UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Information and Communication Technology

EFFICIENT ENHANCED ROUTING PROTOCOL AND ACCURATE TRACKING MECHANISM FOR MONITORING ENVIRONMENTAL CHANGES USING MULTIHOP WIRELESS SENSOR NETWORKS

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DECLARATION

I declare that this thesis entitled “Efficient Enhanced Routing Protocol and Accurate Tracking Mechanism for Monitoring Environmental Changes using Multihop Wireless Sensor Networks” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Date	:	………………………….

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Doctor of Philosophy.

Signature : ……………………………

Supervisor Name : Assoc. Prof. Dr. Abd Samad Hasan Basari

Date : ……………………………

DEDICATION

I would like to present my work to those who did not stop their daily support since I was born, my dear mother and my kindness father. They never hesitate to provide me all the facilities to push me foreword as much as they can. This work is a simple and humble reply to their much goodness I have taken over during that time. I don't forget my sister, my uncles, my aunts, friends and those entire how I love.

Omar Fouad Mohammed

ABSTRACT

The advances in the wireless communication industry have paved the way for wide utilization of Wireless Sensor Networks (WSNs) applications. The main application of WSNs is environmental monitoring where sensors are cooperatively used to monitor physical or environmental events and report their sensed data to a central unit for processing, analysis and decision making. In other words, due to the distinctive capabilities of sensors to monitor different environmental parameters, WSNs can provide better solutions for monitoring abnormal events such as fire incident, gas leak and car accident. However, the existing WSN-based detection and tracking systems still suffer from efficiency and suitability for real-time data traffic control and management issues. These issues include network congestion, high energy consumption and communication overhead. In addition, the systems have poor performance in terms of tracking accuracy and prediction of the event's future location, which means the systems do not provide accurate mechanism for tracking the event's development. In order to deal with the above mentioned issues, this study presents environmental monitoring system to enhance network traffic in the sense of sensed data delivery and to ensure the accuracy of fire event detection and tracking in WSN. The proposed system relies on efficient enhanced routing protocol and accurate tracking mechanism. The enhanced protocol is based on cluster head selection method that aims to reduce the energy dissipation in the cluster construction procedure and prolong the network lifetime. Besides, a dynamic data transmission strategy is also presented by which the load of forwarding the sensed data packets is balanced among the cluster heads and the forwarding nodes in the data transmission procedure. Accordingly, the energy-hole problem is mitigated which in turn the energy efficiency and the throughput of the WSN are improved. By utilizing the communication overhearing in WSNs and some statistical concepts, a tracking mechanism to ensure the accuracy of the monitoring system in estimating the fire spread is thus designed. The simulation results show that, compared with the common routing protocol, the enhanced protocol decreases the energy consumption by about 30%. While in two different simulation tests, the network lifetime is increased by about 30% and 40% respectively. Moreover, more 1.11E+09 bits of data were received by the base station for the last 40 rounds of the network life cycle which indicates that the network throughput is improved. The dynamic data transmission strategy increases the network lifetime by about 22% compared to other existing method and the tracking mechanism is capable of accurately estimating the fire development.

