UNIVERSITI PUTRA MALAYSIA

DISTANCE VECTOR-HOP RANGE-FREE LOCATION ALGORITHM FOR WIRELESS SENSOR NETWORK

AZYYATI ADIAH BINTI ZAZALI

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DISTANCE VECTOR-HOP RANGE-FREE LOCATION ALGORITHM FOR WIRELESS SENSOR NETWORK

By

AZYYATI ADIAH BINTI ZAZALI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

July 2015

DEDICATION

To my beloved parents; Zazali bin Chik, and Zaliha binti Abd Wahab, my siblings, very helpful friends in UPM and my closest friends.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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July 2015

Chairman : Professor Shamala Subramaniam, Ph.D.
Faculty : Computer Science and Information Technology

Wireless Sensor Network (WSN) has become a significant technology that is attracting enormous research interest in the area of localization for sensor nodes. The localization algorithms for sensor nodes can be classified into three categories; range-based, range-free and hybrid. These localization algorithms are used to measure the actual distances between nodes and eventually determine the respective locations. Distance Vector-Hop (DV-Hop) algorithm has become the focus of studies for range-free localization algorithms. However, existing works on DV-Hop localization algorithm held onto the assumption that the placement of sensor nodes has been pre-determined before they are being distributed. This has caused the tasks for each sensor node to be permanently fixed, thus causing the overall process of the localization algorithm to be complex. In addition, these works have limited the flooding process in localization to be mostly done either by manual configuration or through the Global Positioning System (GPS), both of which are used to estimate the position of the sensor nodes. This has caused a complexity in the algorithm, along with the infeasible usage of GPS in the flooding process which requires high power consumption and challenge the limited battery powered sensor nodes. Thus, this research has proposed two ideas. First is the intelligent nodes placement algorithm for sensor nodes in order to introduce algorithm with low complexity and low localization error. The second idea proposed is the improvement of the region area for sensor nodes placement to control the network flooding associated problems, whilst increasing the network lifetime, reduce power consumption and minimizing the localization error. Extensive Discrete Event Simulation (DES) experiments have been conducted to the DV-Hop localization algorithm as one of the typical representative of range-free localization algorithm for the purpose of performance analysis strategy. The process in DES based on the initialization, scheduler and events. During the events, the positioning process of the DV-Hop happened. The performance metrics for the first idea are the average localization error of the nodes and the event time for distribution of nodes inside the area while for the second idea, the average localization error also calculated. The other performance metrics are the power transmission of the nodes and the coordinate accuracy. The acquired results have proven that the proposed algorithms have successfully enhanced the DV-Hop localization algorithm with low complexity, and low localization error, increase the network lifetime and reduce the power consumption for a range-free localization algorithm.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Master Sains

