Faculty of Information and Communication Technology

AN IMPROVED ENERGY-EFFICIENT CLUSTERING PROTOCOL TO PROLONG THE WIRELESS SENSOR NETWORK LIFETIME

Ali Abdul-Hussian Hassan Alhmood

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ALI ABDUL-HUSSIAN HASSAN ALHMOOD

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DECLARATION

I declare that this thesis entitled “An Improved Energy-Efficient Clustering Protocol to Prolong the Wireless Sensor Network Lifetime” 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.

Signature : ……………………………………..

Name : Ali Abdul-Hussian Hassan.......

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	:	Dr. Wahidah binti Md Shah...........
Date	:	....

DEDICATION

First and foremost, Alhamdulillah Almighty for all the blessings of health, wisdom and patience and to overcome all the difficulties that I faced in my PhD journey.

I would like to dedicate these years of hard work to my father, who taught me patience and success and gave me advice.

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Finally, I would like to dedicate this work to my children- Hussien and Zahraa to be an asset to them in the future.

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ABSTRACT

A wireless sensor network (WSN) is an important part of the Internet of Things (IoT). However, sensor nodes of a WSN-based IoT network are constraining with the energy resources. A clustering protocol provides an efficient solution to ensure energy saving of nodes and prolong the network lifetime by organizing nodes into clusters to reduce the transmission distance between the nodes and base station (BS). However, existing clustering protocols suffer from issues concerning the clustering structure that adversely affects the performance of these protocols. In this study, we propose an Improved Energy-Efficient Clustering Protocol (IEECP) to prolong the lifetime of the WSN. The proposed IEECP consists of three sequential parts. First, an optimal number of clusters is determined for the overlapping balanced clusters. Then, the balanced-static clusters are formed on the basis of a modified Fuzzy C-means algorithm by integrating this algorithm with a centralized mechanism to reduce and balance the energy consumption of the nodes. Lastly, cluster heads (CHs) are selected in optimal locations with the rotation of the CH function among members of the cluster based on a new CH selection-rotation algorithm by combining a back-off timer mechanism for CH selection and rotation mechanism for CH rotation. In particular, the proposed protocol reduces and balances the energy consumption of nodes by improving the clustering structure, where IEECP is suitable for networks that require a long lifetime. The simulation results prove that the IEECP prolongs the network lifetime better than Energy efficient clustering protocol based on K-means (EECPK-means)-midpoint algorithm (EECPK-means), Traffic-Aware Channel Access Algorithm (TACAA), and an optimal clustering mechanism based on Fuzzy C-means (OCM–FCM) protocols based on the First node die and Weighted first node die. Furthermore, IEECP performs better than the above protocols in terms of the energy dissipation in the network and the number of messages received by BS.

PROTOKOL PENGKELASAN EFISIEN TENAGA YANG DITINGKATKAN UNTUK MEMANJANGKAN JANGKA MASA RANGKAIAN SENSOR TANPA WAYAR

ABSTRAK

Rangkaian sensor tanpa wayar (WSN) adalah bahagian penting dalam Internet of Things (IoT). Walau bagaimanapun, node sensor rangkaian IoT berasaskan WSN menjadi semakin terhad dengan sumber tenaga. Protokol pengelompokan menyediakan penyelesaian yang cekap untuk memastikan penjimatan tenaga nod dan memanjangkan jangka hayat rangkaian dengan menyusun nod ke dalam kelompok untuk mengurangkan jarak penghantaran antara nod dan stesen pangkalan (BS). Namun, protokol pengelompokan yang ada mengalami masalah mengenai struktur pengelompokan yang mempengaruhi prestasi protokol ini. Dalam kajian ini, kami mengusulkan protokol pengkelasan efisien tenaga yang ditingkatkan (IEECP) untuk memanjangkan jangka hayat rangkaian IoT berasaskan WSN. IEECP yang dicadangkan terdiri daripada tiga bahagian berturutan. Pertama, bilangan kelompok yang optimum ditentukan untuk kelompok seimbang yang bertindih. Kemudian, kelompok-kelompok seimbang-statik dibentuk berdasarkan algoritma Fuzzy C-means yang dimodifikasi dengan mengintegrasikan algoritma ini dengan mekanisme terpusat untuk mengurangkan dan mengimbangkan penggunaan tenaga nod. Terakhir, kepala kluster (CH) dipilih di lokasi yang optimum dengan putaran fungsi CH di antara anggota kluster berdasarkan algoritma pemilihan-putaran CH baru dengan menggabungkan mekanisme back-off timer untuk pemilihan CH dan mekanisme putaran untuk putaran CH. Khususnya, protokol yang dicadangkan mengurangkan dan menyeimbangkan penggunaan tenaga nod dengan memperbaiki struktur pengelompokan, di mana IEECP sesuai untuk rangkaian yang memerlukan jangka hayat yang panjang. Hasil simulasi membuktikan bahawa IEECP memanjangkan jangka hayat rangkaian lebih baik daripada protokol pengelompokan cekap Tenaga berdasarkan algoritma K-means (EECPK-means) -midpoint (EECPK-mean), Traffic-Aware Channel Access Algorithm (TACAA), dan pengelompokan optimum mekanisme berdasarkan protokol Fuzzy C-means (OCM – FCM) berdasarkan mati nod Pertama dan mati nod pertama berwajaran. Tambahan pula, IEECP berprestasi lebih baik daripada protokol di atas dari segi kehilangan tenaga dalam rangkaian dan jumlah mesej yang diterima oleh BS.

