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A Comprehensive Study on Energy Efficient-Cluster Based Routing Protocols in the Internet of Things: Hierarchical Routing Protocol

Noor Raad Saadallah[1*], Salah Abdulghani Alabady[2]

[1] Computer and Information Department, Ninevah University, Mosul, Iraq
noor.saadallah@uoninevah.edu.iq
[2] Computer Engineering Department, College of Engineering, University of Mosul, Mosul, Iraq

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***Abstract*—** Wireless sensor networks (WSNs) have several uses in a variety of industries; they are crucial components in many cutting-edge applications. WSNs are considered one of the newest applications to emerge is in the field of the Internet of Things (IoT), which enables the interconnection of various items or machines over the Internet, including the Internet of Things. This is why increase in the lifetime of the networks requires a strategy (protocol) that reduces the power consumption of the transmission or reception of data by the sensor nodes. A lot of research has been conducted, recently, to extend the lifetime of network sensors. The Hierarchical Cluster-based protocols and the Hierarchical Chain-based approaches have been created as solutions to this issue to reduce network traffic heading down the sink and so increase the lifetime of the network. In this survey, we look into the benefits and drawbacks of clustering when IoT is combined with cutting-edge technologies for computing and communication like 5G, fog/edge computing, and blockchain. Additionally, this survey offers helpful insights into the field of IoT clustering studies, enables a deeper comprehension of its design issues for IoT networks, and sheds the light on its potential future applications in cutting-edge IoT-integrated technologies.

***Keywords*—** Internet of Things; Clustering; Hierarchical routing protocol; Optimization; Energy consumption; Wireless sensor network; 5G .

1. INTRODUCTION

The Internet of Things (IoT) connects billions of devices globally on top of various network infrastructures, primarily the Internet. IoT seeks to combine many classic and cutting-edge network technologies to operate concurrently in a single infrastructure and enable various global applications. Network nodes are very heterogeneous compared to other networks like wireless sensor networks (WSNs). Tiny sensor nodes, also known as sensor nodes (SNs), or simply nodes, were developed as a result of technological advancements in both the electronics and wireless networking industries. These nodes can work together to successfully complete various tasks in a range of fields [1]. WSNs are composite units of several sensor nodes working together cooperatively. WSNs are often made up of several SNs that may monitor, process, communicate with one another, and work together to transfer data to the base station [2]. For too many applications, WSNs are favored due to their convenience of installation, cost-effectiveness of SN, self-configuration, ability to run in difficult or inhospitable environments, and capacity to detect minute details. These characteristics allow WSNs to be used in a wide range of critical industries, including farming, medical services,

* Corresponding author
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surveillance systems, and the military, to mention a few [3]. The purpose of providing a routing protocol is to address the challenge of the growing demand for using WSNs, particularly in Internet of Things (IoT) applications that increase the requirement for high quality of services and energy efficiency to extend the lifetime of network sensors [4]. Topology management is essential for the effective and scalability management of IoT networks and the applications installed over them. Clustering has been established as the most widely used method for topology maintenance in networks like WSNs. To increase efficiency in tasks like data collection and forwarding, managing resources, and maintaining QoS, clustering is the term for gathering devices or sensors together. To efficiently gather information inside a network with the fewest possible communications and distribute it for further processing, clustering is helpful [5]. Clustering also aids in extending the network's life span and a utilized IoT-based applications for a particular task. Clustering algorithms partition the network into groups of nodes and network functions are distributed between these group members. Any IoT-based application needs to gather data from sensing devices and process that data using a variety of algorithms. The information can then be accessible on the Internet whenever and wherever you are. Numerous clustering algorithms have been suggested to increase the network's lifespan. IoT networks, like WSNs, can leverage clustering for topology management to address the aforementioned performance requirements as well as IoT-specific difficulties, like the scalability of the network [6]. IoT networks may be able to use WSN clustering algorithms since they share many essential traits with WSNs and don't need to be designed from the beginning. The great mobility and variety of IoT nodes, as well as the integration of IoT with more modern computing and networking technologies like edge computing and 5G networks, make clustering in the IoT difficult. Clustering routing protocols is motivated by the need to address the problem of the growing demands on using WSNs, particularly in the internet of things (IoT) applications that increase the requirement for high-quality of services. WSNs' distinctive qualities, despite being their favored attributes, create new obstacles for sustaining quality of services (QoS). Clustering algorithms can be divided into segmentation approaches, hierarchical methods, density-based methods, grid-based methods, and model-based methods [3]. Many times, WSNs are viewed as infrastructure-free networks [37] in which the nodes must work together to create a network, collect data, and move it. In WSNs with a large number of nodes, where many nodes may need to act as a hop for data transmission because sensor nodes are resource-limited, resource management is particularly difficult. We must carefully handle the issue of resource use in WSNs, especially the energy utilization, since wireless data transmission consumes the majority of the energy in sensor platforms. One of these protocols, Hierarchical Routing, divides the network into smaller groups, each of which is watched over and managed by a node named Cluster Head (CH). A CH is in charge of transferring the data gathered by its cluster's members, and it can compress the data before doing so [7]. In this paper, we focus on the hierarchical routing protocols' performances in IoT networks, the implemented improvements, and our strategy for extending sensor life [6]. We provide a brief overview of the Internet of Things, its uses, its significance in our lives, and some of the biggest obstacles it will likely encounter in the future, and the remainder of this paper is organized as follows: section 2 related work about routing protocol in IoT applications; section 3 describes the current communication networks and IoT clustering; section 4

describes the clustering technique. Section 5 illustrated the classification of cluster-based protocols, while the conclusion is introduced in section 6.

2. RELATED WORK ABOUT ROUTING PROTOCOLS IN IOT APPLICATIONS

This section reviews several IoT routing techniques for IoT network routing. It covers in detail the classification of various IoT protocols for various applications. These routing protocols offer different algorithms and strategies chosen for secure routing in the IoT [8]. The analysis of various routing strategies offers a detailed picture of the suggested techniques, together with their benefits and drawbacks. Reactive protocols like Ad-hoc On-demand Distance Vector (AODV), which take into account each node's routing table values and next hop, provide a secure path for data. Below, the AODV routing protocol research articles are discussed. An Energy-Efficient Probabilistic Routing (EEPR) algorithm was created by Sang et al. [9] to manage the delivery of packets containing routing requests. EEPR reduces the packet loss ratio (PLR) while extending the network lifetime. The findings showed that the EEPR algorithm improved network longevity and evened out node residual energy usage. In [9], the routing protocol utilized is AODV, and in order to prevent network attacks, a security layer was implemented to cross-validate the sender and the recipient. The simulation results showed that in terms of End-to-End Delay (EED), throughput, Normalized Routing Load (NRL), the number of missed packets, and Packet Delivery Ratio (PDR), the security layer ensured better performance than other versions. Greg et al. conducted the research on the significance of routing protocols for effective and trustworthy data exchange in the multi-hop wireless network in the IoT environment [10]. Path-Based Routing (PBR), high maintenance costs, and erratic data transfer inside the network are all results of link-based routing.