HOP-JARAK VEKTOR BERJARAK BEBAS BAGI ALGORITMA PENEMPATAN BAGI RANGKAIAN SENSOR TANPA WAYAR

Oleh

AZYYATI ADIAH BINTI ZAZALI

Julai 2015

Pengerusi : Profesor Shamala Subramaniam, Ph.D.
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Rangkaian Sensor Tanpa Wayar (WSN) telah menjadi satu teknologi penting yang mana menarik minat banyak kajian dalam bidang penempatan untuk nod sensor. Algoritma nod penempatan boleh diklasifikasikan kepada tiga kategori; jarak berpangkalan, jarak bebas, dan hybrid. Algoritma-algoritma penempatan ini digunakan untuk mengukur jarak sebenar antara nod. Algoritma Hop-Jarak Vektor (DV-Hop) telah menjadi tumpuan kajian bagi algoritma penempatan jarak bebas. Walau bagaimanapun, kajian-kajian ke atas algoritma penempatan DV-Hop yang sedia ada telah bersandar kepada andaian bahawa kedudukan nod sensor telah ditentukan terlebih dahulu sebelum diagihkan. Ini membuatkan tugas untuk setiap nod sensor telah ditetapkan secara kekal, yang mana menyebabkan keseluruhan proses di dalam algoritma menjadi rumit. Tambahan lagi, kajian-kajian ini telah menghadkan proses pergerakan dalam penempatan untuk dikonfigurasikan sama ada secara manual atau melalui Sistem Kedudukan Global (GPS). Ini telah menyebabkan kerumitan di dalam algoritma, bersama-sama dengan penggunaan GPS yang tidak praktikal di dalam proses pergerakan kerana ia memerlukan penggunaan kuasa yang tinggi di dalam nod sensor yang mempunyai had kuasa bateri. Maka, dua idea telah dicadangkan untuk kajian ini. Idea yang pertama mencadangkan penempatan nod pintar bagi nod sensor untuk memperkenalkan sebuah algoritma yang berkerumitan rendah dan mempunyai ralat penempatan yang rendah. Idea kedua yang dicadangkan ialah penambahbaikan kawasan penempatan untuk nod sensor bagi mengawal masalah berkenaan proses pergerakan di dalam rangkaian, yang mana dalam masa yang sama meningkatkan tempoh hayat rangkaian, mengurangkan penggunaan kuasa dan mengurangkan ralat penempatan. Eksperimen simulasi berkeadaan diskrit secara menyeluruh telah digunakan untuk algoritma penempatan DV-Hop ini di mana ia merupakan salah satu wakil algoritma penempatan berjarak bebas bagi tujuan menganalisis prestasi strategi. Proses yang dijalankan semasa simulasi berkeadaan diskrit ini adalah berdasarkan penepatan permulaan, penjadualan dan acara. Proses untuk mencari kedudukan oleh DV-Hop terjadi ketika acara berlangsung. Metrik prestasi yang digunakn bagi idea pertama ialah purata ralat penempatan oleh nod dan juga masa yang diperlukan oleh acara ketika pengagihan nod di dalam kawasan terjadi. Purata ralat penempatan turut dikira untuk idea kedua. Metrik prestasi lain yang digunakan untuk idea kedua ialah penggunaan kuasa oleh nod dan ketepatan koordinat. Berdasarkan keputusan yang diperoleh, algoritma yang telah dicadangkan terbukti berjaya membuat penambahbaikan terhadap algoritma penempatan DV-Hop yang berkerumitan rendah dan mempunyai ralat penempatan yang rendah, lebih tempoh hayat rangkaian dan penggunaan kuasa yang kurang bagi algoritma penempatan jarak bebas.

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Thank you all and may God bless all these individuals for their kind.

I certify that a Thesis Examination Committee has met on 6 July 2015 to conduct the final examination of Azyyati Adiah binti Zazali on her thesis entitled "Distance Vector-Hop Range-Free Location Algorithm for Wireless Sensor Network" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
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Name of Chairman of Supervisory Committee : Shamala Subramaniam, PhD

