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CLUSTERING ISSUES IN INTERNET OF THINGS: STATE OF ART

Ms. Shweta B. Guja
Department of Computer Engineering, NBNSSoE, Pune.

Dr. Amol V. Dhumane
Department of Computer Engineering, NBNSSoE, Pune.

Abstract

Internet of Things is a network of large number of sensing devices which are connected to the internet via other sensing devices for the exchange of information. These sensing devices are resource constrained. Once deployed in a field, it is impossible to charge these nodes. Due to energy scarcity of energy, there is need to provide a solution for building energy efficient IoT network, clustering is one of the solution.

In clustering technique, the nodes are grouped together to form cluster and then cluster heads are selected. In a particular cluster, the member node senses the data and transmits this data to the cluster head. The cluster head then gathers the data, preprocess it and then transmits it to the base station. Clustering the network are having many benefits, including load balancing, scalability, energy efficiency, increased network lifetime etc. In current state of art many clustering algorithms are developed by various researchers but most of them are application specific.

This paper focuses on the study of some of the clustering algorithms and also discusses the open challenges in this research domain.

Keywords*—IoT(Internet of Things), Cluster, Cluster Head, energy-efficiency etc.*

I. INTRODUCTION

In Internet of Things, the scope of Internet is going to expand. The vision of IoT is to connect all the things to each other from anywhere as well as anytime. Things in the IoT are the physical objects in our surrounding, such as lights, refrigerators, air conditioners, PCs, mobile phones, any computing devices etc. There are indefinite numbers of things. Things can be defined as an entity or physical object, an embedded system which is having unique identifier with ability to transfer the data over entire network. Amol Dhumane et al. has discussed various definitions of IoT in **[3].** All these things can act as nodes in the IoT network. In IoT, the internetwork consists of large number of nodes and each node corresponds to distinct an objects. RFID, Nanotechnology, Wireless Sensor Networks and Smart Networks are the basic IoT enablers. IoT contains combination of huge number of sensors, actuators, traditional networks and future networks that might be wireless or wired. IoT echo-system consists of the different functionalities such as sensing and gathering, storage, processing and transmission of the data or information to the different nodes. IoT generates tremendous data through different devices connected to the network. It is a large scale network where each node which might be stationary or mobile, is connected to the different nodes due to which it may face scalability problem. In a large scale IoT network, each IoT device is connected to the server with an individual connection may result in the waste of internet connection as well as wireless resources of an IoT network. The sensor nodes are having very limited memory, power and computational capacities. Once deployed in the network field, it is impossible to recharge the sensor node batteries. [1]

On the basis of network structure in IoT, routing techniques are categorized into two types: normal routing and hierarchical routing. In a flat routing mechanism, all nodes of the network perform the same tasks and have the same functionalities in the network.

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In a hierarchical routing mechanism, nodes in network perform different tasks, nodes may have different functionalities and are typically organized into different groups of nodes based on requirement. Grouping of nodes is done using various clustering mechanisms.

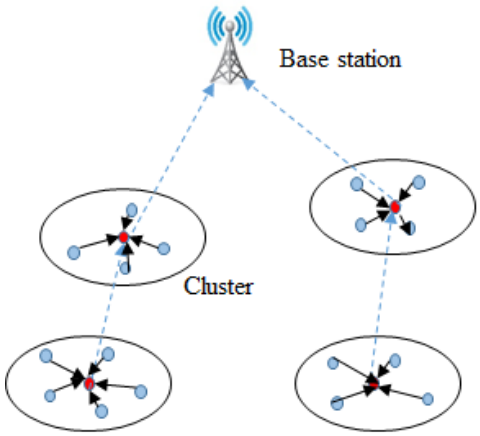

Fig.1: Clustered network

In clustering mechanism, a network consists of multiple clusters of sensor nodes, where, members of the cluster elect a Cluster Head(CH).All the nodes within the clusters sends their sensed data to their respective Cluster Head. It gathers the data from cluster members and further transmits this data to the Base Station (BS).

As shown in above fig.1, nodes in the given cluster sense the data, store it and send it to the elected Cluster Head. Then the Cluster Head processes the gathered data and transmits it to the Base Station. After that, the end user receives the data from BS which can be further connected through the internet. The objective of this paper is to focus on the state-of-art of various clustering algorithms. The rest of this paper is structured as follows. Section II presents the need of clustering in IoT along with the clustering objectives. In section III, various clustering algorithms in IoT are discussed. Section IV puts a beam of light on the various open challenges and direction for future research. Section V concludes the paper.

