AN ENERGY EFFICIENT DISTRIBUTED CLUSTER BASED SELF ORGANISING ALGORITHM FOR AD-HOC DEPLOYED WIRELESS SENSOR NETWORKS

By

A THESIS

This thesis is submitted to the Department of Electronic and Telecommunication Engineering at the University of Moratuwa in partial fulfilment of the requirements for the Degree of Doctor of Philosophy.

October 2010

DECLARATION BY CANDIDATE

I certify that this thesis does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any University; and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where due reference is made in the text.

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UNIVERSITY OF MORATUWA

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Abstract

Wireless sensor networks (WSNs) consist of a large number of inexpensive, low-power, sensors that can be placed in an ad hoc fashion to form a data gathering network. Subsequent to the sensor node deployment, the nodes will self-organize themselves to periodically collect reliable information from the environment to a central location called base station (BS). Once the nodes are deployed, upgrading and maintaining them is not practical. In such a scenario, the main concern would be the optimal utilization of the sensor energy, so that the entire sensor bed lasts as long as possible gathering useful information. Inter node communication for network organization and information gathering requires the most energy. Therefore, it is necessary to manage these activities in an energy efficient manner to optimize the lifetime of the sensor network. This research focuses on finding energy efficient methods of operating the sensor bed such that the lifetime is maximally extended.

Distributed clustering provides an effective way for self-organizing the wireless sensor networks for ... ne most positive and negative ... thms. Based on these finding ... ering algorithm where the cl ... level of sensors.

Further, the cluster boundary determination and cluster head role rotation is governed by the cluster heads residual energy level. The algorithm favors more powerful nodes over the weaker ones thus makes local energy balancing to prolong the lifetime of the entire sensor network at a very low energy overhead. The proposed algorithm has realized near ideal local energy balancing. The proposed algorithm is also extended to achieve global energy balancing by introducing a mix strategy of communication (multi-hop and direct) from cluster head to base station.

The research shows that the algorithm performance is in line with the desired objectives using analytical proofs to back the simulation test results. Further, the research proposes an analytical framework in determining the cluster distribution of the presented algorithm. Subsequently, the framework was extended to other similar types of distributed clustering algorithms. Finally, the research proposes an analytical technique in finding optimum algorithm parameters such as the cluster head message broadcasting range and cluster head role rotation.

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Nomenclature

ϵ_{amp-fs} Radio propagation attenuation constant in Free Space model.

ϵ_{amp-mp} Radio propagation attenuation constant in Multi-path Fading model.

d_0 The distance differentiates the Free Space propagation effect and Multi-path Fading propagation effect in Simplified Multi-path Fading model. This is given by

$$d_0 = \sqrt{\frac{\epsilon_{amp-fs}}{\epsilon_{amp-mp}}}.$$

E_{elec} The energy spent on transmitter and receiver circuits in signal processing of one bit.

E_{DA} Energy cost of data aggregation.

ℓ

P_i ... spect to the other ... evel.

$\mathcal{N}_j^{\mu}$ ... s μ from node j excluding the node j.

$\mathcal{H}$ The set of all cluster heads at a give moment.

$\mathcal{M}_i$ The set of member nodes in a cluster headed by cluster head i including itself.

$\mathcal{SN}_i$ Cluster head node i's second degree neighborhood.

$E^t_{res_i}$ Residual energy of node i at any given time instance t.

$E^t_{res_i}\big|_{t=\tau}$ Residual energy of node i at time $t = \tau$.

$\lambda^{\tau}{}_i$ Dynamic energy threshold value of a given cluster head node i which becomes a cluster head at time $t = \tau$. When it's residual energy drops below this value, it calls for a new cluster head selection phase with the help of the base station.

$\text{dist}(x, y)$ Distance between nodes x and y.

$P_{Rx_{i,j}}$ The received signal strength of the signal transmitted by node i at the node j.

P_{Tx_i} The transmitted signal strength of a data packet by node i.

R Cluster head candidacy broadcasting range.

R_{opt} The value of R which will minimize the total data gathering energy of one round.

c The cluster head role rotation triggering dynamic energy threshold level calculation parameter.

c_{opt} The value of c which will maximize the sensor network lifetime.

$E[k]$ Expected (average) number of clusters for a planned wireless sensor network setup.

D_{CH-CH} Expected (average) distance between two neighboring cluster heads.

$\eta(d_{i,j})$ Compressibility of the data of node j at node i due to the correlation of data of node i and j. $1 \geq \eta(d_{i,j}) \geq 0$.

α Exponential data correlation model coefficient such that $\eta(d_{i,j}) = 1 - e^{\alpha d_{i,j}}$.

λ Deployed sensor node density. Assumed these nodes are uniform randomly deployed in a given area resulting a Poisson point distribution with density

N ... A.

$\mathcal{NH}_i$ ... d node i.

d_{TH} Cluster head nodes whose distance to base station is less than d_{TH} would not relay through another cluster head. This is used with EDCR-MH algorithm to save the energy of cluster head closest to base station by reducing the burden of serving closest cluster heads who can directly reach base station without incurring much energy cost.

E_{CH} The total energy spent by a cluster head in a given data transmission round for useful work.

E_{nonCH} The total energy spent by a non cluster head node in a given data transmission round for useful work.

E_{CHoh} The energy overhead that a cluster head node has to spend in each cluster setup phase.

$E_{nonCHoh}$ The energy overhead that a non cluster head node has to spend in each cluster setup phase.

β_i^T This is an energy level calculated at the beginning of any new cluster formation phase in EDCR-EB algorithm. Given cluster head i stops forwarding any incoming relay packets at this pre calculated energy level.

a_i This is used in calculating β_i^T for each cluster head i making global energy balancing.