The routing information in content-based routing protocols differs depending on the content. Below is a list of the various research projects using content-based routing. To lower energy usage in IoT applications, the Content-Centric Routing (CCR) protocol was created by Yichao et al. [11] to address the problem of traffic congestion in IoT applications. This approach predicts the routing paths according to the content, increasing the data aggregation ratio and lowering network traffic. According to the results from the simulation, the CCR offers better energy efficiency and minimal network latency, as well as enhanced reliability. The DSR protocol is an on-demand mode protocol that chooses the secure path according to the shortest path maxim. Wei designed an enhanced DSR protocol for the effective use of channel resources in the Internet of Things networks [12]. The rate of data transmission and hop count were taken into account when choosing the secure routing option. The results of the simulation showed that the DSR improved performance by fully utilizing the channel and minimizing the network congestion issue. The networks are combined to produce a tree network, which serves as the foundation for the tree-based routing system. So, here is a discussion of the research projects using tree-based routing protocols. For IoT sensor networks, the authors in [13] created the Efficient Tree-Based Self-Organizing Protocol (ETSP). All nodes were categorized into two groups for this protocol: network nodes, which disseminate packets to nearby nodes, and non-network nodes, which collect packets disseminated by network nodes. To reduce the amount of energy used by IoT devices, Zhangbing et al. [14] created an energy-efficient index tree (EGF-Tree). The minimal merging

approach in grid division and sensor node sample variance distribution served as the foundation for this technique. The recombination of the area is a major focus of this procedure. According to the simulation results, the EGF-Tree consumed less energy than other original index trees. Minimum Spanning Tree Particle Swarm Optimization (MST-PSO) is an efficient clustering method that was developed by Fernando and Sebastian [15]. The initial goal of this plan was to maximize network lifetime while minimizing energy usage and reliance on routers. The simulation results demonstrated how this algorithm outperformed competing protocols in terms of energy usage and the lifetime of the network. A centralized routing protocol is used by the SDN controller to gather network data. Below is a discussion of research projects using SDN-based routing protocols. The following research articles using fuzzy-based routing are provided. Fuzzy logic can forecast trade-offs between various network characteristics. The majority of IoT applications use RPL, a distance-vector tree-based standardized routing protocol.

Different optimization algorithms are typically implemented into the intelligent method-based routing protocols for secure routing [16]. Below is a presentation of research projects using routing protocols based on intelligent methods. The cluster head node is taken into consideration when developing the clustering-based routing protocol. Table 1 explains the research articles used with the clustering-based routing technique.

Table 1. Routing schemes for IoT applications.

Ref.	Strategies and contribution	IoT protocols	Objective	Platform and evaluation	Achieved performance
[9]	Present the energy-efficient probabilistic routing (EEPR) method, which stochastically controls the transmission of routing request packets.	AODV routing protocol	Extend network lifetime and lower packet loss.	NS2 simulation	The remaining energy of each node and the ETX measure when compared to the standard AODV protocol, the suggested EEPR algorithm has a prolonged network lifetime and distributes each node's residual energy consumption more fairly.
[10]	A path between users is constructed via a succession of point-to-point links. New methodology such as "smart-flooding" protocol. This protocol investigates how successful routing is for delivering data consistently and efficiently in a wireless network.	AODV and OLSR routing protocols	Efficient routing is done, effectively and reliably in transferring data by using multi-hop technic in wireless networks	NS3 simulation	Two standards (STD) and ETX (Expected Transmission Count). packet error rate (PER) data delivery that is reliable while utilizing the least amount of network resources.

Table 1. Routing schemes for IoT applications - Continued (1).

Ref.	Strategies and contribution	IoT protocols	Objective	Platform and evaluation	Achieved performance
[11]	The content-centric routing (CCR) method was proposed, in which content determines routing paths. The main concept is to route various content kinds via well-chosen, dependable communication channels to nodes that can aggregate and process the information before transmitting the total information.	Content-based Routing protocol	Minimum latency, increase energy efficiency, and maximum reliability.	CONTIKI COOJA Emulator based on the TelosB platform	Results show that CCR can greatly increase communication reliability, decrease transmission delay, and prolong lifetime of the network.
[23]	Illustrates a dynamic multipath routing protocol that can select the best path to meet various data traffic requirements. In order to provide the required QoS for various traffics, multiple-path metrics are used, including weighted cost function, available bandwidth estimation, and data-driven expected transmission (DDET) count.	AODV routing protocol	A robust route that satisfies the needs of the application's QoS. Improved delay and packet delivery ratio compared to the current routing procedures	NS2 simulation	Ability of new technique to improve ratio of packet delivery and round trip time as assessed by the present protocols. In order to offer QoS for different types of traffic in mobile ad-hoc networks, this work has shown that an enhanced throughput and decreased delay could be obtained using the multipath metrics selections.
[12]	Because of the unpredictable network environment and limited resources, choosing a protocol of "shortest-path routing" routing strategy in the internet of things is a difficult task.	DSR Routing protocol	The protocol of "shortest-path routing" is commonly used to improve channel utilization efficiency and reduce data transmission time.	NS2 simulation software	Enhance network communication efficiency and fully utilize the network. Improve throughput and delivery rate.

Table 1. Routing schemes for IoT applications - Continued (2).

Ref.	Strategies and contribution	IoT protocols	Objective	Platform and evaluation	Achieved performance
[17]	In order to use the least amount of energy feasible, the Energy-Efficient Content-Based Routing (EECBR) protocol was suggested for the Internet of Things. The proposed method generates the virtual topology from a central location using a virtual topology generator and then distributes the events from the publishers to the targeted interested subscribers.	Content-based Routing protocol	Offering an effective routing service for the Internet of Things sensors that are in charge of gathering and distributing data.	OMNET++ simulator	by identifying the covering nodes for a group of targets, it increases network longevity.
[13]	An effective tree-based self-organizing protocol is presented for IoT sensor networks (ETSP). A tree-based network can then be built, layer by layer. The topology is dynamically changed to balance energy consumption and increase network lifetime.	Tree-based Routing protocol	Build an efficient network. The average hop, self-organization time, and packet loss ratio will not increase further as the network scale grows.	NS2 simulation	Reliable tree-based networks can be created using ETSP. ETSP for IoTs lowers energy use and increases the lifespan of sensor networks.
[18]	For routing wireless sensor networks with a shifting sink, propose a localized overlay tree utilizing the particle optimization approach, Through the exchange of routing information, aim to locate a tree that uses less energy and delay.	Tree-based Routing protocol	exchanging routing information results in less delay and energy use.	MATLAB simulator	According to the simulation findings, the proposed protocol improves the MWST approach by an average of 30%, 40%, and 36% in terms of energy, distance, and step, accordingly.

Table 1. Routing schemes for IoT applications - Continued (3).