Signature : ____________________

Name of Member of Supervisory Committee : Zuriati Ahmad Zukarnain, PhD

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LIST OF ABBREVIATIONS

2-D	2-Dimensional
A-MBL	Adaptive Mobile Beacon-assisted Localization
AoA	Angle of Arrival
AC	Apollonius Circle
ADO	Arrival and Departure Overlap
AHS	Average Hop Size
APIT	Approximated Point-In-Triangulation
APS	Ad hoc Positioning System
BS	Base Station
BLI	Binary Location Index
CA	Centroid Algorithm
CAB	Concentric Anchor Beacon
CAB-EA	Concentric Anchor Beacon with Equal Area
CAB-EW	Concentric Anchor Beacon with Equal Width
CBC	Connectivity-Based Centroid
CeNSE	Central Nervous System for the Earth
CKN	Connected K-Neighbourhood
CLOS	Clear Line of Sight
DES	Discrete Event Simulation
DOI	Degree of Irregularity
DV-Hop	Distance Vector-Hop
DDSPAN	Dynamic Derivation of Scalable Position Aware Nodes
EP	Estimated Position
FCDV-Hop	Flood Control DV-Hop
FCsDV-Hop	Four Corners DV-Hop
FM	Flooding Message
GFF Algorithm	GPS Free-Free Algorithm
GP	Generated Position
GPS	Global Positioning System
HC	Hop Count
HCRL	Hop Count Ratio Based Localization
HDV-Hop	Hybrid DV-Hop
HP	Hewlett-Packard
IBM	International Business Machines
ICB	Improved Connectivity Based Centroid
ID	Identification
IDV-Hop	Iterative DV-Hop
IWC	Improved Weighted Connectivity Based Algorithm
IoT	Internet of Things
LAs	Local Aggregators
LLSiWSN	Localization Algorithm for Large Scale in WSN
LMAT	Localization Algorithm that core is a Mobile Anchor node which based on Triangulation
LS-SOM	Distributed Range-Free Localization Algorithm Based on Self-Organizing Maps
LSM	Least Square Method
MB	Mobile Beacon
MBL	Mobile Beacon-assisted Localization
MBP	Mobile Beacon Positioning

MBWLSM	Meshless Better Weighted Least-Square Method
MDV-Hop	Manual Distance Vector-Hop
MSL	Mobile and Static Sensor Network Localization
MWSN	Mobile Wireless Sensor Networks
NetTopo	Network Topology
NS-2	Network Simulator-2
OSI model	Open System Interconnection model
PSO	Particle Swarm Optimization
RDV-Hop	RSSI-based DV-Hop Algorithm
RIM	Radio Irregularity Model
RL	Reinforcement Learning
RSSI	Received Signal Strength Indication
SDDV-Hop	Shortest Distance DV-Hop
SOM	Self-Organizing Maps
TDoA	Time Different of Arrival
TDS	Trace-Driven Simulation
ToS	Termination of Simulation
TR	Trajectory Resolution
UDG	Unit Disk Graph
UN	Unknown nodes
WBSN	Wireless Binary Sensor Network
WCA	Weighted Centroid location Algorithm
WDV-Hop	Weighted DV-Hop
WLSM	Weighted Least Square Method
WSN	Wireless Sensor Network

CHAPTER 1

INTRODUCTION

1.1 Wireless Sensor Network

Wireless Sensor Networks (WSN) has become a significant technology attracting enormous research interest (Potnuru and Ganti, 2003). WSN are composed of multiple sensor nodes which monitor the physical real world entities by having communication without devices i.e. wireless known as sensor nodes. The sensor nodes are deployed in a designated monitoring field and form a multi-hop self-configured network by means of wireless communication. Sensor networks represent a significant improvement over traditional sensors, which are deployed either far away from the actual phenomenon or several sensors that perform only sensing can be deployed. Sensor nodes are fitted with an on-board processor. Instead of sending the raw data to the nodes responsible for fusion purposes, sensor nodes use their processing abilities to locally perform simple computations and transmit only the required and partially processed data.

Ad-hoc networks have mostly been studied in the context of high mobility, high power nodes and moderate network sizes. An Ad-hoc network can be defined as a network which deals with specific nodes under specific purpose. The Ad-hoc Positioning System (APS) done by Niculescu and Nath (2001) is appropriate for indoor location aware applications, when the network's main feature is not the unpredictable, highly mobile topology, but rather deployment that is temporary, and ad-hoc. The Global Positioning System (GPS), which is a public service, can satisfy some of the above requirements. However, attaching a GPS receiver to each node is not always the preferred solution for several reasons such as cost, limited power, inaccessibility, imprecision and the sensor size which is currently the size of a small coin.

WSN behaves as a digital skin, providing a virtual layer where the information about the physical world can be accessed by any computational system. Recent advances in wireless communications and electronics have enabled the development of low-cost, low-power and multi-functional sensors that are small in size and communicate in short distances. As a result, they are an invaluable resource for realizing the vision of the Internet of Things (IoT) (Alcaraz, et al., 2010). In the upcoming IoT, the objects that surround us will generate and consume information. The elements of the IoT comprise not only those devices that are already deeply rooted in the technological world (i.e. cars, fridges, television), but also objects foreign to the environment (i.e. garments, fresh food), or even living being (i.e. plantations, woods, livestock). By embedding computational capabilities in all of the kinds of objects and living beings, it will be possible to enhance significantly several sectors such as the healthcare, logistics, domestics and entertainment.