II. NEED OF CLUSTERING

Clustering the set of nodes is performed with various objectives. Some of them are listed below:

A. Load balancing:

Due to the resource limitations of wireless sensor nodes in the network, congestion may occur due to high-data rate application in the network, which may adversely affect the overall performance of the network. To handle this kind of problem, multipath routing algorithms can be used by different applications for splitting network traffic into multiple paths which may reduce the probability of congestion in the network.

B. Scalability:

Large number of sensor nodes may get deployed in a field for a specific application. The hierarchical architectures can increase the scalability of large scale networks by dividing the network into different layers, and then each layer into some clusters. When a node located in a cluster has to transmit data to another node located in another cluster, then node must have some information about the associated cluster head of that cluster that may result into reducing the size of routing table and increase in the scalability of the network.

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C. Increased Network Lifetime:

In IoT application, large number of sensor nodes are deployed over large areas or fields. Sensor nodes are having limited memory, computational capacity and battery life. It is very much difficult to recharge the battery of sensor node or replace it once it deployed. Clustering is an important method used for extending the lifetime of a network. It involves a cluster head (CH) which collects data from the cluster members (CMs) present in its cluster, and reports this data to the base station (BS). Thus, energy is conserved by sending data to the cluster head instead of the sink node directly [3]. However, distributing network traffic over more sensor nodes can result in even energy consumption among the sensor nodes and prolonging the network lifetime [4].

D. Data aggregation / Data fusion:

In network, large amount of heterogeneous data are generated through different sensors. Data aggregation/ Data fusion technique is required to avoid sending the redundant data to the Base Station. In case of flat routing, all the sensor nodes are sending data directly to the Base Station. So, Base Station may get the redundant data through multiple sensor nodes. But in hierarchical routing, clustering allows all the data are being collected at Cluster Head. This Cluster Head aggregates the data by removing redundancy, processes it and sends the aggregated data in fused form to the Base Station which increases the network lifetime.

E. Minimizing the routing delay:

In Most of the IoT applications, such as Health Care Application, Disaster Management Application, Event Management applications, strict deadline has to be followed. For that purpose, routing of data has need to be accelerated in and among the networks. While routing the data in WSN, it usually uses the multi-hop technique. As compared to the flat routing, clustering minimizes the routing delay. Because, in a network, if we have n sensor nodes and k clusters where k<n, routing data among k cluster heads is very much efficient than that of n nodes.

III. CLUSTERING ALGORITHMS

Clustering algorithms are based on various parameters such as clustering approaches and schemes, types of data transmission and clustering objectives. This section discusses some recent clustering protocols in the area of Internet of Things and Wireless sensor networks. Authors have done a brief survey of these protocols and stated them. There are three main phases of any Clustering Algorithm: Cluster formation, Cluster Head election and data transmission [5].

A. Low Energy Adaptive Cluster Hierarchy(LEACH):

It is a hierarchical clustering algorithm, designed for homogeneous network. Each node in cluster takes decisions independently, based on the local information of the sensor nodes. Any node may become a cluster head independent on the other sensor nodes, so every node gets a chance to become a cluster head. Cluster heads are elected based on Probabilistic threshold that is randomly chosen by the node [6].As Cluster Head consumes maximum energy among all the sensor nodes in a cluster, due to that after certain time interval, randomized rotation of Cluster Head is done so that it will not discharge whole battery life of the selected cluster head. Each associated CH is having scheduling of cluster nodes. The sensor nodes can communicate with CH according to schedule and for the rest of time nodes will be in sleep mode [7].

B. Hybrid Energy Efficient Distributed Clustering (HEED):

Like LEACH, this clustering protocol is also designed for Homogeneous Network. It is also hierarchical clustering algorithm. HEED works in multi hop network where all nodes are having equal

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importance which increases the network lifetime.. It minimizes the control overhead. Irrespective of network size, it terminates after fixed iteration. Communication cost or node degree and a hybrid of the residual energy is used to elect the CHs. HEED appropriately distributes the CHs across the network. After electing the CH, the CHs transmit the sensed data of the nodes to the BS by using multi hop approach.

C. Power-Efficient Gathering in Sensor Information Systems (PEGASIS):

This protocol is also designed for homogenous WSNs. It is used to increase the network lifetime and uniform energy consumption among the nodes. It uses the chain-based multi-hop technique which tries to reduce the delay between the source and the BS. To establish the chain of nodes, it uses greedy algorithm. While building the chain of nodes, each node communicates only with its close neighboring node which takes turn to transmit fused data to the BS per cycle [8].