Ref.	Strategies and contribution	IoT protocols	Objective	Platform and evaluation	Achieved performance
[19]	This study proposes the cluster tree-based routing protocol (CT-RPL). The CT-RPL includes cluster formation, cluster head selection, and route establishment. The CH choice is made using a game theoretic method.	Tree-based Routing protocol	Increase the network's lifespan and decrease data traffic between nodes.	CONTIKI COOJA simulator	The quantity of parent node changes, the packet loss ratio, the end-to-end delay, and the amount of energy consumed. An increase in the packet delivery rate of 5–10%, as well as a 30–40% improvement in the network's lifetime.
[20]	Provides a ground-breaking SDN-based routing architecture for WSNs that may be implemented by extending existing protocols in legacy mobile devices.	SDN based Routing protocol	Extending existing protocols to offer a WSN routing architecture is based on SDN concepts that may be used in existing modules.	sunspot platform	Increased forward packets, improve energy consumption, and energy efficiency.
[21]	Provide a creative modeling paradigm based on a two-level method of control and suggest a novel Routing Protocol for Low-Power and Lossless Networks (RPL) based on a multi-hop clustering approach (MHC-RPL).	SDN based Routing protocol	To meet the required QoS for the IoT network in terms of delay, hop count, and energy consumption, in large-scale networks	COOJA simulator	Throughput, packet loss, and energy consumption. Manages traffic between many RPL instances using Q-routing in SDN controllers, which enables us to select the best paths for traffic.
[22]	The proposed routing protocol enables the distributed SDN iterative solver controller to balance the expenses associated with flow reconfiguration and flow allocation.	SDN based Routing protocol	Increase network lifetime and improve network stability	MATLAB simulator	Maximum network lifetime and improve the stability, and scalability for the heterogeneous network in a different environment, improve residual energy of sensor nodes and enhance packets delivery to the Bs.

Table 1. Routing schemes for IoT applications - Continued (4).

Ref.	Strategies and contribution	IoT protocols	Objective	Platform and evaluation	Achieved performance
[24]	Based on the selected cluster head, clusters are created using cluster routing protocols (CH). Following that, the data packets are sent from one CH to the next before being sent to the base station. The multi-hop transmission used by this technology sends the data packets from one hop to the next. Using a cluster head to send packets from a source sensor to the base station of a wireless sensor network, fuzzy logic type 1 .	Fuzzy based Routing protocol	The objective is to increase the network's lifespan and offer load balancing for it. The three criteria, such as energy, weight, and sink distance, are used by each cluster to choose the CH.	MATLAB simulator	Choose the best node as the CH, and it uses the trust factor as an input when choosing the best intermediate CH, which reduces packet loss, and boosts maximum delivery of data. Data forwarding to the sink that results to reduced energy consumption will be related to high minimum energy CH.
[25]	Fuzzy-Based Energy Efficient Multiple Cluster Head Selection Routing Protocol is a new routing protocol that is presented for Wireless Sensor Networks (FEMCHRP). The Base Station then receives the aggregated data from the cluster leaders (BS). The Dijkstra Algorithm is used to find the shortest energy path for data transmission, and fuzzy logic is used to select the cluster heads and cluster head leaders.	Fuzzy based Routing protocol	Extending network life and balancing energy use.	MATLAB simulator	Compared to previous protocols, the network uses less energy to send all aggregated data to the base station. The proposed protocol exceeds other protocols in terms of network longevity . The study's high average remaining energy also indicates that it transfers extra data than in other protocols.

Table 1. Routing schemes for IoT applications - Continued (5).

Ref.	Strategies and contribution	IoT protocols	Objective	Platform and evaluation	Achieved performance
[26]	Comprehensive comparisons with AODV and DYMO are made in order to evaluate performance. To determine the average packet end-to-end delay, routing overhead, and network topology change.	RPL Routing protocol	Simulated RPL routing protocol behavior and evaluated its effectiveness against other routing protocols.	COOJA based on contiki operating system	The overhead, which might be very high, can be reduced even further without compromising its effectiveness. The RPL routing protocol must be implemented and studied in a network with thousands of nodes.
[27]	In addition to three multipath RPL-based multipath approaches (Energy Load Balancing (ELB), Fast Local Repair (FLR), and their combination), a revised IPv6 communication stack for the Internet of Things is presented (ELB-FLR).	Intelligent method based Routing protocol	End-to-end delay is improved, overhead is greatly reduced, and a more equally balanced network is maintained with accelerated packet delivery.	OMNET++ simulator	Compared to the conventional RPL approach, achieved increased energy effectiveness, improved end-to-end delay, network throughput, and network load balancing.

3. CLUSTERING TECHNIQUE

The objective of the clustering approach is to effectively regulate the energy consumption of networks [29]. Grouping is one of the most famous strategies for WSN geography that the board can work on the productivity of the organization. Bunching arranges hubs into a bunch of gatherings called groups in light of several predefined rules, such as supporting Quality of Service (QoS), improving asset usage, managing network load, etc. [28-30]. Each bunch has a minimum of one Cluster Head (CH) [31], who gathers data from various hubs within the group known as individuals and sends the (combined) data directly or indirectly to BS using various hubs known as broker hubs. Utilizing bunching strategies, asset-compelled hubs do not have to send their information to sinks straightforwardly, bringing about energy exhaustion, asset utilization failure, and obstruction. The network may operate and provide services to the user for a longer period. Hence, the longer network life results in greater performance [32]. The network lifetime of a WSN is influenced by a number of factors, including data transmission, networking energy consumption, data collection, and aggregation, CH selection, node placement policy, etc. [33, 34]. The cluster-based technologies used in WSN have a variety of goals that center on extending the network's life and improving performance [35]. To accomplish their goals, the clustering protocols take into account several techniques. The goals of clustering procedures in WSN are depicted in Fig. 1.

Fig. 1. The objectives of clustering procedures in WSN.

One of the best methods for addressing WSN-related difficulties with energy and efficiency is thought to be the clustering process [36]. An objective or several objectives may be supported by a clustering technique. Ad-hoc IoT networks like WSNs have a lot in common when it comes to traditional quality-driven goals [38]. Ad-hoc IoT's characteristics present new obstacles to attaining clustering goals in IoT networks. We have many clustering objectives and solutions:

1. Reducing Energy Consumption:

Clustering algorithms can balance energy usage and prolong network lifetimes, which is their main goal. In any clustering technique, energy consumption is one of the variables that determine the network's overall performance and lifespan [40, 42]. To hold the network running for a longer period, the protocols put focus on minimizing the nodes' energy consumption [43]. To lessen the energy consumption of nodes, the clustering protocol employs various clustering algorithms, CH selection policies, and methodologies. It is taken into consideration as a major issue for practically all WSN clustering techniques [44]. The network protocols focus on reducing the packets because sending and receiving data packets consumes energy [45, 46]. Since data communication accounts for the majority of energy consumption in WSN [37, 41], clustering can reduce it through data aggregation in CHs and inter/intra-cluster routing by intermediary nodes. The technics and the current solutions are illustrated in Table 2.

Table 2. Existing solutions to achieve reduction in energy consumption using the clustering technique.

Existing solution	Ref.	Remarks
CH selection	[47]	A multi-objective selection technique
	[48, 49]	Fuzzy logic
	[50]	AI methods
	[51, 52]	Heuristic methods
	[53]	K-means algorithm

Table 2. Existing solutions to achieve reduction in energy consumption using the clustering technique - Continued.

Existing solution	Ref.	Remarks
Hierarchical clustering	[54]	Provide a hierarchical clustering index tree that organizes areas, referred to in Internet of Things networks as grid cells based on (ECH-tree). The technique makes sure that the grid cells on the upper levels have fewer dead spaces than those on the lower levels.
	[55]	For industrial IoT networks, introduce hierarchically unbalanced layers to balance energy consumption as the layers nearest to the base station (BS) includes smaller clusters.
Balanced clusters	[56]	To balance energy usage, introduce a technique that divides industrial IoT networks into grid clusters at each layer.
	[57]	The clustering strategy is designed using a traffic-engineering model, and descriptions of the services are being used by sensor nodes are provided to extend the lifetime of the network.
Applications	[58]	Offer a Kmeans-based clustering technique for multimedia IoT. To meet the needs of multimedia applications.
Routing techniques	[59- 61]	The issue of IoT has been addressed by the introduction of (RPL) as the conventional routing protocol.