One of the most important elements in the IoT paradigm is WSN. The benefits of connecting both WSN and other IoT elements go beyond remote access, as various information systems can be able to collaborate and provide common services. This integration has received substantial support from the commercial sector. As an example is the 'A Smarter Planet', a strategy developed by International Business Machines (IBM) which considers sensors as fundamental pillars in intelligent water management systems and intelligent cities. The other example of the rich WSN IoT is the Central Nervous System for the Earth (CeNSE) project by Hewlett-Packard's (HP) Labs that focused on the deployment of a worldwide sensor network in order to create a "central nervous system for the Earth". It is clear that the potential of the WSN will be maximized once connected to the Internet, and then becoming part of the IoT.

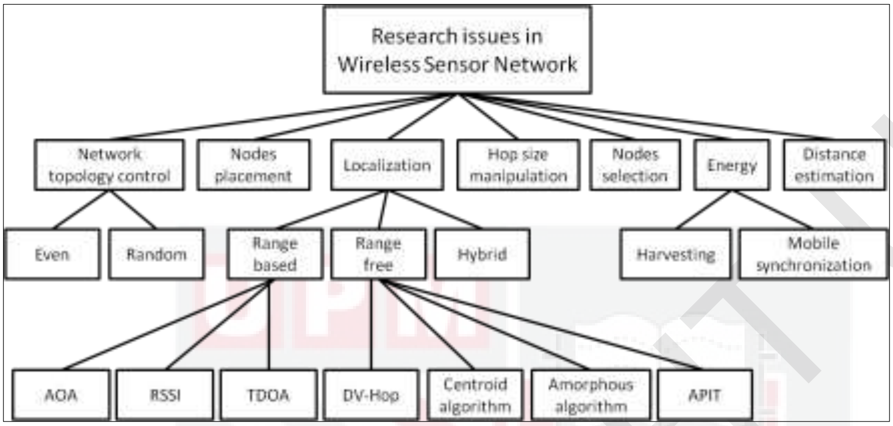

Figure 1.1 Research issues in WSN

Researches in WSN are intense and the areas stated in Figure 1.1 are among the integral parts. First aspects that can be discussed are the network topology control (Agashe and Patil, 2012; Bolin and Zengwei, 2011; Jiang, et al., 2012; Liu, et al., 2010; Meng, et al., 2011; Paul and Wan, 2009; Rabaey, et al., 2002; Shu, et al., 2010; Teng, et al., 2009; Vivekanandan and Wong, 2007; Zhang, et al., 2011). There are two categories of sensor network topology which is even and random. The even topologies distribute the sensor nodes and anchors over the deployment area in an exact grid, whilst the random topologies trouble individual nodes positions on the grid with random noise. There are several others classification of topology in WSN. There are the isotropic and anisotropic topology (Vivekanandan and Wong, 2007), the triangle shape topology (Liu, et al., 2010), the square region (Rabaey, et al., 2002), the square region which divided equally into smaller square region (Bolin and Zengwei, 2011; Meng, et al., 2011), the non-planar physical topology (Shu, et al., 2010), L-shaped square (Agashe and Patil, 2012), the uniform grid, the irregular C-shaped grid square, the irregular random C-shaped square and the uniform random square (Zhang, et al., 2011), the rectangular region (Paul and Wan, 2009) and also the ring shape (Jiang, et al., 2012). Figure 1.2 illustrates a few of the network topologies.

