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A Review on Clustering: From WSNs to IoT

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ABSTRACT
Numerous Internet of Things (IoT) networks are made as an overlay over conventional adhoc networks like Zigbee. In addition, IoT networks can look like adhoc networks over networks that help gadget to-gadget (D2D) communication, e.g., D2D- empowered cellular networks and WiFi-Direct. In these adhoc types of IoT networks, effective topology management is a pivotal prerequisite, and specifically in massive scale deployment. Generally, clustering has been perceived as a typical methodology for topology management in adhoc networks, e.g., in Wireless Sensor Networks (WSNs). Topology management in WSNs and adhoc IoT networks has many design commonalities as both need to move information to the destination hop by hop. Consequently, WSN clustering strategies can probably be applied for topology management in adhoc IoT networks. This requires a study on WSN clustering techniques and researching their applicability to adhoc IoT networks. In this paper, we did a survey of this field dependent on the goals for clustering, like reduced energy utilization and load balancing, as well as network properties for effective clustering in IoT, for example, network heterogeneity and mobility. Moreover we examine the benefits and difficulties of clustering when IoT is integrated with modern computing and communication Technologies, for example, Blockchain, Fog/Edge registering, and 5G. This review gives valuable bits of knowledge into research on IoT clustering, permits more understanding of its design challenges for IoT networks, and reveals insight into its future applications incorporated with IoT.

Index Terms—IoT, Clustering, WSNs, Survey

I. INTRODUCTION

Smart gadgets have encouraged the pervasive presence of different things, collaborating one another through addressing schemes—Internet of Things (IoT). IoT, presented first in 2008-2009 [1], interfaces billions of gadgets around the globe on top of various network infrastructures, predominantly the Internet. IoT intends to incorporate conventional and next generation networks to work simultaneously in a common infrastructure and support different pervasive applications [2]. Contrasted with different networks for example, WSNs, IoT hubs are exceptionally heterogeneous [3] . Numerous IoT networks look like adhoc networks, following a similar example of information transmission to the

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Internet as WSNs, e.g., Internet of Vehicles (IoV). In such networks, IoT hubs communicate with one another as an overlay network on top of an existing adhoc network, e.g., Zigbee. The essential building blocks of these sorts of IoT networks are WSNs in which sensors, communicate, connect and share information on a massive scale [5]. Besides, there are numerous IoT applications that run over adhoc and MANET networks, for example, medical services [7], smart cities [5], [8], vehicular networks [9], military applications [10], and smart agriculture [11].

In adhoc IoT networks, topology management is a basic prerequisite for efficient and scalable administration of the network, as well as applications deployed for such networks. In adhoc networks like WSNs, clustering has been presented as the most popular approach for topology management. Clustering strategies partition the network in to groups of hubs and distribute functions among group members to improve efficiency, e.g., gathering and sending information, resource management, and supporting QoS. Many clustering techniques have been proposed for WSN topology management, for example, LEACH [12], HEED [13] and TEEN [14], to name a few. Clustering in IoT can be challenging because of high heterogeneity and mobility of IoT hubs, and integration of IoT with recent computing and networking paradigms, for example, Edge computing and 5G networks. So conducting a survey on existing WSN clustering strategies and exploring their applicability to IoT networks would be advantageous for the IoT research community.

Review Methodology:

The methodology adopted for conducting this survey consists of the following steps. First, we extracted the list of main WSN clustering techniques from the relevant papers in reputable conferences and journals, such as ICCCN, WCNC, GLOBCOMM, ICPS, CNCS, SECON, IPDPS, ICDCS, INFOCOM, EWSN, PerCom, SenSys, IT- PDS, IEEE IoTJ, ITWC, ITN, ITVT, and ATSN. Based on the extracted relevant papers, we then checked their referencesand related work to find any other papers that were concealed. Having the main clustering techniques compiled, we finally searched for all other research works that either cited themain techniques like LEACH or proposed their own clustering technique. Finally, few papers were extracted as the distinguished clustering techniques proposed for WSNs and IoT.

II. CLUSTERING:BASIC CONCEPTS AND TAXONOMY

Topology management is one of the primary difficulties in establishing networks, particularly in adhoc networks [23]. Clustering, as a kind of topology nanagement, improves the efficiency by isolating the networks in to group of hubs and disseminating network functions among the group members, e.g., gathering and sending information, and resource management. Different network types have used clustering for topology management, for example, MANET [24], VANET [25], WSN [15], and IoT [26]. From the application layer perspective, clustering strategies have been presented for various kinds of necessities, for example, resource allocation [27], applying reputation models [28], service discovery [29], intrusion detection [30], fault monitoring [31], and anomaly detection [32]. A cluster is made out of various hubs (i.e., individuals) and has one or more Cluster Heads (CH) to deal with the individuals and shared resources. Additionally, CHs can gather, fuse, and process members information, and move it to gateway(s). Each network can have one or more gateways (otherwise called base stations or sinks) that connects CHs to outside of the network. clustering can address a few quality-related goals, like reducing resource utilization, improving load balancing and QoS, and adaptation to internal failure.