2. Load Balancing:

The second most significant clustering-specific conventional goal is load balancing. To balance energy usage, it is a method for distributing the workload among all network nodes [62]. The network's load is distributed, so that network energy can be conserved, extending the life and enhancing performance [63]. In clustering protocols, the CH role is rotated across all nodes to balance workload and consumption of energy. To lessen the strain of CH and conserve CH energy, to transfer CH data to BS, the clustering techniques can use redistributor nodes. Network performance can be improved, and energy use can be reduced, through effective load balancing [64]. To transmit data from nodes to BSs, clustering algorithms typically employ a form of divide-and-rule strategy. High data transfer loads can affect QoS support and lead to uneven resource use. In WSNs [65] and IoT [66], the network performance is affected by increased transmission activity, which causes the nodes closest to the BS to consume energy more quickly than the other nodes [38]. Network isolation brought on by the energy exhaustion of nodes that are nearer to the BS is known as the "Hot Spot problem" [39]. The data is passed from one node to another when the nodes use a multi-hop route to communicate with the BS. The additional duty of sending the data to the BS is performed by the nodes closest to it, which uses up their energy more quickly. To address the hot spot problem in the network, some clustering protocols use various strategies. These techniques include giving additional energy to nodes closest to the boundary station (BS), shrinking the sizes of clusters that are nearer to BS, etc. [40]. The "Hot Spot problem" is a prevalent issue that can be resolved via load balancing. Due to the immense scale, an enormous number of data, and mobility of IoT networks, which might result in inefficiency, load balancing is typically a crucial issue. In [67], a technique is developed to balance the load of the network to decrease. As shown, Table 3 illustrated the solutions to balance the load of the network to reduce interference among nodes.

Table 3. Existing solutions to achieve load balancing using the clustering technique.

Existing solution	Ref.	Remarks
Intensive clusters	[68]	More CHs will make it possible to spread out the network strain among more (middle nodes). Additionally, adding layers to a hierarchical clustering system can increase the number of hops since additional nodes are accessible in each layer to serve as the next hop for packet forwarding.
	[69]	Clustering technique based on a multi-path routing that offers additional routes for regions needing to transport larger volumes of data.
Balancing clustering	[70]	In communicating directly, balancing clusters according to the size of the data would be a solution. The number of nodes might be a criterion to balance the load among clusters if nodes are homogeneous.
	[71]	Present a Software Defined Network (SDN) architecture to create a clustering table using Particle Swarm Optimization (PSO), which the SDN controller uses to balance the clusters and achieve load balancing.
	[72, 73]	In IoT, combine compressive sensing and clustering techniques. To improve these technics, they provide a brand-new cluster size-based load balancing technique. The packet rate per node can be a factor in balancing clusters in heterogeneous networks like the Internet of Things, but it is difficult to anticipate and process on the fly since it requires network traffic classification techniques.
Congestion control techniques	[74]	Offer a clustering strategy to address the load balancing issue associated with congestion control in M2M IoT networks. They presumptively use M2M communication as the foundation of the IoT network, with clustering serving as a proposed scheduling method based on Q-Learning to prevent congestion.
	[75]	To deal with multimedia big data in mobile IoT, provide a clustering technique. They put out a novel MANET-IoT strategy based on an altered LEACH clustering technique. Additionally, they suggest a link reuse congestion mitigation strategy depending on the link status.
Energy consumption	[76]	Describe a clustering method that distributes the network load according to a cost function.
	[77]	Implemented in to instruct CHs and members about their location in the system and balance their energy usage. Examine the lognormal shadowing channel, intra-, and inter-cluster traffic, and packet error rate to examine energy consumption. Based on the stochastic deployment scheme, they believe that both CH and cluster members have a predefined placement.

Table 3. Existing solutions to achieve load balancing using the clustering technique - Continued.

Existing solution	Ref.	Remarks
Different destinations	[78]	Applications running at the same time must accommodate varying packet stream rates and data volume. Additionally, by utilizing cutting-edge technologies like Fog and Edge, destinations of streams are no longer limited to BS(s) or gateways but also other networking devices.
	[79]	As a result, load balancing becomes difficult in IoT networks where the communication model is changed to a multipoint-to-multipoint one.
Cross-network communication	[80]	Propose a novel concept known as Intelligent IoT gateways, which have the ability to dynamically determine which services should be moved from the Cloud to the IoT network and conversely. Nodes can introduce services that originate outside the network into it by using intelligent gateways to monitor network performance, such as QoS and load balancing.
Dynamism	[81]	In the Internet of Things, users and service providers may not be foreseen and may develop and vanish over the course of an application, such as multimedia applications. The IoT nodes can become more unreliable in terms of data load if unanticipated service requests are made. Due to the dynamic nature of the network's traffic, load balancing needs to be regularly checked and optimized.

3. Fault Tolerance :

In IoT and WSN networks, node failure can be caused by a variety of things, including battery drain or malfunction in hardware like the transceiver and CPU that might be harmed by outside forces. Additionally, defective, mobile, or environment-related nodes, as well as physical and environmental issues, might cause connection failure. Fault-tolerant clustering algorithms have been developed to address these failure patterns to maintain the network stable by replacing malfunctioning nodes with other nodes [82]. Table 4 shows some of the solutions provided for Fault Tolerance.

Table 4. Existing solutions to achieve fault tolerance using the clustering technique.

Existing solution	Ref.	Remarks
Cluster-based breakdown detection	[83]	Offer a routing approach for Internet of Things (IoT) networks based on the bio-inspired particle multi-swarm optimization (PMSO) technique that can quickly identify problematic nodes and replace them with different routes. They use super nodes acting as a CH to collect information.
Spares nodes (CHs)	[82]	Some solutions use spare nodes to assume responsibility and prevent data loss to tolerate malfunctioning nodes. Ineffective CHs might be replaced with malfunctioning CHs as Hot Spots to effectively remedy the issue.

Table 4. Existing solutions to achieve fault tolerance using the clustering technique - Continued.

Existing solution	Ref.	Remarks
Re-clustering	[84]	The easiest method is because spare nodes add overhead to choosing and maintaining them. Clusters may be deleted and re-established if problems are discovered, restoring the necessary network infrastructure for information transmission. The authors present a clustering-based routing strategy for the Internet of Things networks that substitutes vice CHs for problematic CHs. Re-clustering will be carried out if vice CH is defective.
Unreliable connections and services	[85]	Faulty connections are frequent in the IoT. Faulty connectivity can make the clustering and routing between nodes unreliable, leading to, for example, data loss. Efficient communication channels, such as WiFi, 4G, and 5G, can mitigate these problems.
	[86-88]	Unreliable services are another IoT problem source. They have the potential to impair network performance, particularly in clustered networks. Running the defective services in other nodes is one way to handle them, but this can reduce the effectiveness of the clustered network because new routes must be established, which affects load balancing .