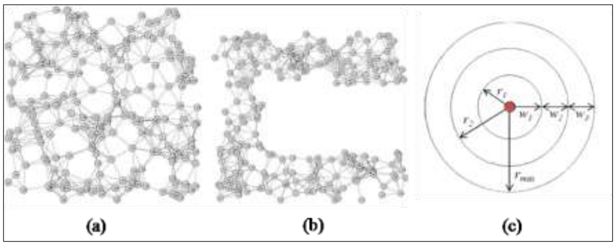

Figure 1.2 Examples of topologies existed. (a) Isotropic topology, (b) Anisotropic topology / C-shaped and (c) Multiple rings topology

The second aspect is the nodes placement (Agashe and Patil, 2012; Chen, et al., 2008; Chen and Zhang, 2012; Hu, 2011; Li, et al., 2011; Ramazany and Moussavi, 2009; Tinh and Kawai, 2010; Yassine and Safa, 2009). The placement of the nodes affect the algorithm as the accuracy and location coverage are obtained when the anchor nodes placed uniformly instead of the randomly and as more anchor nodes are placed, the localization average error decreases (Chen, et al., 2008; Yassine and Safa, 2009). The third aspect is the hop size manipulation (Chen, et al., 2010; Liu, et al., 2009). Hops are used to measure the distances of the nodes inside the network to the landmarks. Hop size used in Liu, et al., (2009) assumed to be an average, while in Chen, et al., (2010) the hop-size calculated by adopting the Least Square Method (LSM) (Chen, et al., 2008). The sensor nodes selection is the forth aspect that was raised in (Du and Yan, 2010; Fang and Yang, 2011; Hai-qing, et al., 2011b; Kristalina, et al., 2011; Ying, et al., 2010; Zhu, et al., 2009). A typical WSN is built of several hundreds or even thousands of sensor nodes (Yu and Jain, 2011).

The power consumption takes place as the fifth aspects for the issues in WSN research area that is presented in (Ahn and Hong, 2011; Jiang, et al., 2011; Tang, et al., 2011; Yang, et al., 2007). The multi-power sensor nodes used inside Ahn and Hong, (2011) during the communication proved to estimate the distance between sensor nodes more accurately. The energy consumption is considered as the main factor during the path planning for the sensor nodes inside Jiang, et al., (2011) as to maintain the localization accuracy. The density of the sensor node inside the deployment area is significant to the performance of localization algorithm since high density of sensor nodes contributes high energy consumption and communication overload between sensor nodes. The energy during the sensor nodes transmission consists of 1 bit information for 100 meter distance. To save the energy, the communication between sensor nodes can be discarded during the information broadcasting (Tang, et al., 2011). By not only controlling the power consumption of the nodes, the cost of buying the sensor nodes is also reduced as lesser sensor nodes are needed inside the network (Yang, et al., 2007).

For the sixth aspect, the distance estimation and measurement which needs to be considered and this aspect has been deliberated in (Al Alawi, 2011; Benbadis, et al., 2005; Hu, et al., 2012; Jahangiry, et al., 2011; Liu, et al., 2012; Yin, et al., 2006; YingJie, et al., 2012; Yingxi, et al., 2012; Zhang, et al., 2011; Zhang, et al., 2012). The shortest distances commonly take place to be the main reason on selecting the sensor nodes because the shorter the distance, the lesser the energy consumption and the higher accuracy can be produced (Hu, et al., 2012; Jahangiry, et al., 2011; Liu, et al., 2012; Yin, et al., 2006; Yingxi, et al., 2012). The Unit Disk Graph (UDG) rules considered to measure the distance estimation where the UDG states that if the sensor nodes connected distance is lesser than 1 unit, then it is proved to be connected (Kaewprapha, et al., 2011; Kuhn, et al., 2004; Kuhn, et al., 2008).

