Clustering in Mobile Wireless Sensor Networks: A Review

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ABSTRACT- Wireless Sensor Networks (WSN) find its applicability from military to medical fields. Many of these applications requires node mobility. One of the systematic technique to incorporate efficient utilization of constrained resources in WSN is through clustering and also mobility aids to avoid hotspots. Clustering is a process in which the randomly deployed nodes of WSN are divided into non-overlapping groups called clusters and each one is assigned with a leader responsible for coordination and proper functioning of the cluster. We aim to provide a detailed insight to a novice researcher in this field with the state of art clustering schemes with their impact on the mobile WSN.

Keywords – Mobile WSN, Clustering, Node Mobility.

I. INTRODUCTION

Operations in Wireless Sensor Networks (WSN) must be resource efficient in order to maximize the lifetime of the network. WSN are networks with resource constraint and nodes are battery operated with no option of recharging. Clustering is one such operation to increase the longevity of the network. Clustering is a technique where nodes are divided into non overlapping groups, each group is governed by a node and will further be referred to as Cluster Head (CH) with all the nodes within a cluster referred as Cluster Members (CM). Though many clustering algorithms are proposed in literature for Ad-Hoc networks, these techniques are not applicable due to critical design goals of the WSN [22]. CH can be either pre-assigned by the network manager or it could be selected or elected by the other members in the cluster. The CH is assumed to be richer in resources as compared to that of the other nodes in Cluster. The CM are fixed for a static network or else if the nodes are mobile the CM keep changing.

Organization of the paper is as follows, in section II we discuss about the advantages of Clustering. Section III discussed the factors that influence clustering, followed by overview of clustering schemes based on mobility in section IV. In the last Section V we conclude with open research issues of clustering in WSN with mobile nodes.

II. CLUSTERING ADVANTAGES

The Network Model

A Mobile WSN is made of innumerable number of nodes that are deployed in hostile area where human reachability and operability is nearly impossible. Hence these nodes once deployed should self-organize and work appropriately to cater to the needs of the network. These nodes are battery operated and hence the lifetime of network is constrained. There are two types of nodes possible in WSN, static or mobile. Here in this paper we consider nodes are mobility, hence the name Mobile WSN. The main aim of any scheme should be to efficiently utilize the resources to maximize the network lifetime.

The Mobile WSN architecture [20] includes, Base Station (BS): The BS is the node with high energy responsible for processing and providing interaction interface between end user and other members, Clusters: Clustering is organizing the nodes of WSN into groups, Cluster Members (CM): are the nodes within a cluster responsible for sensing the environmental parameters and communicating to CH, they are capable of moving from one location to another. Cluster Head (CH): Leads the cluster members by coordinating cluster activities, aggregation of environmental data sensed by the CM, and they may also possess the capability to move. End Users: are the ones that use the data sensed and collected. They can either query or receive the reports from WSN.

Advantages of Clustering

Some of the advantages of clustering in WSN are enlisted below,

- Clustering supports scalability of WSN [19].
- Organization of nodes into clusters will localize the routing tables and also reduce the size of the routing tables stored at each node [22].
- The number of interactions and exchange of redundant messages among the nodes is reduced due to the organization of nodes into cluster [22].
- Cluster Heads evenly distribute the activities among the CM to balance the load and aid in increasing the performance of WSN [18].
- Clustering reduces the topology maintenance overhead by stabilizing network topology [19].
- Handling network is easier with clustering as Global changes made will not affect the networks locally [20].
- CH in order to prolong the life of network imposes strategies on its CM by scheduling the activities and manage whole of the cluster [22].
- CH aggregates data and passes this data to the BS hence reducing the number of message exchanges if all nodes had to communicate with the BS [21].

III. FACTORS INFLUENCING CLUSTERING

Clustering in resource constrained WSN should be energy efficient and hence it's important to consider the factors that influence such a process,

Node Type: Nodes in WSN are of two types Homogeneous and Heterogeneous. For Clustering with Homogeneous nodes, all nodes in the cluster have equal probability of being selected as the CH. The CH can conserve its energy by delegating the sensing work to the CM and perform only significant operations such as reporting to the BS or other CH, Data Aggregation and CM coordination. In case of clustering for Heterogeneous nodes [22], the nodes have different levels of energy. Nodes with highest level of energy perform the task of CH and nodes with low energy level perform the common task of sensing environment factors. Hence clustering of Heterogeneous nodes impose more constraints. [20,21,22] Shows that Heterogeneity of nodes is more appropriate for WSN.

