Energy Efficient Heterogeneous Wireless Sensor Networks - Recent Trends & Research Challenges

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Abstract. In recent times, Heterogeneous Wireless Sensor Networks (HWSNs) are gaining increasing interest from various research communities due to their potential applications in large number of domains such as environmental applications, area surveillance and health monitoring. However, the performance of a HWSN primarily depends on a set of critical decision parameters including robustness, security, connectivity and efficient usage of energy and so on. Specifically, one of the most important research challenges is, enhancing the network lifetime of HWSNs, so that the object monitoring activities can be conducted without any interruptions. More specifically, Energy usage in a network is an essential factor, which directly influences the lifetime of the given network. In contrast, efficient energy utilization within a network can be achieved by means of grouping the nodes into clusters using effective clustering algorithms. In this paper, an overview of HWSNs is presented along with the different state-of-the-art techniques used for implementing energy efficient clustering strategies. Furthermore, this article also explores the future key directions and highlights the research challenges that need to be addressed in achieving energy efficient clustering in HWSNs.

Keywords: HWSN · Energy efficiency · Clustering in HWSNs

1 Introduction

In the past few decades, there is an bigger research curiosity in the possible uses of Wireless Sensor System (WSN) in variety of field including border security surveillance, disaster management, and surveillance of battle field and so on [1]. Generally, Wireless sensor system (WSN) consists of small sensors/nodes having capabilities such as sensing, calculation and communications. These sensors collect data by sensing their environment, collect the sensed facts to figure useful information and send out it to the base location or the adjacent node for further processing. However, sensor nodes are limited in power, memory, computational capacities and specifically shorter life span. One of the strategies is to extend the lifetime of WSN is to incorporate a definite percentage of sensor nodes outfitted with additional energy sources, by means of

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building the WSN as heterogeneous WSN (HWSN) in terms of energy. Due to this incorporation of additional sensor nodes, HWSNs stay alive for a longer time, as compared to homogeneous WSNs, which is sufficiently demonstrated in the literature in terms of many present schemes for heterogeneous wireless sensor networks (HWSNs) such as SYLPH [1] and EEHC [2]. Researchers of WSN believe that, if nodes are non-homogeneous having some of the nodes with different energy levels, might extend the lifetime of a WSN and its reliability to a greater extent [3].

Generally, there are three types of resource heterogeneity may exist in HWSN-based sensor nodes, namely computational heterogeneity, link heterogeneity and energy heterogeneity.

Computational heterogeneity indicates that, few of the mixed nodes consist of more potent microprocessor and more memory compared with the other regular nodes. Link heterogeneity represents, some of the nodes in HWSN have more bandwidth and longer distance network transmission capabilities compared to the other normal nodes. Energy heterogeneity denotes that, some of the heterogeneous nodes are line powered or battery replaceable. Energy heterogeneity is considered as the most important heterogeneity among all the three types of resource heterogeneities, since both the computational heterogeneity and link heterogeneity mainly depends upon consumption of amount of energy resources. In addition, the effectual position of heterogeneous nodes in the sensor network significantly reduces average energy consumption and also increases network lifetime as well as reliability of data transmission. Due to these reasons, HWSN have broader applications than homogeneous WSNs. However, due to their replace ability of nodes, one of the major challenges in HWSN is dealing with effective consumption of energy in order to extend the network life span in complex heterogeneous network environments.

2 Literature Survey

Clusters are the organizational unit for WSNs. A WSN can be able to changed in size by gather together the sensor nodes into groups i.e. clusters. Every cluster have got a head, which is called as the cluster head (CH), which may be selected by the sensors in a bunch or pre allocated by the network designer. In the literature, a no. of clustering algorithms are introduced for designing HWSNs, which in turn can enhance scalability, data communication as well as efficient energy utilization.