ABSTRAK

Kemajuan dalam industri komunikasi tanpa wayar telah membuka jalan untuk penggunaan aplikasi Rangkaian Penderia Tanpa Wayar (WSN). Aplikasi utama WSN adalah pemantauan alam sekitar di mana penderia digunakan secara kolektif untuk memantau peristiwa fizikal atau alam sekitar dan melaporkan data yang dikesan ke unit pusat untuk pemprosesan, analisis dan membuat keputusan. Dengan kata lain, disebabkan oleh keupayaan penderia yang berbeza untuk memantau parameter alam sekitar yang berbeza WSN dapat memberikan penyelesaian lebih baik untuk memantau peristiwa yang tidak normal seperti insiden kebakaran, kebocoran gas dan kemalangan kereta. Walau bagaimanapun, sistem pengesanan dan penjejakan berasaskan WSN yang sedia ada masih mengalami isu kecekapan dan kesesuaian untuk kawalan lalu lintas dan pengurusan data masa nyata. Isu-isu ini termasuk kesesakan rangkaian, penggunaan tenaga yang tinggi dan jumlah pengguna komunikasi. Di samping itu, sistem mempunyai prestasi yang lemah dari segi ketepatan pengesanan dan ramalan lokasi masa depan kejadian, iaitu sistem tidak menyediakan mekanisma yang tepat untuk menjejaki perkembangan kejadian itu. Untuk menangani isu-isu yang disebutkan di atas, kajian ini membentangkan sistem pemantauan alam sekitar untuk meningkatkan trafik rangkaian dalam pengertian penghantaran data yang dikesan dan untuk memastikan ketepatan pengesanan dan penjejakan kejadian kebakaran di WSN. Sistem yang dicadangkan bergantung pada protokol penghalaan yang lebih baik dan mekanisma penjejakan yang tepat. Protokol yang dipertingkatkan adalah berdasarkan kepada kaedah pemilihan kepala kluster yang bertujuan mengurangkan pelesapan tenaga dalam prosedur pembinaan kluster dan memanjangkan jangka hayat rangkaian. Di samping itu, strategi penghantaran data yang dinamik juga dibentangkan di mana beban penghantaran paket data yang sensitif adalah seimbang di antara ketua kelompok dan nod pemajuan dalam prosedur penghantaran data. Sehubungan itu, masalah lubang tenaga dapat dikurangkan dan hasilnya kecekapan tenaga dan daya tampung WSN dapat diperbaiki. Dengan menggunakan komunikasi yang didengar di WSN dan beberapa konsep statistik, mekanisme pengesanan untuk memastikan ketepatan sistem pemantauan dalam menganggarkan penyebaran api itu dapat direkabentuk. Hasil simulasi menunjukkan bahawa, berbanding dengan protokol penghalaan biasa, protokol yang dipertingkatkan dapat mengurangkan penggunaan tenaga sebanyak kira-kira 30%. Sementara itu, dalam dua ujian simulasi yang berbeza, hayat rangkaian meningkat masing-masing sebanyak 30% dan 40%. Selain itu, lebih banyak 1.11E + 09 bit data telah diterima oleh stesen pangkalan bagi 40 pusingan terakhir kitaran hayat rangkaian yang menunjukkan bahawa daya tampung rangkaian telah ditingkatkan. Strategi penghantaran data dinamik meningkatkan jangka hayat rangkaian sekitar 22% berbanding dengan kaedah sedia ada yang lain dan mekanisme penjejakan mampu menganggarkan secara tepat perkembangan kebakaran.

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ACQUIRE	-	Active Query Forwarding in Sensor Networks
APTEEN	-	Adaptive Periodic Threshold Sensitive Energy Efficient Sensor Network Protocol
BVGF	-	Bounded Voronoi Greedy Forwarding
BS	-	Base Station
CADR	-	Constrained Anisotropic Diffusion Routing
CH	-	Cluster Head
CHR	-	Cluster Head Relay Routing
CM	-	Cluster Member
DTA	-	Direct-Transmission Advertisement
DTAF	-	DTA Flag
EAD	-	Energy Aware Data Centric Routing
EDRS	-	Energy-Efficient Data Reporting Strategy
EEP	-	Event Evolution Perceiving
EPT	-	Event Path Tracking
FG	-	Fire Growth Rate
FN	-	Forwarding Node
FREQ	-	Forwarding Request Packet
GAF	-	Geographic Adaptive Fidelity

GEAR	-	Geographic and Energy-Aware Routing
GeRaf	-	Geographic Random Forwarding
GPS	-	Global Positioning System
HEED	-	Hybrid Energy-Efficient Distributed Clustering
HRR	-	Heat Release Rate
IDSQ	-	Information Driven Sensor Query
KW	-	Kilowatts
LEACH	-	Low-Energy Adaptive Clustering Hierarchy
MECN	-	Minimum Energy Communication Network
NS-2	-	Network Simulator version-2
OR	-	Overlapping region
OTcl	-	Object Tool Command Language
PLE	-	Path-Loss Exponent
QoS	-	Quality of Service
RE	-	Residual Energy
RES	-	Response Packet
RGG	-	Random Geometric Graph
RR	-	Rumor Routing
SAR	-	Sequential Assignment Routing
SEAD	-	Scalable Energy-Efficient Asynchronous Dissemination
SHA	-	Single-Hope Advertisement
SHAF	-	SHA Flag
SMECN	-	Small Minimum Energy Communication Network
SPIN	-	Sensor Protocols for Information via Negotiation
TBF	-	Trajectory-Based Forwarding

TDMA	-	Time Division Multiple Access
TEEN	-	Threshold Sensitive Energy Efficient Sensor Network Protocol
TH	-	Total Heat Release
W	-	Watt
WSN	-	Wireless Sensor Network