Clustering Methods:

There are two techniques to set up clusters in an network: I) Determining clusters by gathering hubs and choosing one or more hubs as CH(s), and ii) Selecting CHs first and inviting different hubs to join a neighbor CH. Joining of hubs to a group is basically founded on the actual vicinity of hubs and other parameters, for example, cluster size, number of hubs, and adjusting network load and resource utilization.

With respect to CH selection, there are various techniques as described below:

- In some clustering methods, resource rich hubs are determined as fixed CHs for the entire network life time [34]. In networks with homogeneous or resource constraint hubs, this strategy isn't productive. Indeed, even in a heterogeneous network, being CH for a long stretch of time will deplete the hub power rapidly, prompting hub death.
- In some clustering strategies, randomly circulate the CH duty among hubs [12]. This is useful in homogeneous networks, unfair randomness leads to network clog and persistent energy utilization in some CHs.
- The most common solution for such issues is the conscious CH choice strategy in which CHs are chosen dependent on the conditions of the hubs and the network[35], [36]. In this strategy, suitable hubs are chosen as CHs dependent on available resources, location, and number of neighbors.

The CH selection process can be performed either in a centralized or distributed way. In the centralized model, CH selection parameters are gathered, compared, analyzed and processed in a central node (i.e., generally BS). On the other hand, distributed methods impose less overhead, but due to relying on local CH selection criteria, selected CHs cannot always fulfill the whole network requirements. Due to this fact, distributed methods can cause network inefficiency in different performance aspects, e.g., QoS and load balancing.

Re clustering Techniques:

Re-clustering refers to any activity identified with re-choosing CHs or re- arranging existing clusters. CH selection strategies are for the most part intended to respond against any unforeseeable conditions by re-choosing or replacing CHs powerfully with more suitable hubs. Also, a hub cannot serve as CH for a long period of time because of resource depletion, so CH role is rotated among various hubs for the network lifetime.

There are two methods to trigger re- clustering:

i) Time-based technique: The network will be re-clustered at a certain time to balance resource consumption and ii) Event-based strategy: A event triggers the network to reselect CHs.

Data forwarding in clustering techniques: The network data can be transferred in its raw format or as a fused value (i.e., data fusion). In clustered networks, CHs are used to gather and fuse the members' data. The CH can transmit individual data items to BS or send the fused values. Since common clustering techniques are based on the proximity of the nodes providing data for the same application, it would be possible to perform data aggregation in CHs and reduce the amount of data to be transmitted. In addition, in some cases, CHs are able to compress data to reduce the data volume. Last but not least, data can be processed locally in CHs and results can be sent to the gateway(s). There are two methods to transmit packets from CHs to BS(s):

1. CH can send data directly to BS leads to energy wastage for long distance.
2. CH can use middle nodes to forward data to gateways called inter cluster routing, it leads to delay, also hubs inside a cluster can communicate called intra cluster routing.

III. CLUSTERING ALGORITHMS

Because of the energy constraint of sensor hubs, cluster based methodologies have acquired research interest. Clustering is a method of monitoring WSN's energy and sorting out an enormous number of hubs efficiently. This segment presents a writing overview of the existing cluster based methodologies. The algorithms under unequal approaches address the hotspot problem when compared to equal clustering approach. In view of the manner in which CHs are chosen and cluster range is computed, the algorithms are categorized into, (I) Probabilistic, (ii) Deterministic, and (iii) Fuzzy logic based algorithms.

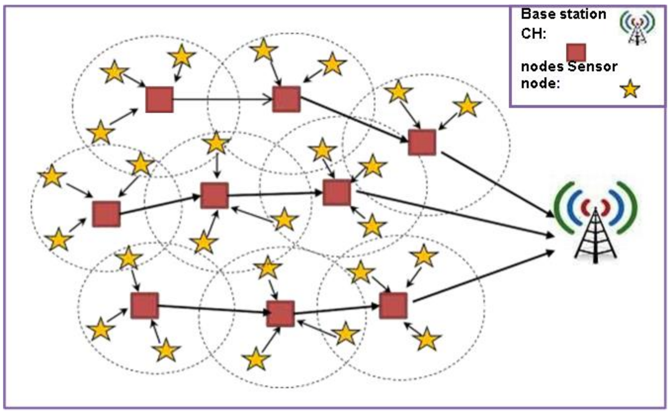

Figure 1.Clustered WSN

A. PROBABILISTIC ALGORITHMS

Probability based clustering algorithms are simple and less complex. They are energy efficient with faster convergence.This algorithm selects the CHs randomly with optimal overhead, and uses some more parameters like node density, remaining energy etc.. to form clusters.