The last aspect is the localization of nodes (Chaurasiya, et al., 2009; Chen, et al., 2011; Jiang, et al., 2012; Kumar, et al., 2012; Li, et al., 2012a; Li, et al., 2012b; Lim, et al., 2010; Niculescu and Nath, 2003; Tian, et sl., 2007; Yu, et al., 2008). The nodes localization algorithms can be classified into three categories that are range-based and range-free which used to measure the actual distances between nodes. The hybrid localization is the combination between of range-free and range-based method. Centroid Algorithm (CA) and the Distance Vector-Hop (DV-Hop) algorithm use the estimated distance instead of the metrical distance to localize the unknown nodes. For the range-free category, the localization has considerable focus on the DV-Hop algorithm. Due to the high cost of hardware facilities and energy consumption required by range-based approaches, the range-free algorithms attract more researcher attention. The DV-Hop localization algorithm is one of the typical representatives of range-free localization algorithm (Niculescu and Nath, 2001). DV-Hop algorithm has proven the ability to reduce the localization error. The enhancement on DV-Hop is centric on several elements. It is analytically proven that better accuracy can be achieved if the anchors are uniformly spread on the parameter of the network. The basic idea of DV-Hop is that the distance between the unknown nodes and the reference nodes is expressed by the product of average hop distance and the hop count. At first, a number of anchor nodes are properly distributed. The average hop distance is calculated in a method in which not only the global property of average hop size and anchor nodes are considered.

Most distributed localization algorithms demands less communication overhead than centralized algorithms which require relaying the connectivity or range measurements from every sensor to the base station. On the other hand, DV-Hop is the only distributed localization algorithm that has a large communication overhead because of the flooding algorithm which occurs in two phases. Thus, generating redundant communication and power consumption. Furthermore, in DV-Hop as the network size increases, the number of deployed anchors necessary for accurate localization increases. This increase in the number of anchors together with the increased communication makes DV-Hop not suitable for sensor networks used for the event monitoring and other large scale WSNs.

1.2 Problem Statement

DV-Hop is one of the range-free localization algorithms which are fundamental and largely used until today by the researchers. Although there are lots of research has been done, DV-Hop still can be improved. The problem statements found by this research are as follows:

- Existing works on localization in WSN for types of sensor nodes placement inside the range-free localization algorithm are pre-determined before the nodes distribution process. Therefore, causing the sensor nodes task to be rigid and fixed causing the overall process of the algorithm to be complex.
- Existing preference methods that are used to control the sensor nodes localization and flooding involves nodes which are irrelevant or which involvement are due to redundancy. This redundancy causes a complexity in the algorithm, along with the infeasible usage of GPS in the flooding process which uses high power consumption and challenge the limited battery powered sensor nodes.

1.3 Research Objectives

The research objectives are as follows

- To propose and develop an enhanced localization algorithm by using intelligent nodes placement algorithm for sensor nodes to solve the range-free localization problems in WSN that produces low complexity and low localization error.
- To propose and develop an enhanced algorithm that is able to improve the region area for sensor nodes placement within the specific localization area to address

the network flooding associated problems, whilst increasing the network lifetime and reduce power consumption while minimize the localization error.

1.4 Research Scope

Range-free is one of the self-localization for sensor node in WSN. This research consists of localization algorithms which are of this category. There are lots of applications of the WSN that requires the knowledge of the nodes position. Therefore, algorithms that can compute the location of sensor nodes within a WSN form a central focus of this research. The process for localization needs to be control as to limit the sensor nodes performance during the sensor nodes movement inside the area. In real WSN application, this research happened in network layer inside the Open System Interconnection (OSI) model because the nodes communicate between each of them in order to transfer the information from and to the sensor nodes. In this research, localization will involve sensor nodes which are commonly used to represent two types of nodes; the anchor nodes and the unknown nodes.

1.5 Thesis Organization

This thesis is organized into six chapters including this introductory chapter. Chapter 2 presents a detail review and analysis localization algorithms which have been developed for range-free localization in WSN in particular hop based. The details of the algorithms, their respective advantage and disadvantages are deliberated in detail. Chapter 3 discusses the methodology pertaining to the developed simulation, control parameters, events and definitions of performance metrics. Chapter 4 and 5 present the details of the proposed and developed enhanced localization algorithms in WSN respectively. Chapter 6 concludes the thesis with suggested future work.

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