4. Reliable Quality of Service and Minimizing Data Redundancy:

When some sensors collect the same information, data redundancy may happen. The network's performance may suffer as a result of the duplication wasting energy. Data aggregation techniques are used in clustering protocols to address the issue of data redundancy. The information acquired from several nodes is combined into a single packet before being sent to the BS [89]. The CH manages the data aggregation tasks in the majority of clustering protocols by removing unnecessary data through data fusion and aggregation processes. The technique of data aggregation increases network performance by reducing the energy used to handle redundant data [90]. Introduce a clustering-based routing technique for IoT networks. In wireless mesh IoT networks, lessen interference that causes delay and balance the load across nodes. Reliability means the amount of data that is successfully received by the network's destination node. By enhancing the network's stability, clustering can increase the reliability of the system. Table 5 shows some of the solutions provided for QoS.

Table 5. Existing solutions to achieve reliable QoS using the clustering technique.

Existing solution	Ref.	Remarks
Reliable QoS	[90-92]	Improve stability
Delay	[93, 94]	Minimize number of hop
	[95-97]	Balanced loading
	[98, 99]	optimal Routing
Throughput	[100, 101]	Improve stability
	[102]	Number of CHs
	[103]	data gathering
jitter	[104]	Tree-based clustering
	[105]	splitting data stream

5. Network Management and Enhancement of Stability Period:

The network lifetime has always been a significant determinant of how well clustering techniques operate in WSN [37]. The protocols emphasize maximizing network life by utilizing a variety of strategies and tactics. The energy-aware methods seek to identify the best data connection paths, which lengthens the network lifespan [38]. It is necessary to utilize node batteries in a way that will support longer-term viability. The number of rounds until the first node dies is called the node's stability period [106]. As it demonstrates the effectiveness of the network, the stability period is regarded as a major element in assessing the effectiveness of clustering approaches. To increase network performance, the protocol seeks to extend the network's stability period [107]. Because of their large deployments, heterogeneity, and mobility of nodes, IoT networks have a significant problem in this area. In contrast to WSNs, IoT applications use more dynamic networks, which makes network administration challenging. The main option for managing the IoT network is to segment it into geographically distinct regions and delegate management of those regions to local nodes. Since network partitioning is clustering's primary goal, the following features of topology managers are met by clustering techniques in Table 6.

Table 6. Existing solutions to achieve network management using the clustering technique.

Existing solution	Ref.	Remarks
Scalability	[108, 109]	Distributed management
	[110]	Reducing communication overhead
Stability	[111]	Avoiding node death
Mobility management	[112, 113]	Inter-cluster handover mechanisms

6. Network Connectivity:

The network's interconnectedness demonstrates how the sensors are connected to one another. It decides how the nodes, CHs, and BS will communicate with one another. These connections are used for data transmission tasks. Some clustering methods enable network connectivity to establish an efficient connection among the nodes [106, 114]. If all nodes within a network can communicate with one another directly or through relay nodes, the network is said to be linked [115]. Relay nodes are employed in clustering techniques that employ multi-hop connections to link the CH and BS [116]. Clustering can increase connectivity because each node has at least one direct or indirect connection between both the BS and other nodes. Table 7 illustrated some solutions for the connectivity objective.

Table 7. Existing solutions to achieve network connectivity using the clustering technique.

Existing solution	Remarks		Ref.
Coverage	The control of radio range		[117]
	Connectivity between nodes	Network interfaces	[118]
		Network infrastructures	[119]

7. Minimizing Delay and Collision Avoidance:

The longer time it takes a packet to get to its destination might be viewed as a delay. The network reliability can occasionally suffer as a result of increased delay brought on by the network's high traffic volume [120]. By reducing the rate at which packets are received,

the delay has a direct impact on network performance. Some clustering techniques employ a variety of ways to reduce network delay and enhance network connectivity [121]. By decreasing packet retransmission, data loss, and other issues, it can improve QoS while lowering energy use and network overhead. The nodes in the cluster send their sensed data to their respective CH when using cluster-based protocols, the data should be delivered to the CH in a fashion that prevents data from various nodes from colliding with one another. Data loss may occur as a result of the data collision, and CH won't get any data from the nodes. The clustering protocols use a variety of scheduling algorithms to deal with data collisions that occur during data transport. Some methods use Time Division Multiple Access (TDMA) scheduling to control the data movement between cluster nodes, preventing data collisions [122]. The parameters for data packets stated below can all be enhanced by clustering techniques as shown in Table 8.

Table 8. Existing solutions to minimize network delay using the clustering technique.

Goal	Remarks	Ref.
Maximize reliability		[123]
Minimize data loss		[101]
Optimal number of packets delivered to Bs	Network lifetime improvement	[102, 124, 125]
	Data aggregation	[126]

8. Security:

Due to ad-hoc properties, numerous attack types, including hole assaults and DDoS, are possible [127]. To counter attacks and find rogue nodes, various strategies are developed, particularly for hole attacks, which are widespread in ad-hoc networks the clustering-based security measures in IoT networks [128]. Table 9 mentions the solutions for security objective.

Table 9. Existing solutions to achieve security using the clustering technique.

Existing solution	Ref.	Remarks
Distributed trust-based models	[129]	Offer a strategy for selecting CHs for WSN-based smart transportation systems that are based on trust (ITS). Based on neighbor count, trust value, and remaining energy, each CH is chosen. Each node is in charge of keeping an eye on what its neighbors are doing. Each member's reliability is assessed by CHs based on an analysis of assessments made by other members.
Highly dynamic IoT		IoT deployments' enormous scale and great dynamics may present new security concerns. Using decentralized trust-based models would've been difficult because, in applications like smart cities, unknown IoT devices can join the network, making it difficult for trusted nodes to thoroughly assess new nodes.
Resource-constrained IoT devices		Services for security Authentication and authorization are primarily the emphases of IoT. Providing authentication is a difficult process since supporting security resource-intensive authorization procedures. Clusters in distributed models may contain heterogeneous nodes, ensuring that they share the same local authentication and the CH and members would use authorization methods to be difficult due to the diversity of the nodes.

9. Multi-Sink Support:

Allowing many sinks is an excellent way to increase the end node's data routing possibilities, which will increase the network's efficiency. It can decrease delay while enhancing throughput, packet delivery, and fault tolerance. Despite the fact that multi-sink networks are more effective than single-sink networks, designing clustering approaches that can handle multi-sink networks is more difficult. Table 10 mentions the solutions to achieve Multi-Sink Support by using the clustering technique.

Table 10. Existing solutions to achieve multi-sink support using the clustering technique.

Existing solution	Ref.	Remarks
Multi-point to multi-point clustering-routing	[130]	The authors provide a technique to accommodate several mobile sinks. It makes use of CHs to keep the best routes with the fewest hops. Mobile sinks' most recent location.
Selecting the best sink (gateway)	[131]	The majority of multi-sink clustering algorithms concentrate on creating a routing scheme that determines the optimum path for data transmission across the network. Although several clustering algorithms take multi-sink networks into account, particularly when evaluating their efficiency, there aren't many strategies that have a dedicated solutions for multi-sink networks. Choosing the best sink depending on the expenses associated with transmitting data through the sink; choosing the optimal path from the node to the chosen sink, which is a difficult problem in the Internet of Things since nodes along a route could have varying network interface features such as (channel capacity and delay).