There are two types

Equal sized and unequal sized

1. Equal size probabilistic clustering algorithms

These algorithms generate clusters of equal size. Some of the popular clustering algorithms of this type are

1. **LEACH[40]:**
   Clusters are formed among the large set of sensor nodes and some nodes are chosen as CHs randomly and other nodes join the CH within its range. CH is elected and the position of CH is rotated among all the nodes in the network. Each node Si generates a random value between 0 and 1 and compares it to a threshold T (n). If the random valueis less than T (n), it is selected as CH; otherwise, it acts a non- CH node for that round.
2. **CentralizedLEACH(C- LEACH)[41]:**
   C-Leach is a centralized algorithm which is executed at the BS to overcome the drawbacks of the LEACH protocol. In LEACH random selection of CH may select some low energy nodes, which reduces the energy again.In C- LEACH, each sensor send its information like location and energy to the BS, which uses this information to select the number of clusters using the simulated annealing (SA) method.
3. **HEED algorithm[42]:**
   CHs are selected by considering the residual energy of sensor nodes. Nodes having high residual energy can become CHs and other nodes join the clusters based on intra cluster communication cost.HEED uniformly distributes CHs throughout the network and better load balancing.
4. **Stable Election Protocol(SEP)[43]:**
   Along with sensor nodes, some high energy nodes called advanced sensor nodes are also deployed .These nodes act as CHs more often as compared to normal sensor nodes. Also the time of first node death and last node death increases twice.

2. UnEqual size probabilistic clustering algorithms

These algorithms forms clusters of unequal size.This approach overcome the problems of energy holes in the network. The size of clusters can be energy dependent or location dependent.

1. **Energy Driven Unequal Clustering (EDUC) [38]:**
   It is a distributed algorithm that forms unequal sized clusters which avoids hotspot problem and reduces energy consumption. It works in two steps.: cluster formation and data collection. CHs are elected randomly and all nodes will get a chance to become CH and data is transmitted directly to BS. This approach is not feasible for large sized networks.
2. **Unequal HEED [44]:**
   It is an improved version of HEED which addresses the hotspot problem. The UHEED structures distinctive sized clusters dependent on the distance of CHs from the BS, where small clusters are formed nearer to BS. It utilizes the distance data to find the estimated cluster size. This unequal size brings about lesser energy exhaustion in smaller clusters due to intra cluster traffic and saves its energy to emphasize on intercluster traffic.
3. **Energy Efficient Unequal Clustering (EEUC) [45]:**
   It is a hybrid algorithm which is used for periodic data collection applications. It selects the CHs randomly based on the distance from BS and it is a distributed algorithm. It forms smaller clusters closer to BS to avoid the hotspot problem. It uses multihop routing to forward CHs data to BS. During communication CH selects the forwarder node based on residual energy and distance.

B. DETERMINISTIC ALGORITHMS

CH selection and cluster formation are done by considering various parameters like residual energy, node degree,node centrality, distance from BS etc. these informations are obtained from neighbours.

1. **Equal sized deterministic clustering: It forms clusters of equal size.**

i. **Energy-aware Routing Algorithm (ERA) [46]:**
   ERA is a cluster based routing algorithm in which if a CH have multiple next hop nodes then based on energy availability next hop node is selected. But it suffers from hotspot problem.

2. **Unequal sized deterministic clustering:**

It generate clusters of unequal size.

i. **EADUC [47]:**
   It is an energy balanced distributed multihop routing protocol that has low complexity. Unequal sized clusters are formed based on residual enegy and distance from BS to avoid hotspot problem. In this algorithm, the CHs are selected based on the ratio of the average remaining energy of the neighboring nodes to the remaining energy of the node. During routing, if the distance of CH is less than the threshold distance, then CH transmits its data directly to BS; otherwise, a relay CH is selected considering the residual energy.

ii. **Arranging Cluster size and data Transmission WSNs (ACT) [48]:**
   It balances the energy dissipation of the CHs. This algorithms divides the networks hierarchically and interlevel data transmission is done to enhance the network lifetime.approximation technique is used to compute unequal cluster sizes.