In PEGASIS, it is assured that each node becomes a leader once in a cycle. The load is equivalently distributed among all nodes as the numbers of cycles are equal to the number of nodes. While constructing the chain, we start with the node which is located at the maximum distance from the BS and its nearest neighbor are selected as next node in the chain and so on. The last node must be the BS and the node before BS acts as a leader of the nodes where this leader node processes and aggregates the data. PEGASIS will not support the dynamic topology. For the large area network, it increases the routing delay which may create the scalability issue.

D. Distributed Energy Efficient Clustering (DEEC):

It is a distributed clustering algorithm designed for heterogeneous WSNs. It selects the Cluster Head with the help of probability based on the ratio of residual energy of each node and the average energy of the network. With the help of initial and residual energy of a node, DEEC decides how long a particular sensor node would be a Cluster Head [9].The nodes with maximum initial and residual energy are having more chances to be a cluster head as compared to the nodes with minimum energy[10]. DEEC provides maximal lifetime and the more efficient messages as compared to the current available algorithms in heterogeneous system.

E. Distance Aware Intelligent Clustering (DAIC):

DAIC is a hierarchical routing algorithm. Energy consumption at the time data transmission depends on the distance over which data has to be transmitted. The network is divided different tiers and in each tier, the CHs has to be selected. CHs are selected in such a way that they are having minimal distance from the BS. Each and every node in the cluster sends the information which includes location and status of residual energy to the BS. Based on this information CHs are selected dynamically. CH from primary tier collects data from non CH nodes from the same primary tier and CH nodes from secondary tier of the same network. It then sends collected data to the BS.

F. Multi-Objective fractional gravitational search algorithm :

In this algorithm [11] formation of cluster and selection of cluster heads are done by using Gravitational Search Algorithm and Fractional Theory. Authors have used Gravitational Search Algorithm which is a meta-heuristic algorithm which mimics the behavior of gravitational forces applied by the objects to each other in the universe whereas Fractional Theory is used for updating the search agent’s positions towards the optimal solution. Finally, after completing the desired number of iterations, the search agents gathers at the place of most fit solution and that solution is considered as the optimum solution. Multi-objective fractional gravitational search algorithm for energy efficient routing in IoT.

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IV. CLUSTERING ISSUES IN IoT

Current state of art shows that there are still many open issues while clustering the IoT networks. Researchers need to put a beam of light on that. Three of them are enlisted below which are yet to be resolved.

A. Cluster Formation

As sensor nodes in IoT network are mobile most of the times, so it is very much difficult to re-cluster or reconfigure the nodes[13].While forming the cluster, lots of control messages are transferred among the node that consumes the node energy to huge extent. Mobility of nodes may result into sending the control messages repeatedly for the formation of stable cluster. One can reduce these control messages by considering the neighboring nodes instead of considering the entire network.

B. Cluster Maintenance:

In Internet of Things network architecture, network maintenance is the preferred task. Therefore, Finding the neighboring nodes in the given network with an efficient synchronization scheme is a challenge. Nodes in the network are not static or having fixed location, so due to the mobility of the nodes in the network stability of clusters is one of the issue. It is necessary to do the maintenance of the network due to constantly changing environment in the IoT networks. The prime challenge in the network having mobile nodes is to select the precise CH to preserve long lasting network.

C. Data Redundancy:

As IoT network consists of huge number of sensor nodes, there may be possibility to transfer the redundant information to the Cluster Head. This kind of issue can be minimized by adding data fusion/aggregation technique[14].

D. Resource constraint nodes:

Resource constraint nodes is the major challenge in the current IoT networks. The nodes may be constraint of resources such as memory, processing power and energy. Due to such constraints in the resources, it becomes difficult sometimes to include the node into clusters. Energy constraint in nodes plays a vital role while selecting the cluster head.

E. Multi Path Challenge:

Another challenge is while transmitting the data in the cluster-based algorithms is, when multiple paths exists, it normally decreases the capability of paths because of the intervention caused by the close paths. It results into increase in packet loss ratio which further causes the degradation in the network performance [11].

CONCLUSION

IoT network may be a homogeneous or heterogeneous network with huge number of sensor nodes. To apply energy efficient routing techniques in IoT, clusters of nodes can be formed. Cluster divides the whole distributed network into number of groups to lessen the network overhead and the data redundancy at Base Station. This paper has discusses certain clustering algorithms along with certain challenges in Clustering.

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