Topology management is one of the most difficult aspects of constructing computer networks, particularly ad-hoc networks, where the number of nodes is a lot and the network infrastructure is unreliable [132]. Determining possible neighbors to form connections and recognizing the best neighbors for hop-by-hop data transmission are two subjects that are critical to the enhancement of scalability, resource consumption, dependability, and other aspects of topology management approaches in ad-hoc networks. Clustering is a form of topology management strategy that groups nodes to increase network efficiency by managing resources and rotating tasks among nodes to ensure fairness.

There are several members in each cluster, each of which is managed by one or more CHs, which fuse, process, transport, and manage the data of the members. Finally, each network has one or more BSs that can act as gateways or data processing nodes locally [133]. BS(s) receive data from CHs either directly or indirectly through middleman nodes, which are nodes that connect the CH and the BS. The steps for establishing clusters and establishing connections between members and BS(s) are outlined below [134]. Clustering is divided into two phases: grouping nodes and assigning tasks. In a network, there are two ways to create clusters [135]:

- Identifying clusters by clustering nodes and choosing one or more nodes as the cluster's CH(s): Different parameters can be used to organize nodes.

- Identifying CHs and encouraging nodes to join a neighboring CH: This strategy is founded on factors like the separation between the CH and the BS, as well as the separation between the CH and the BS. The studies that were included in this survey are listed in Table 11.

Table 11. Routing protocols surveys.

Ref.	Focus	Conclusions	Advantages	Notes
[136]	To describe different hierarchical routing algorithms that try to choose an appropriate CH, and minimize the redundancy of transmitting data to conserve energy.	It gave a range of routing protocols to drastically cut communication latency and conserve energy.	The routing protocols covered, such as TEEN, APTEEN, SPEED, RAP, and RPAR, minimize latency and save energy through the use of distinct design methods.	The number of protocols covered by the study is few
[137, 138]	The four basic categories of routing protocols are data-centric, hierarchical, location-based, and multipath-based routing systems.	The extensibility and transmission efficiency of hierarchical routing protocols are good, however, additional study is required to increase the energy efficiency.	In these studies, the classification of sensor network routing protocols is developed, and the present level of IoT standards is updated. Additionally, a comparison of the described protocols for each class of algorithms is given, and a brief discussion of key technical issues.	
[139]	Combining standardization, flooding, and clustering approaches for route on-demand and segmenting the large network.	The distance between nodes can be calculated using gradient methods, hop counts, power distances, and Similarity distances.	This paper examines this paradigm change for routing in WSNs and, in contrast to earlier milestone surveys, organizes its information rather chronologically inside the established protocol classification.	
[140, 141]	It also describes several attacks on LEACH to demonstrate how clusters develop and how cluster heads are chosen.	It offers numerous suggestions on how to secure LEACH.	Many methods are used to secure the LEACH protocol.	There aren't many results in the paper. Only a few comparison parameters are used.

Table 11. Routing protocols surveys – Continued (1).

Ref.	Focus	Conclusions	Advantages	Notes
[44, 46]	To examine the WSN's sleep and wake-up timings and illustrate the issues with broadcast and multicast routing for duty-cycled WSNs.	Duty-cycle networks cannot be solved by integrating a tree-based network with duty cycles, even though this can reduce delay times and broadcast methods.	The study discussed basic issues about the existing routing protocols for duty-cycled WSNs, such as; Joint design of route selection and sleep schedules, Broadcast/multicast routing in duty-cycled WSNs, and Routing for multi-channel duty-cycled WSNs.	There needs to be more research done on routing for multi-channel duty-cycled WSNs.
[122]	To talk about the problems and restrictions that WSNs face, as well as the advantages and disadvantages of various methods and criteria for rating WSNs.	No one routing algorithm works in every scenario.	Comparison between routing protocols in different parameters, such as CH election, clustering type, and so on. Describe the advantages of each protocol in terms of improving the energy consumed and extending the life of the network.	When addressing the advantages of each protocol is not discussed QoS, and load balancing.
[68]	Investigates a few of the conventional and unusual protocols used in IoT applications for network routing.	The Internet and the applications where the six non-standard routing protocols are utilized are assessed.		Six types of routing protocols are studied in the survey lacks to mention the pros and cons of each protocol
[69]	Based on the latest advancements of IPv6, compatibility, interoperability, and configuration difficulties of the present and new protocols and schemes are explored.	Every networking technology that wants to be a part of this computing paradigm must upgrade. Security is a more important necessity.	Open networking difficulties with respect to their associated qualities are discussed, including security, scalability, mobility, and energy management.	The study dealt with the routing protocols and energy management in a simplified way.

Table 11. Routing protocols surveys – Continued (2).

Ref.	Focus	Conclusions	Advantages	Notes
[52]	The study investigates several routing techniques for the seamless item connectivity of the IoT.	Swarm intelligence is the most practical and successful method for solving the complex, multi-hop, and dynamic requirements of wireless networks.	Investigated are the numerous attributes, advantages, and challenges of the aforementioned methods. The underlying principle of the protocols is swarmed intelligence.	
[62]	The cutting-edge routing techniques of the Contiki OS. Classify the information available on the Contiki OS routing system, highlighting any open questions and unfinished business.	A summary of the routing protocols related to the Contiki OS was given, along with details on issues.	The goal of this research was to lay the framework for academics and business professionals who are eager to work on IoT routing protocols.	
[145]	Compare various RPL-based protocols concerning their energy consumption, dependability, scalability, safety, and security.	Even if many RPL modifications in the literature improve RPL's efficiency, this is especially true when it comes to concerns like traffic, mobility, and security.	The study illustrates that RPL can be utilized effectively in a variety of applications, that are not exclusive to those related to healthcare, smart environments, transportation, business, and military uses.	Packet delivery ratio, latency, and control traffic are three significant metrics that show how well the RPL protocol performs.
[146]	Several routing protocols are covered, routing strategies are reviewed	Various techniques, metrics, and the pros and cons of the current research field are examined to help guide future researchers.	The advantages and disadvantages of various routing protocols are all covered.	
[147]	Investigate the integration of WSN and MANET in the Internet of Things and consider a crucial question, namely how a converged (WSN-MANET) network maintains the QoS for rich multimedia applications.	It is a difficult task to build QoS-aware routing protocols for multimedia (application) WSN-MANET.	Analysis of QoS-aware routing protocols during the past ten years that was published in the IEEE Xplore Digital Library Database between 2010 and 2021.	None of the protocols that the review mentioned is better in MANET networks in terms of QoS.

4. PARADIGMS FOR CURRENT COMMUNICATION NETWORKS AND IOT CLUSTERING:

We have so far talked about how clustering can help with various IoT quality-related goals. Along these lines, clustering can be used to lower acceptance hurdles for new technologies integrated with IoT systems, especially when it comes to those resulting from networking problems. We concentrate on four cutting-edge computing and networking paradigms; Block chain, SDN, Fog/Edge, and 5G, that are quickly integrating with IoT. We begin by briefly describing each of them, particularly from the perspective of networking. Then, we discuss how clustering can be used to enhance several parts of such technology's designs.

