comparison of OMNET++ and other simulator for WSN simulation. In *the 3rd IEEE Conference on Industrial Electronics and Applications.* 3-5 June. Singapore: IEEE, 1439–1443.

Xiaonan, W., Deguang, L., Hongbin, C., and Conghua, X. (2014). All-IP wireless sensor networks for real-time patient monitoring. *Journal of Biomedical Informatics*, 52(1), 406-417.

Xu, D., and Gao, J. (2011). Comparison Study to Hierarchical Routing Protocols in Wireless Sensor Networks. *Procedia Environmental Sciences*, 10(A), 595–600.

Xu, H., Huang, L., Liu, W., Wang, G., and Wang, Y. (2009). Topology control for delay-constraint data collection in wireless sensor networks. *Computer Communications*, 32(17), 1820–1828.

Xue, Y., Ramamurthy, B., Vuran M.C. (2011). SDRCS: A service-differentiated real-time communication scheme for event sensing in wireless sensor networks. *Computer Networks*, 55(15), 3287-3302.

Xun, J., Ning, B., Li, K., and Zhang, W. (2013). The impact of end-to-end communication delay on railway traffic flow using cellular automata model. *Transportation Research Part C: Emerging Technologies*, 35(1), 127–140.

Yan, M., Lam, K.-Y., Han, S., Chan, E., Chen, Q., Fan, P., Nixon, M. (2014). Hyper graph-based data link layer scheduling for reliable packet delivery in wireless sensing and control networks with end-to-end delay constraints. *Information Sciences,* 278(1), 34-55.

Yan, R., Sun, H., and Qian, Y. (2013). Energy-Aware Sensor Node Design with Its Application in Wireless Sensor Networks, *IEEE Transactions on Instrumentation and Measurement*, 62(5), 1183–1191.

Yigitel, M.A. Incel, O.D., Ersoy C. (2011). Design and implementation of a QoS-aware MAC protocol for Wireless Multimedia Sensor Networks. *Computer Communications*, 34(16), 1991-2001.

Younis, M., Senturk, I. F., Akkaya, K., Lee, S., and Senel, F. (2014). Topology management techniques for tolerating node failures in wireless sensor networks: A survey. *Computer Networks*, 58, 254–283.

Younis, M., and Akkaya, K. (2003). An Energy-Aware QoS Routing Protocol for Wireless Sensor Networks. *In the Proceeding of the IEEE Workshop on Mobile and Wireless Networks*, 19-22 May Baltimore, USA: IEEE, 710-715

Yuan, Y., Yang, Z., He, Z., and He, J. (2006).An integrated energy aware wireless transmission system for QoS provisioning in wireless sensor network. *Computer Communications*, 29(2), 162–172.

Zeng, W., Cote, J., Chen, X., Kim, Y.-A., Wei, W., Suh, K., Shi, Z. J. (2014). Delay monitoring for wireless sensor networks: an architecture using air sniffers. *Ad Hoc Networks*, 13(1), 549–559.

Zeng, Y., Li, D., and Vasilakos, A. V. (2013). Real-time data report and task execution in wireless sensor and actuator networks using self-aware mobile actuators. *Computer Communications*, 36(9), 988–997.

Zhang, D., Jiang, J., Anani, A., and Li, H. (2009). QoS-guaranteed packet scheduling in wireless networks. *The Journal of China Universities of Posts and Telecommunications*, 16(2), 63–67.

Zhang, L., and Xiao, D. (2012). An Error-Aware Routing Protocol over Lossy Links in Wireless Sensor Networks. *Procedia Engineering*, 29, 1492–1500.

Zhang, R., Berder, O., Gorce, J.-M., and Sentieys, O. (2012). Energy–delay tradeoff in wireless multihop networks with unreliable links. *Ad Hoc Networks*, 10(7), 1306–1321.

Zhu, C., Zheng, C., Shu, L., and Han, G. (2012). A survey on coverage and connectivity issues in wireless sensor networks. *Journal of Network and Computer Applications*, 35(2), 619–632.

Zhu, J., Hung, K.-L., Bensaou, B., and Nait-Abdesselam, F. (2008). Rate-lifetime tradeoff for reliable communication in wireless sensor networks. *Computer Networks*, 52(1), 25–43.

Zhu, X., He, C., Li, K., and Qin, X. (2012). Adaptive energy-efficient scheduling for real-time tasks on DVS-enabled heterogeneous clusters. *Journal of Parallel and Distributed Computing*, 72(6), 751–763.