C. FUZZY BASED ALGORITHMS

Clustering in WSN uses different parameters like residual energy, node degree, node centrality,distance from BS etc. Fuzzy logic concept is very useful in clustering. It combines different parameters. It is further classified in to equal and unequal size clustering algorithms.

1. **Equal sized fuzzy based clustering**

i. **Cluster Head Election mechanism using Fuzzy logic (CHEF) [49]:**
   In this method, some tentative CHs were selected from the alive nodes by applying some probabilistic method. Then, from the tentative CHs, the final CHs were elected by considering the energy of the tentative CHs and their distance from the neighbors as fuzzy input parameters. Then, the fuzzy if-then mapping rules were

applied to eval- uate these input parameters. The resultant defuzzified output provides the chance of a tentative CH to be selected as final CH. However, the probabilistic selection of tentative CHs may lead to some low energy node as CH, which will result in the early death of such nodes.

ii. **Energy-aware distributed Clustering Protocol using Fuzzy logic (ECPF) [50]:**
In this method, initially a set of tentative CHs was selected based on residual energy of nodes. Final selection of CHs was performed by considering residual energy and node centrality of the tentative CHs with its neighbours.

2. **UnEqual sized fuzzy based clustering**

i. **EAUCF [51]:**
This is a distributed clustering algorithm and the selection of CH is similar to CHEF. It computes the range of cluster based on residual energy and distance of CH from BS as fuzzy input parameters.

ii. **DFCR algorithm [55]:**
This is an enhanced version of EAUCF. Two fuzzy parameters are considered namely node degree and node centrality for cluster range selection. Also residual energy and distance from BS are used as selection parameters. Other non CH nodes select its CH using multi-objective cost function for uniform load balancing among CHs.

iii. **DECUC algorithm [56]:**
It is a coverage aware fuzzy logic based algorithm which considers both CH selection as well as cluster formation using fuzzy logic. A special parameter called coverage significance is considered which ensures the total coverage of the network when few nodes dies. The fuzzy input parameters such as residual energy and distance from BS is also considered.

iv. **LEACH-FL[59]:**
LEACH protocol using fuzzy logic uses fuzzy logic. It uses node degree as input parameter to select clusterhead. The fuzzy output is compared with the probability value .

v. **FCHA[60]:**
Fuzzy based cluster head amendment, base station performs dynamic clustering. It uses adjacency matrix for cluster head selection.
FCHA chooses three input parameters to calculate election periodicity such as node centrality, residual energy and articulation point. It improves the lifetime by 10%.

IV. COMPARISON

Comparison is done based on network lifetime and energy efficient parameter.
Network lifetime is the measure of the network at which the first node of the network completely drains out of energy. It can be observed that the unequal clustering algorithms have substantial superiority of the equal ones. Furthermore, the fuzzy logic- based protocol has performed best as it considers multiple parameters both for CH selection as well as cluster range computation. Therefore, it can be concluded that energy consumption is also more balanced in unequal clustering approaches as it can deal with the hotspot problem by forming more CHs closer to BS. Further, the consideration of other parameters apart from adistance to BS ensures the dynamic adjustment of CH's radius as the residual energy or nodes degree changes with time.

Further, the below table provides a comparative study of all the discussed algorithms in terms of different cluster parameters.

Table1: Comparison of different clustering protocols

Protocol	Cluster Properties							
	Distributed/ Centralised	CH selection	Inter cluster multihop	Mobility	Heterogeneity	Unequal cluster size	Coverage Aware	Fault Tolerant
LEACH [40]	Distributed	Random	No	No	No	No	No	No
EDUC [38]	Distributed	Random	Yes	No	No	Yes	No	No
C-LEACH [41]	Centralized	Hybrid	Yes	No	No	No	No	No
HEED [42]	Distributed	Hybrid	Yes	No	No	No	No	No
SEP [43]	Distributed	Hybrid	Yes	No	No	No	No	No
UHEED [44]	Distributed	Hybrid	Yes	No	No	Yes	No	No
EEUC [45]	Distributed	Hybrid	Yes	No	No	Yes	No	No
ERA [46]	Distributed	weight	Yes	No	No	No	No	No
EADC [57]	Distributed	weight	Yes	No	No	No	No	No
EADUC [47]	Distributed	weight	Yes	No	No	Yes	No	No
ACT [48]	Distributed	weight	Yes	No	No	Yes	No	No
DUCR [58]	Distributed	weight	Yes	No	No	Yes	No	Yes
CHEF [49]	Distributed	Fuzzy	Yes	No	No	No	No	No
ECPF [50]	Distributed	Fuzzy	Yes	No	No	No	No	No
EAUCF [51]	Distributed	Fuzzy	Yes	No	No	Yes	No	No
DFCR [55]	Distributed	Fuzzy	Yes	No	No	Yes	No	No
DECUC [56]	Distributed	Fuzzy	Yes	No	No	Yes	Yes	No