Mobility of nodes: The nodes of the WSN can be of Static: the nodes are in fixed location till the network dies, Quazi: the nodes are static until the bootstrapping is complete then the nodes can continue to be static or move, Mobile: the nodes move from one location to another in the network. In such a network with mobility, clustering is very challenging due to network dynamics. Not much work is done in the clustering of nodes with quazi or mobile capability.

Mobility of Cluster Head: Clustering is affected if the CH is Mobile, as the cluster membership changes. In case of stationery CH, clustering and its management is very convenient.

Cluster Head Selection: When clustering is done with pre-assigned CH, the number of clusters will be fixed in the network and in case of elected CH then the number of clusters in the WSN varies. Many election algorithms are published in literature.

Network Topology: The organization of nodes in the network can be Flat or Hierarchical. In Flat topology, all nodes have similar function whereas in al topology nodes with different capabilities are present. Clustering is organizing the network into multiple hierarchy.

Clustering Process: The clustering process can be initiated by End User or BS and hence such a coordinated clustering is said to be centralized, whereas clustering without any central coordination or authority is said to be distributed. In Hybrid clustering process the CH election would be distributed and coordination within the cluster would be centralized and managed by the CH.

Number of Clusters formed: In some clustering schemes the number of clusters and the CH are Pre-defined and when the number of clusters in the WSN varies over time due to network dynamics then clustering is Adaptive.

Intra Cluster Topology: Clustering is easy task when the number of CM is Fixed and challenging task when the CM keep changing over time such an intra cluster topology is said to be Adaptive and very challenging for clustering.

Node Deployment: are of two types, 1: Deterministic - When the nodes are placed in pre-determined locations then clustering is preset. In Self Organized WSN the nodes are deployed randomly and makes clustering more challenging.

Connectivity between BS to CH: Single-Hop and Multi Hop.

Connectivity between CM to CH: Single-Hop and Multi Hop.

Convergence time of Clustering Process: In case of Constant convergence: the number of iterations for clustering process is constant regardless of the number of nodes in the network. Variable convergence is the one where the number of iterations for completing the clustering process is dependent on the number of nodes in the network at that instance.

IV. SOME OF THE PROMINENT CLUSTERING ALGORITHMS

From the literature, lot of work has been done in clustering of Mobile WSN. Mobility of nodes help in eliminating hotspots which are created when CH die due to excess load. These hotspots leave the network partitioned. Other advantages of mobility include scalability, increase in energy efficiency, improvement of network lifetime, and increased fault tolerance. Many schemes published in recent times are

Nasser et al [1] proposed a routing based on partitioning Mobile WSN into zones and a clustering with zone head election scheme. It has low overhead and is based on velocity of node, localization, mobility factor attributes. This scheme is applicable for nodes with low mobility.

Kim et al [2] proposed a scheme that is an extension of LEACH called LEACH-Mobile which included mobility. A node with low mobility is elected as CH and distributed evenly over the sensing area, once elected CH is stationary. CH is selected based residual energy, mobility and location attributes. A mobile node requests for joining new CH when it does not receive request from its CH for 2 consecutive data frames.

Santhosh et al [3] LEACH-ME scheme is an extension of LEACH and LEACH-M to support mobility. It uses remoteness concept for CH election with mobility, residual energy and GPS based location detection mechanism as clustering attributes. The CH being mobile but fixed BS. Node will wait for two message transmission failures before joining new CH.

Awaad et al [4] proposed a clustering scheme based on mobility and adaptability for mobile heterogeneous WSN called Clustering Based Routing Protocol (CBRP). Based on node residual energy, CH is elected. The nodes moved out of one cluster to another have to be reassigned to new CH. This scheme reduces packet loss and energy consumption.

Deng et al [5] proposed a Mobility based clustering (MBC) scheme with mobile WSN and CH selection is based on mobility and residual energy attribute. BS is fixed, nodes are mobile and homogeneous. The authors claim that the scheme is proactive with reduced control overhead, good packet delivery date but does not provide fault tolerance.

Sahi et al [6] proposed Enhanced MBC an extension of [5] which is reliable and fault tolerant in mobile WSN

environment. SN conserve energy and show its existence by sending special packets to CH when they have no data for transmission. The scheme is more energy efficient and increases network lifetime when compare to [5].

Anita et al [7] proposed an Enhanced CBR (ECBR) for Mobile WSN. It is an extension of [4] where CH election is based on high residual energy, low mobility, location awareness, distance between BS and node. The scheme is energy efficient where nodes are mobile and BS is fixed.