For example, Smaragdakis et al. [4] discuss stable election protocol (SEP), which uses heterogeneity concept. As per this procedure, a node can become a cluster head based on weighted election prospect, which uses a function of the residual energy of the nodes in order to make sure consistent usage of node energy. The fundamental network of the SEP considers two levels of heterogeneity namely advanced nodes and normal nodes. However, the energy of the superior node is somewhat advanced than the ordinary nodes and their count is lesser than that of the normal nodes due to the bigger cost factor.

Li et al. [5] introduced the distributed energy efficient clustering DEEC protocol by considering 2-level and multilevel heterogeneous WSN. In this multilevel non homogeneous network plan, the energy of each sensor node is arbitrarily assigned from a given energy time. However, in this group all nodes are having diverse levels of energy because of arbitrary allotment. Due to these reasons, this multilevel non homogeneous network model is hardly of any use, since designing sensor nodes of large number energy levels may not be nearly viable.

Mao et al. [6] presented an efficient data assembly algorithm known as (EDGA) for heterogeneous WSNs that considers 3 levels of non uniformity by introducing 3 forms of nodes: traditional, advanced, and super nodes. However, the performance of this approach is slightly less due to the fact that, the vitality of a propelled hub is higher than that of a normal node and the vitality of a super hub is higher than its counterpart propelled hub.

Recently, in 2014, two distributed protocols namely, single-jump vitality productive bunching convention (S-EECP) also, multi-bounce vitality proficient grouping convention (M-EECP) are introduced by Kumar [7]. In S-EECP, the cluster heads are chosen by a weighted likelihood dependent on the proportion between remaining vitality of every hub in examination with the normal vitality of the system. But, M-EECP uses a greedy method to take care of the single source most brief issue to locate the most brief way from each bunch head to the BS.

Farouk et al. [8] presented a stable and vitality proficient grouping (SEEC) convention followed by the extension of multi-level SEEC. Zhou et al. [9] presented a technique based on bunching convention vitality scattering forecast and bunching the board (EDFCM), which uses two-level network composed of super hubs and normal hubs. In this method, the best number of gatherings calculated using LEACH. Also, a mathematical energy consumption model to compute the weighted likelihood of hub for choosing bunch head node is employed. However, the technique achieves slightly less performance, since the computation of normal vitality utilization at the next round of organize causes deviations in practice, which might form an ideal value.

Chand et al. [10] conducted a study of heterogeneous HEED protocol. It considers three parameters, namely residual energy, hub thickness, and separation. The authors used fuzzy logic techniques to determine the cluster heads. However, if cluster heads are not ready to speak with one another, then the data may be lost.

In 2015, Xiao et al. [11] detailed a cell-grouped calculation known as CC-HEED for energy efficiency in HWSNs. Though the performance of this approach is better, yet power consumption constrains limit the output rates, since cell nodes in cell-shaped areas are assembled together to collect the data in each cell region by taking into account power utilization model.

Very recently in 2016, Singh et al. [11] introduced a novel vitality proficient bunching convention (NEECP) for expanding the system lifetime in WSNs. This strategy chooses the bunch heads effectively with a movable detecting range and performs information total utilizing anchoring approaches. It likewise stays away from transmission of excess information by utilizing a repetition check work for improving the system lifetime. However, the performance of this scheme is slightly poor, due to the limitations of aggregation functionalities.

3 HWSNs - Network Model

HWSN in general, consists of multiple sensors with different processing capabilities as well as initial energy. Since, each node in a HWSN has staggered control choices; it can consume different energy levels per round during their ordinary execution depending upon its present power level. Further the connection quality and bundle loss rate are primary performance bottleneck issues in HWSN, which needs to be tackled with at most care, in convoluted remote situations. In addition, the node interferences can occur among hubs and clusters. In this way, the heterogeneous WSN with considerable amount of limitations is continuing as one of the potential research domain in the recent few decades (Fig. 1).

