



Faculty of Information and Communication Technology

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

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA
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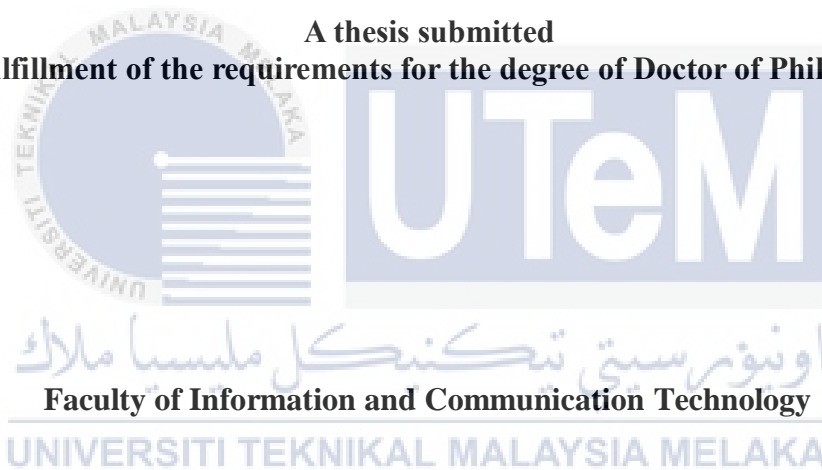
Doctor of Philosophy

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PROLONG THE WIRELESS SENSOR NETWORK LIFETIME**

ALI ABDUL-HUSSIAN HASSAN ALHMOOD

**A thesis submitted
in fulfillment of the requirements for the degree of Doctor of Philosophy**



UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2021

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.



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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.

| | | | |
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| | Date | : | |

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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.

My beloved mother, who provided me with affection, love and support, and had her prayer, I would not have reached this result.

My dear wife who stood beside me in good and bad times, and she endured the suffering of alienation and gave me psychological and moral support to complete this thesis.

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

Thanks to all my family members who supported me psychologically and emotionally.

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 constrained 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 berlawanan. 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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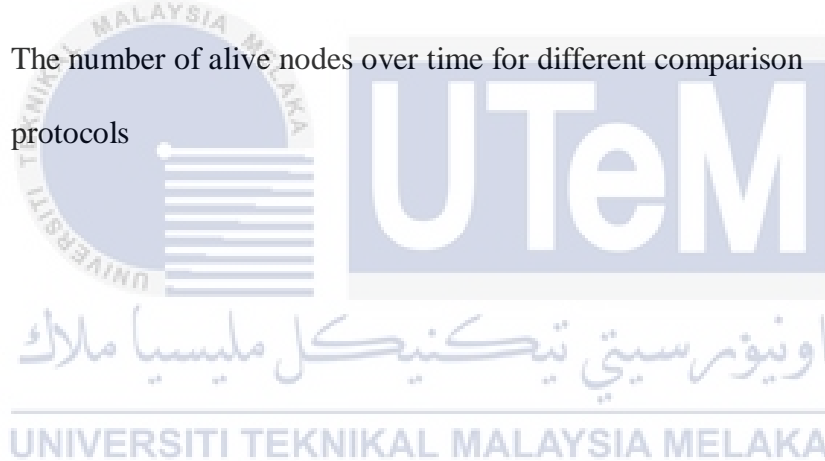
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LIST OF ABBREVIATIONS

| | | |
|---------------|---|--|
| 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 |
| C_j | - | 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 |
| $E_{CH-per-rnd}$ | - | 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-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 |
| H_a | - 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 |
| $N_{Msg (BS)}$ | - | 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 |
| P_e | - | 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 |
| R_c | - | 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_{spnt} | - | 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 |