Jose et al [8] proposed a Mobile sink Assisted Algorithm (MSA). Both static and mobile sink are part of Mobile WSN with static sink controlling and coordinating the mobile sinks. The Clustering is based in LEACH based on residual energy and general behavior of nodes, along with path planning for mobile sinks. The mobile sinks collect that from various parts of network and pass this data to static sink for processing.

Zhao et al [9] proposed a Load Balanced Clustering and Dual Data Uploading (LBC-DDU) which divided the heterogeneous WSN in 3 layers Sensor Nodes Layer : is used to sense and collect the data, Cluster Head Layer: Multiple CH are selected for each cluster which guarantee the communication and connectivity. Mobile Collector Layer: the data aggregated by the second layer from first layer is collected by third layer called Mobile Collector Layer.

Zahhad et al [10] The Mobile Sink – Based Adaptive Immune Energy Efficient Clustering Protocol (MSIEEP) is based on Adaptive Immune Algorithm to find the stability period of the network and also optimal number of CH. AIA acts as a guide to mobile sink. This protocol improves lifetime and stability periods of heterogeneous network in mobile scenario.

Srithar et al [11] proposed an Adaptive Weighted Fuzzy Clustering Based Cluster Head Selection Algorithm (AWFCA) which tries to combat the problem of nodes distribution, holes in network and flat structure by incorporating heterogeneous mobile nodes. This scheme selects a representative path to CH based on weights using a centralized approach. The network lifetime is increased based on three fuzzy parameters, energy concentration and centrality.

Jason Li et al [12] proposed a Distributed Efficient Clustering Approach (DECA) a distributed clustering approach and is efficient with mobility of nodes. The clustering in DECA is based in the score function which is in-turn a calculation of residual energy of node, node computation capability, mobility, identifier and connectivity. The higher the score, more the chances of that node being selected as a CH.

Ali et al [13] proposed a scheme for distributed clustering for mobile WSN called Distributed Efficient Multi-Hop Clustering (DEMC). The mobility model for nodes in this scheme is mass mobility model, nodes are aware of their location and homogeneous in nature. The clustering involves recovery mechanism that reduces the packet loss during inter-cluster communication also improves inter-cluster communication between the CHs.

C Tang et al [14] This Collaborative Weighted Clustering Algorithm (CWCA) is based on weighted clustering using multiple metrics to calculate weight such as degree, Euclidean distance, relative mobility, lifetime of a node. This scheme has dual applicability to both static and mobile sensors. Some of the potential benefits of the scheme are energy efficiency, higher power gain and distributed sensing.

S. Park et al [15] proposed a Two Tier Clustering (TTC) scheme for mobile environment based the self-organizing capability. The clustering is done in two phases which make sure that the CHs are distributed evenly in the mobile network and also prevents the CH clumping. TTC is able to reduce data and also provide high energy efficiency.

S Basagni [16] proposed a Generalized Distributed Mobility Adaptive Clustering (G-DMAC). This scheme requires each node to have local knowledge and direct communication with the CH, this fastens the intra and inter communications between the nodes. Cluster formations is based on weight and mobility parameters, the nodes are mobile even during the clustering set up. The stability of this clustering scheme is measured in the terms of number ofelections and affiliations.

V. CONCLUSION AND RESEARCH ISSUES

Mobility of nodes in WSN helps achieve scalability, fault tolerance and also energy efficiency. From the literature survey it is very evident that not much work is carried out about clustering nodes with mobility. And those schemes available are not optimal as they do not consider all the issues.

Node Mobility factor is not appropriately addressed and majority of the clustering schemes are based on the static nodes in the network or just considering the mobility of the CH. These conventional schemes proposed for static WSN find it hard to deal with mobile WSN.

5.1. Other Issues of the published work include:

Even if the mobility of nodes is considered in a scheme, the work does not focus on the network dynamics, where nodes migrate to different clusters. The joining and leaving the cluster procedure has to be properly addressed.

When considering securing the WSN with mobility almost no work or very insignificant work is carried out. No proper schemes are present to address the dynamic network management, Network adaptability. The current performance metrics used for the static WSN are not suitable for the mobile WSN, hence new metrics are required to measure the performance such networks. Other design issues that still need to be addressed in mobile WSN are CH or nodes moving out of communication range and appropriate localization and security schemes.

The Clustering process can be initiated in the network based on need i.e on demand to conserve resources. This issue is still unaddressed.

The paper provides an insight regarding clustering in WSN with nodes mobility summarized in Table 1 and also presents the scope for future work for the same.

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