4.1. 5G and IoT

Various cellular network generations currently cover at least 90% of the world's population such as previous 2G and 3G. Now, the Long Term Evolution (LTE) generation, the 3G generation, and the 4G generation all support IoT applications by implementing genuine overlay network infrastructures. To support IoT applications in the 4G network, several difficulties including capacity, data rate, end-to-end delay, huge design performance, communication overhead, and QoE must be solved. A new cellular generation network called 5G is intended to improve transmitting data effectiveness and solve LTE's issues. IoT is not directly targeted by 5G. Many different approaches to integrating IoT applications with 5G infrastructures have been put forth. Projects that result from the interaction of many associations create standards for cellular systems like 5G to create physical infrastructures that support applications with low latency, quality of service, energy efficiency, criteria etc. [148-151]. To increase the effectiveness of 5G, many technologies are emerging, and new standards are being published based on them. Despite the fact that there are numerous such technologies, few serve as the cornerstones of 5G. Despite not being a critical technology for 5G, Device 2 Device (D2D) is growing in importance to support 5G goals. D2D communication in 5G can facilitate the creation of new mobile applications and improve ones that already exist. D2D can be used, for instance, by social media apps and games to locate users nearby and transfer data between them. Wi-Fi direct is utilized today for direct data transmission in such applications [152].

The establishment of D2D 5G networks is required for additional applications kinds, including crisis management and natural disasters. When BSs are not available, a network with no infrastructure is. D2D can decrease latency, increase coverage, maximize energy consumption, and enhance QoS in the IoT. To increase the effectiveness of the network infrastructure, many applications like Vehicle to Vehicle (V2V) can employ a mix of D2D and Small Cells [153]. Combining D2D and Small Cell results in a network infrastructure that is similar to multi-gateway (i.e., multi-sink) WSNs from the standpoint of topology management. This topology must be controlled just like WSNs, achieved a variety of goals, such as energy consumption, dealing with bandwidth restrictions, and delay minimization. In 5G networks, clustering may be possible using these two techniques.

As far as we are aware, the article of [154] is the only article that examines the impact of clustering in IoT 5G scenarios. To enable energy efficiency, distributed systems, and hierarchical administration of the network architecture in 5G IoT networks, the authors

consider this. The authors looked at five issues: node heterogeneity, resource, and cost of transmission, user utility, and smart core network. To improve fairness and throughput, the authors in [155] adopt a clustering algorithm in D2D-assisted LTE-A networks for connection. We have five important issues, including resource scarcity and node heterogeneity. To manage traffic for the cellular systems, their solution uses CH in an opportunistically different way at each scheduling frame.

The author proposed user-centered coordinated multi-point cluster-based systems in 5G. By restricting inter cell collaboration to the cluster itself, clusters can lower the administrative burden associated with it. Additionally, they disperse cell traffic to nearby cells via the re-clustering technique. Another strategy that can be used to increase the effectiveness of spectrum usage is network densification [156].

In [157], the authors employ a clustering technique to implement green IoT in 5G networks and address the changeover issue. In [158], Song et al. employ a clustering technique based on the k-means algorithm to reduce network energy costs and maximize connected IoT devices in 5G small cells. A clustering algorithm based on enabling Massive MIMO in 5G is described in [159]. In [160], the author introduces a technique for supporting D2D using cluster forms in 5G cellular networks. According to the literature mentioned above, clustering increases 5G performance by administering nodes and resources directly in each cluster.

4.2. SDN and IoT

The primary idea behind Software-Defined Networking (SDN) is to separate the control plane from the data plane of data transfer [161]. In SDN, the data forwarding plane is separated for use by applications and network services, while the network intelligence (also known as the control function or the control plane) is centralized at one or more control entities (also known as SDN controllers).

4.3. Fog and Edge Computing and IoT

IoT systems, services, and data are moving to the Cloud due to the exponential growth of IoT devices and services. This allows for more robust processing and sharing of IoT data. Moreover, the cloud computing paradigm has lately been extended from the network's core to the edge—Fog Computing—in response to demands for features like mobility assistance, location awareness, and low latency. Fog nodes, which sit in between IoT devices and the cloud, can be organized in several ways, including hierarchical topologies. More effective data gathering, processing, and transfer to the Cloud may result from the more effective organization of fog devices [162].

Typically, computing takes place either immediately on a Sensor node or on a gateway that is situated adjacent to sensing and IoT devices. Fog computing brings edge computing processes to LAN-connected computer nodes or into the LAN infrastructure itself, allowing them to be physically dispersed from edge devices and further away from sensors and Internet of Things devices.

4.4. Blockchain and IoT

The core purpose of blockchain (BC) technology, which is particularly useful for cryptocurrencies, is to securely preserve transactions across a dispersed network. A decentralized network's security, dependability, and efficiency are all improved by using BC, a distributed database across nodes in the network, to store transactions. The BC's decentralization, dependability, and security are ensured using consensus algorithms [163]. In a Blockchain network, every node participates in processing, saving, and accessing transactions over P2P connections akin to those found in BitTorrent for the purpose of encrypting and decrypting communications to and from each node accordingly. To increase the privacy and effectiveness of IoT, clustering techniques can make it easier to integrate BC with IoT. To complete resource-intensive BC tasks, nodes can share their resources in a distributed management architecture using clustering techniques. Additionally, clustering nodes can assist BC in supplying more compact logical networks that can cooperate or share resources based on reliability. As a challenging task, mining should be carried out by several nodes, and clustering techniques can enable distributed execution of it. She et al. in [164] introduces a proposal for a BC trust model in 3D environments based on clustering and Block chain Networks to identify rogue nodes in WSNs. Contracts are published by BS, and CHs employ those contracts as verifying nodes while also giving cluster members identifying data based on digital certificates. The suggested approach uses pre-selected CHs to find malicious nodes. Based on clustering algorithms, the authors of [165] offer an IoT security layer to identify and separate malicious nodes. They regard CHIs as resource-rich nodes that maintain a copy of each node's firmware in addition to acting as miners. They believe that clusters are already readily accessible and that if the CH were corrupted, the cluster as a whole would be unreliable. They are using an authentication service that is a smart contract on CHs to authenticate nodes, all nodes in a trustworthy cluster should be able to approve other members for permission.

5. CLASSIFICATION OF CLUSTER-BASED PROTOCOLS

To give a general representation of how the clustering protocols work and perform, they are divided into various categories based on their methodology. Three types of clustering protocols are categorized in this study: traditional cluster-based protocols, fuzzy-based clustering protocols, and heuristic-based clustering protocols. Classification is done based on the methods the clustering protocols use to carry out the clustering processes. The clustering procedures are divided into many groups. Clustering protocols are divided into:

5.1. Traditional Cluster-Based Protocols

For the cluster creation, CH selection, and data transfer activities in this category of protocols, it does not consider any specific strategy or optimization techniques. Instead, probability-based techniques are used to perform clustering. The core clustering approaches are used for CH selection and cluster building in the typical classification of protocols, which also takes into account conventional clustering methods.

5.2. Fuzzy Logic-Based Clustering Protocols

Fuzzy logic-based procedures are used to address uncertainties in the clustering process, including those related to cluster development and CH appointment [166]. By considering a variety of input characteristics, it can handle the inherent uncertainties in the clustered network. The fuzzy model is composed of a fuzzifier, an inference framework, a rule base, and a defuzzifier [167]. The defuzzifier converts the clean input into linguistic variables. It derives a membership function for the inputs. These inputs are processed using the rule base by the inference system, which establishes a relationship between input and output. The defuzzifier converts the linguistic variable into the crisp value [168].