LIST OF SYMBOLS

α	-	The energy dissipation over the operational amplifier (op-amp) during data transmission
φ	-	Angle of a sector
∇	-	The gradient
ε_0	-	The initial energy of sensors
$\hat{\imath}$	-	The unit vector in the *x*-direction
$\hat{\jmath}$	-	The unit vector in the *y*-direction
$\hat{k}$	-	The unit vector in the *z*-direction
l	-	The length of data packet in bits
B_{direct_si}	-	The number of bits sent directly by s_i to BS
B_{relay_si}	-	The number of bits relayed by s_i
B_{sensed_si}	-	The number of sensed bits in slices i
C and C'	-	Overlapped circles
$C°$	-	Celsius degree
D_t	-	The amount of data (in bits) that need to be forwarded directly from sensors in s_i to the BS
d	-	Transmitter-receiver distance
$d\ (i,j)$	-	Euclidean distance between sensor i and sensor j
E_{elec}	-	The electronic energy of the sensor

$E_{i,j}$	-	Edge connecting every two sensors (vertices) *i* and *j*
E_{rx}	-	The reception energy needed for receiving one bit of data
E_{si_txd}	-	The energy required to send data from s_i directly to the BS
E_{si_rx}	-	The energy needed for receiving the relayed data
E_{tx}	-	The energy required to send one bit of data
EC_{si}	-	Energy consumption in any slice
G	-	Geometric graph
G'	-	Sub-graph of *G*
H	-	Number of hops to reach the controller
i.i.d.	-	independently and identically distributed
k	-	Number of sensors in the network
L	-	Number of levels the monitoring area is divided
Ls_i	-	The lifetime of slices *i*
M	-	Uniform sensors in the area of monitoring
$\mathcal{M}$	-	Particular region of the monitoring area
m	-	Number of slices in a sector
m	-	Number of communication links
m^2BN_{si}	-	The total data bits sent where BN_{si} is the data bits generated by sensors in s_i
N_{si}	-	Number of sensors in i^{th} slice
P_f	-	Probability of sensed data cannot be forwarded over *i* to *j* link
p_{ovr}	-	Probability of sensed data forwarded by the overhearing sensors

R	-	Transmission Range
R`	-	The smallest integer not less than the fraction of the sensor's distance from the BS (*d*) over *R*
R^2	-	Two-dimensional monitoring area
rD_t	-	The ratio of direct data sending to one-hop sending
s_i	-	Slice in a sector
S_k	-	Number of sensors that are independently and identically distributed in a particular region *M* of the monitoring area
t	-	Time
TS	-	Total number of neighboring sensors within the overlapping region *OR*
Tx	-	Sensor transmitting range
v	-	Vertex in the network graph
v_x, v_y, and v_z	-	Scalar factors of *v*
$\bar{x}_{mass}$ and $\bar{y}_{mass}$	-	The coordinates of mass center
$\bar{x}_{gravity}$ and $\bar{y}_{gravity}$	-	The coordinates of gravity center

LIST OF PUBLICATIONS

Indexed Peer-Reviewed international Journals

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CHAPTER 1

INTRODUCTION

1.1 Research background

This research requires combined knowledge of the characteristics and applications of wireless sensor networks. This section lays out an overview of the most significant and concerning concepts.

1.1.1 Overview on Wireless Sensor Networks (WSNs)

Nowadays, Wireless Sensor Networks (WSNs) have been widely recognized as one of the most important technologies deployed in a physical area and networked through wireless links and the Internet since they provide unprecedented opportunities for a variety of civilian and military applications (Nikookar and Ligthart, 2016; Kocakulak and Butun, 2017). WSN is defined as a combination or network of the sensor nodes (few to thousands sensors) that are used for sensing the environment, collecting information such as seismic, infrared, acoustic or magnetic information, and communicating the sensed or control data whether directly or via multi-hop connections to a sink node (also called Base Station (BS)) which in turn reports to the party that interested in the information (see Figure 1.1), provided that the forwarding nodes in the network are within the transmission range of each other (Zheng and Jamalipour, 2009; Younis et al., 2014) as shown in Figure 1.2. Sensor's data make use of the radio transmission. These data can be of different forms including digital and analogue, spatial and temporal, alphanumeric or image, fixed or moving. As the sensor nodes are limited in computational and memory capacities, the