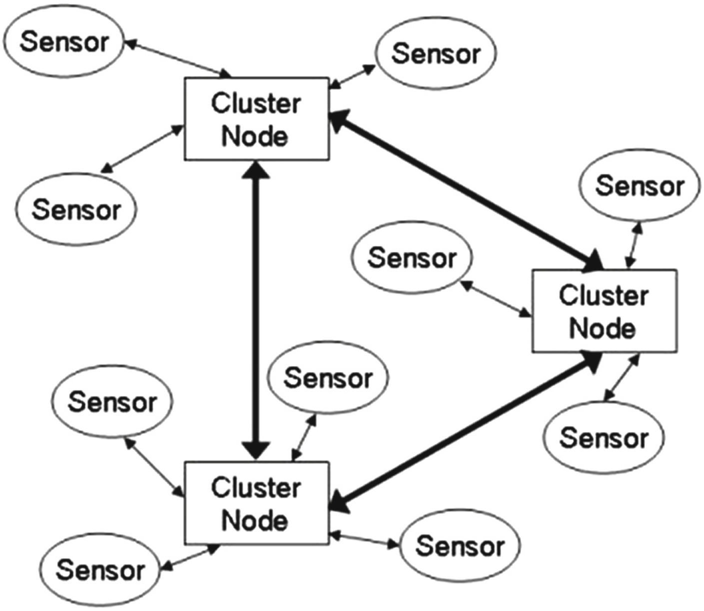

Fig. 1. Example two-layered heterogeneous WSN for energy efficiency

4 Future Research Challenges

In the current writing, though various techniques are introduced to achieve energy efficient clustering, yet few of the research challenges are not yet completely solved, which need to be addressed in future are as summarized below:

A. Computing ideal number of cluster heads:
In the literature, most of the techniques select the cluster head in a predefined way. However, achieving the ideal number of bunch heads is essential to ensure the least energy dissipation in the network so that the power consumption is reduced to extend the life of the network.

B. Maximize network lifetime:
In HWSN, the sensors are resource constraint and dependent on batteries as source of energy, due to which maximizing the lifetime becomes an important concern in HWSN design.

C. Cluster size:
In HWSN, balanced number of cluster members can distribute the load of cluster head uniformly. Since, if the cluster head is overburdened, this can cause more energy consumption and early death of nodes, which needs to be resolved.

D. Ignoring residual energy, geographic location information:
In the existing algorithms less focus is given towards remaining energy as well as geographic location of nodes, which prove to be very effective while selecting cluster heads. Therefore, incorporation of residual energy and geographic location information may significantly enhance the energy utilization of nodes in terms efficient clustering process.

E. Reduce the Energy Spent per Round:
This measurement is related to the total energy used in routing messages in a round. It is a measure of the short term which can be intended to improve the energy efficiency of nodes in any HWSN.

F. Effective Low-Duty Cycle Operations in Idle States of Nodes:
In general, from the data sensing point of view, the To collect environmental data from the field, sensor nodes should remain in active state, whereas sensor nodes are expected to be powered off periodically for energy conservation concerns. To solve this issue, effective low duty-cycled operations need to be employed, where In order to save energy consumption in idle conditions, each node periodically switches between sleep mode and wake mode.

G. Uniformity in Cluster head distribution:
In the literature, though cluster head distribution is focused more, yet suitable metrics for computing uniformity in cluster head distribution are completely unexplored, which might result in longer network lifetime.

5 Conclusion

Only just, more popular are heterogeneous wireless sensor networks (HWSNs) among various research communities due to their potential applications in large number of domains such as environmental applications. Specifically, one of the most important research challenges is, enhancing the network lifetime of HWSNs. However, Energy usage in a network is an essential factor, which directly influences the lifetime of the network.

On the other hand, efficient energy utilization in a network can be achieved by means of grouping the nodes into clusters using effective clustering algorithms. In this paper, an overview of HWSNs is presented along with the different state-of-the-art techniques used for implementing energy efficient clustering strategies. Further, future key directions and research challenges are highlighted in this article which could be beneficial for achieving energy efficient clustering in HWSNs.

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