V. MIGRATING FROM WSN TO IOT

WSNs essentially connect sensor nodes to the Internet through a gateway, contrary to smart devices in IoT that are often able to connect directly to the Internet. In centralized networking solutions, nodes connect to on-premise servers or cloud platforms to process data. In the decentralized model D2D, and ad-hoc networks allow IoT networks to connect nodes directly. In the decentralized model, topology management is a critical requirement for efficient and scalable management of IoT networks. Being the primary solution for topology management, clustering can be applied to decentralized IoT networks in order to improve resource usage, QoS, and load balancing.

Clustering in IOT:

Clustering in IoT introduces new challenges that are discussed below.

1. Heterogeneity:

A fundamental challenge in IoT is supporting heterogeneity. Compared to WSNs, IoT network management techniques need to consider heterogeneity as a contingent characteristic of the network. In IoT, in addition to WSN nodes, other types of smart devices (e.g., smartphones and cameras) may be used in one application scenario [61].

2. Mobility:

Supporting mobility of nodes in IoT net- works has been an important issue, Mobility in WSNs has often been proposed for rather simple scenarios such as mobile sinks, unlike highly dynamic IoT applications such as smart cities [5], Additionally, mobile nodes not only change their locations in the IoT network, but also may switch between different networks which is related to handover mechanisms in IoT networks . These issues make designing clustering techniques in IoT networks challenging.

3. Device Identity:

The other issue is that the IoT network includes not only ID-based devices but also IP- enabled de- vices [62]. This implies that clustering techniques should be designed in such a way that they can support clustering both these types of nodes. For instance, IP-enabled devices can basically communicate with ID-based devices, while the opposite direction of communication may not be straight forward [63]. Therefore, clustering techniques can adopt two different approaches for clustering: clustering devices with the same network type, or clustering both IP-enabled and ID- enabled devices.

4. Device-to-Device (D2D) Communication:

D2D communication involves direct short-range communication between IoT devices without the support of network infrastructures, such as BSs or access points [64].

5. Applications:

Although clustering is targeted toward the network layer requirements, there are challenges, raised by IoT applications that should be considered in IoT clustering: Deployment model: Contrary to WSNs which usually host a single application [66], IoT network infrastructures may be offered to host multiple applications with their own quality requirements.

Design models:

Unlike WSNs which are mostly data-centric, IoT applications are often service-based [1], in which services can run on various devices and platforms, from local computing platforms to the Cloud. To further facilitate IoT services development and improve their efficiency, new computing technologies such as Edge/Fog computing [67], [2] have been recently emerged.

Table2:Technical differences of WSN and IoT to use clustering

Technical Differences		WSNs	IoT
Heterogeneity	Energy	Occasionally	Common
	Computing Power	Selodm	Common
	Storage	Seldom	Common
	NIC	Mostly single NIC	Common Multi-NIC
Mobility		Occasionally	Very common
Communication Type		Mostly ad-hoc	Possibly ad-hoc
Applications	Deployment model	Single application	Multi-application
	Design model	data-centric	Service-based

VI. CONCLUSION

Topology management is an important issue in the IoT networks that resemble ad-hoc networks. Clustering is the most popular method for topology management, especially in WSNs. Some existing approaches for WSN clustering have the potential to be applied to IoT networks, even though special characteristics of IoT networks such as heterogeneity and nodes mobility make clustering a challenging issue in IoT. The clustering approach integrated with multi- hop routing in energy constrained WSN have significantly reduced the energy consumption. But, due to the hotspot problem, the network lifetime of such protocols degrades by a large extent. The adaptation of unequal clustering approach has shown a substantial improvement of network lifetime. Furthermore, the fuzzy logic based multiobjective methods have shown the importance of multiple parameters like node degree, density, energy in cluster formation and cluster range computation. In this paper, we conducted a comprehensive survey on existing WSN clustering techniques and investigated their applicability to IoT networks. Classifying the well-known clustering literature shows that clustering can not only reduce energy consumption as its primary objective, but also achieve several other quality- related objectives. In addition, our investigations show that existing clustering techniques can contribute to better support of quality- related requirements of ad-hoc IoT networks, e.g., QoS and fault tolerance, although their high dynamicity and heterogeneity make clustering challenging.In IoT system the number of devices are very large, so proper WSN clustering protocol affects the whole performance.

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