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Vishal Kumar[1], Vinay Kumar[1], D. N. Sandeep[1], Sadanand Yadav[1], Rabindra K. Barik[2], Rajeev Tripathi[3], and Sudarshan Tiwari[3]

[1]Department of ECE, Visvesvaraya National Institute of Technology, Nagpur, India -440010
[2] School of Computer Applications, Kalinga Institute of Industrial Technology, Bhubaneshwar, India - 751024
[3] Motilal Nehru National Institute of Technology, Allahabad, India - 211004
[1]{*vkvishalkumarv, vinayrel01, sandysmilent, sadanand.0501*}*@gmail.com*
[2]{*rabindra.mnnit*}*@gmail.com*
[3]{*rt,stiwari*}*@mnnit.ac.in*

***Abstract*—Energy saving is always an important issue as most of the Wireless Sensor Networks (WSNs) work in an unattended geographical environment where human access and monitoring are practically impossible. One of the existing ways of saving energy in WSNs is clustering of sensor nodes. Furthermore, the clustering process can be made more effective by optimizing the number of clusters. Cluster shape, Intra-cluster and Inter cluster topologies are some of the impacting factors for energy conservation in WSNs. In this paper, for the purpose of further saving the energy consumption, we considered a network with multi-hop communication. An analytical expression is developed for finding optimal clusters particularly, when the sensing field is split into hexagonal and voronoi clusters. Besides, the effect of data aggregation ratio, position of base station on the overall energy consumption is analysed through different case studies. The obtained results are compared with the single-hop counterparts. A significant reduction in the energy consumption can be observed from the results. Thus, multi-hop based optimal clustering results in a substantial reduction of energy consumption in WSN.**

***Index Terms*—Hexagon, Multi-hop, Optimal cluster, Voronoi, Wireless Sensor network.**

List of Symbols and abbreviations

A	Area of sensing field
b	Packet size
BS	Base Station
CH	Cluster Head
CM	Cluster Member
DAR	Data Aggregation Ratio
d^n_{toCH}	Distance between CM and CH with n = 2 if distance is small, n = 4 if distance is large
d^n_{toBS}	Distance between CH and BS
E_{elec}	Energy dissipated in electronics
E_{amp}	Energy dissipated in power amplifier
E_{DA}	Energy dissipated in data aggregation
E_{fs}	Energy Dissipated due to free space
E_{mp}	Energy dissipated due to multipath
E_{TX}	Energy dissipated in transmitting data
E_{RX}	Energy dissipated in receiving data
E_{CH}	Energy dissipated by a CH
E_{NonCH}	Energy dissipated by a non-CH
E_1	Energy consumption of CH independent of λ
E_{2_n}	λ dependent energy consumption of n^{th} level CHs
E_{3_i}	λ dependent energy consumption of i^{th} level CHs during a single frame
E_{Total}	Total energy consumed in sensor network
h	Hop count
k	Cluster count
M	Dimension of sensing field
MH	Multi Hop
N	Total number of sensor nodes
n	Level of the Cluster Head
R	Radius of sensing field
r	Transmission range of cluster head
SH	Single Hop
WSN	Wireless Sensor Network

I. Introduction

A Sensor is a device that converts a physical quantity into some measurable data. A wireless sensor node is an integrated block of sensor and radio units. It can gather sensory information, process it and communicate with other nodes in a network. A Wireless Sensor Network (WSN) comprises a large number of small sized sensor nodes which possess limited energy reserve. It is found in a variety of potential wireless applications such as surveillance of battle field, air pollution monitoring, forest fire detection, landslide detection etc. In these applications, many sensor nodes are deployed either in deterministic or random fashion to perform an assigned wireless operation. Owing to this, the energy conservation is indispensable to increase lifetime of the nodes. Therefore, it is a challenge to develop a robust and energy efficient WSN.

Clustering is an important method in this regard. Clustering refers to partitioning the sensor network into small groups of nodes. Each group is called as a cluster, and the features used