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LIST OF ABBREVIATIONS

3D	-	Three-dimensional
ABC	-	Artificial Bee Colony Optimization
ACO	-	Ant Colony Optimization Optimization
ADV	-	The advertisement message received
BS	-	Base Station
CH	-	Cluster Head
CHSRA	-	Cluster Head Selection Rotation Algorithm
Cj	-	The cluster centroid
CM	-	Centralized Mechanism
CoV	-	The coefficient of variation
C_{over}	-	The overlapping distance among clusters
d	-	Transmission distance
$d\ (x_i, c_j)$	-	The distance between node and centroid
D&D	-	Designing and Development Phase
DAC	-	Distances Adjuster Coefficient
d_{BCH}	-	The distance to nearest backward CH
d_{BS}	-	The distance between the sensor node x and the BS
d_c	-	distance to the cluster centroid or the current CH
DCEM	-	delay-constrained energy multi-hop protocol

DE	-	Differential Evolution algorithm
d_{FCH}	-	The distance to the nearest Forward CH
diff	-	The difference between K and the AV of numbers of clusters
d_{next}	-	The distance to the next-hop or the next CH.
DSP	-	Deterministic Sensor Placement
D_T	-	Cost difference in the distance
E_{AD}	-	The energy consumption for aggregation one bit
$E_{CH\text{-}per\text{-}rnd}$	-	The energy consumption per round for the CH
E_{com}	-	The energy consumption of the node
E_{disp}	-	The energy dissipation
EECPK-means	-	Energy efficient clustering protocol based on K-means protocol
E_{elec}	-	The energy consumption in the electronic system for sending or receiving one bit
E_{ini}	-	The initial energy of the node
$E_{n\text{-}rnd}$	-	The energy consumption per round for the nodes
E_r	-	The residual energy of the node
E_{RX}	-	The energy consumption for the received node
E_{TH}	-	The threshold value for CH rotation
E_{TX}	-	The energy consumption for the transmitted node
Ev	-	Evaluation Phase
F	-	The objective function for CH selection
FABC	-	Fractional Artificial Bee Colony Optimization
FCM	-	Fuzzy C-mean algorithm
FL	-	Fuzzy logic algorithm

FLION	-	The fractional lion optimization algorithm
FND	-	The first node die
GA	-	Genetic algorithm
GPS	-	Global Positioning System
GWO	-	Grey Wolf Optimization algorithm
H_0	-	Null Hypothesis
Ha	-	Alternative Hypothesis
HC_{BS}	-	The hop count to BS
HND	-	The half node dies
ID	-	Identification number for the node
IEECP	-	Improved Energy Efficient Clustering Protocol
IoT	-	Internet of Things
ISO	-	International Standardisation Organization
IT	-	Information Technology
K	-	The number of clusters
KM	-	K-means algorithm
L	-	Message size
LEACH	-	Low Energy Adaptive Clustering Hierarchy
LIM	-	Literature Investigation Method
LND	-	The last node dies
M	-	Dimensions of the square sensing area
M-FCM	-	Modified- Fuzzy C-mean algorithm
MN	-	member node
MRQ	-	The Main Research Question

MSE	-	The mean square error
N	-	The number of total nodes in the network
n	-	The number of the cluster's members
$NMsg_{(BS)}$	-	The number of messages received by the BS
NoN	-	The number of neighbours for the node
non-DSP	-	non- Deterministic Sensor Placement
OCM-FCM	-	An optimal clustering mechanism based on Fuzzy-C means for wireless sensor networks
ON	-	Ordinary Node
OSI	-	Open System Interconnection
PA	-	Problem Awareness Phase
Pe	-	The Permittivity value of the cluster size
PSO	-	Particle swarm optimization
R	-	The maximum number of rounds
r	-	The current round
RAM	-	Random Access Memory
Rc	-	The transmission range for CH
R_{CHs}	-	The rounds of all CHs in the cluster at the ETH
R_{HND}	-	The round number that the half nodes dead HND occurs
RM	-	Research Methodology
R_n	-	The rounds of the member node in the cluster at the ETH
R_{over}	-	The overlapping clusters is more than
RP	-	The random probability for the CH selection
R_{sprt}	-	The radius of the separated clusters

RSS	-	The received signal strength
RSSI	-	Received Signal Strength Indicator
SA	-	Simulated Annealing
S_j	-	The cluster size
SN	-	The transmitter Sensor Node
T	-	The ratio of the initial energy for the node
t	-	One-sample t-test
TACAA	-	Traffic-Aware Channel Access Algorithm for Cluster-Based Wireless Sensor Network
Tb	-	The node timer
TCP	-	Transmission Control Protocol
TDMA	-	Time Division Multiple Access
$TH_{cluster}$	-	The threshold of the cluster size
UDP	-	User Datagram Protocol
VSC	-	The variation value in the size of the clusters
WFND	-	The weighted first node dies factor
WLND	-	The weighted last node died
WSN	-	Wireless Sensor Network
XBI	-	Xie and Beni’s index

LIST OF SYMBOLS

d_0	-	The threshold of the transmission distance
m	-	The value of fuzzifier
$\bar{x}$	-	The arithmetic mean for numbers
α and β	-	The controlling parameters
ε	-	The threshold for terminate the algorithm operation
ε_{fs}	-	Energy consumption for the free space model
ε_{amp}	-	Energy consumption for the multipath model
ρ	-	Nodes density
μ	-	The membership of the node to the cluster
μ_0	-	The population mean
σ	-	The standard deviation