5.3. Heuristic-Based Clustering Protocols

The WSN clustering problem is regarded as an NP-hard problem and has a number of possible solutions. The heuristic technique attempts to produce the most advantageous answer within the given time restriction, even though it does not always produce the best solution [169, 170]. Heuristic approaches are employed to arrive at the clustering problem's best possible solutions [171]. The difficulties of CH appointment, cluster formation, routing, etc. are solved using heuristic strategies in clustering. Heuristic methods used by the numerous clustering protocols include genetic algorithms, ant colony optimization, particle swarm intelligence, etc. to carry out the clustering tasks [172]. Table 12 shows the research that discusses the issue of energy efficiency in the Internet of Things networks and hieratical-based cluster routing protocols.

Table 12. Energy enhancement technics in WSN for IoT applications.

Ref.	Strategies used for energy conservation in WSN	Network simulator	Advantages	Disadvantages
[173]	Using various parent selection techniques in GA.	Matlab	Enhancing reliability and the life time of the network.	No mobility consideration.
[174]	To extend network lifetime and optimize sensor node energy consumption, suggest an effective technique for cluster head selection using evolutionary algorithms.	Mathematical analyzed	Increasing network lifetime and reducing energy consumption by load balancing at the CH.	No practical test bed
[175]	Creates a novelizing hybrid optimization for cluster head selection mechanism to increase energy efficiency and network longevity	Matlab	Enhancement in lifetime network by using optimization techniques and improve energy efficiency.	Uses only Matlab simulations
[176]	The multi-objective genetic algorithm and the gravitational search algorithm have been combined to give a unique optimization strategy for clustering WSNs.	Matlab	Decrease energy consumption, Improve data delivery rate, and increase lifetime.	No load balancing consideration

Table 12. Enhancement technics energy in WSN for IoT applications – Continued (1).

Ref	Strategies used for energy conservation in WSN	Network simulator	Advantages	Disadvantages
[177]	This approach is also tested on a heterogeneous wireless sensor network using the Diversity-Driven Multi-Parent Evolutionary Algorithm optimization issue of cluster head selection.	Matlab	Increases the network's dependability and stability over time	Does not take the base station change position as a metric
[178]	In comparison to existing protocols, the μGA-LEACH approach is stronger in terms of cluster head (CH) selection and uses less energy overall.	Matlab	High Improvement in Energy consumption and network lifetime	Does not take the base station change position as a metric
[179]	Provides a clustering technique using particle swarm optimization with linearly decreasing inertia weight, and enhanced weight factor.	Matlab	Different number nodes, different position base stations, and many scenarios have implemented.	No mobility consideration.
[180]	The Type-2 Fuzzy Logic-based Particle Swarm Optimization (T2FL-PSO) algorithm is suggested as a method for choosing the best CH to increase network longevity.	Matlab	Enhances the performance of the network as a whole, that is, the network packet transmission ratio, more stability and, lifetime.	Does not take the size of monitoring area change as a metric
[181]	With the help of the fruit fly optimization method, the suggested work promotes load balancing and energy-efficient data transmission (FFOA). The strategy selects the best cluster head for each cluster using the LEACH protocol and differential evolution (DE). The program is made to offer data transmissions that use a minimum amount of energy and is based on how fruit flies locate food using their senses of smell and sight.	NS2	Using multi-hop routing, improve packet delivery ratio, high residual energy	The improvement in results is minimal compared to pre-existing protocols
[182]	LEACH protocol turns the sensor nodes into CH, then collects and transfers data to the target node in a compact form. Utilizing its fitness function, the genetic algorithm aids in locating the best path.	Matlab	Enhancement the quality of service, improve in the throughput, Packet delivery ratio, reduced transmission delay, and load balancing	No mobile consideration and no data fusion consideration

Table 12. Enhancement technics energy in WSN for IoT applications – Continued (2).

Ref	Strategies used for energy conservation in WSN	Network simulator	Advantages	Disadvantages
[183]	Outlines a real-time routing technique that integrates clustering and location data. It is decided to mix cluster head elections with variable forwarding transmission rate changes.	Matlab	Uniform energy consumer, load balancing, enhancing reliability, and improved real-time performance.	No algorithm to avoid redundancy and no data fusion consideration
[38]	By analyzing the benefits of the Grenade Burst and Cauchy operators, a more effective artificial bee colony optimization-based clustering method that ensures the best clustering mechanism and cluster head selection is proposed.	NS2.34	Improved energy efficiency, delay, throughput, and delay.	No balancing in the number of nodes in each cluster.
[39]	The suggested method uses a K-Mean methodology to cluster data depending on network density. A Whale Optimization Algorithm (WOA) is additionally used.	Matlab	Extending the lifespan of the network by about 300 communication rounds, while also reducing energy use and improving reliability and stability.	The network complexity is not considered in the proposed protocol
[184]	Describe a clustering strategy that resolves the clustering issue in WSNs by selecting cluster heads using an enhanced artificial bee colony (ABC) algorithm. In order to find the most effective clustering method, the augmented ABC algorithm is used to improve fuzzy C-means clustering during the network beginning phase, when all nodes have the same energy level.	Matlab	Increase Network lifetime, Network stability, throughput, remaining energy for the network, and different scenarios with changes in the number of nodes, base station position, and area field.	Does not support mobile networks
[185]	The suggested approach is based on the PSO and Tabu search algorithms.	Matlab	Increase the number of clusters created, the percentage of nodes that are alive, and show a decrease in average packet loss rate and average end-to-end delay, all of which demonstrate the effectiveness of the proposed Tabu PSO.	Not achieves load balancing, and does not support mobile nodes.

Table 12. Enhancement technics energy in WSN for IoT applications – Continued (3).

Ref	Strategies used for energy conservation in WSN	Network simulator	Advantages	Disadvantages
[186]	Presents an energy-balanced clustering and Artificial Bee Colony-based Data Gathering Optimization technique on Multiple Mobile Sinks.	Matlab	Reduce records transmission, preserve energy, improve the performance and reliability of community records collection, extend the life of the community in comparison to different algorithms increased data collection, and decreased total energy consumption.	No algorithm to avoid redundancy and no data fusion consideration
[187]	Emphasis on a cluster head election method that is efficient and rotates the cluster's location among nodes with higher energy levels than others.	Matlab	By limiting the network's energy consumption, the lifetime of the network can be increased, high throughput, and support homogenous IoT networks	Not achieves load balancing, and does not support mobile nodes.
[188]	An improved Artificial Bee Colony (ABC) method for CH selection. Based on intra-cluster distance, distance from the base station, and residual energy, this ABC optimization is performed	Matlab	Using many metrics Different number nodes, different position base stations, and many scenarios have been implemented. Minimizes the energy consumption, and Maximizes lifetime of WSN.	Does not use the number of nodes and the number of clusters in the networks as a parameters to find optimum CH.
[189]	The method has been suggested to choose cluster heads based genetic Algorithm (GA) and Differential Evolution (DE).	Matlab	Increase network lifetime, Increase residual energy, minimizes transmission failure, lower fitness convergence, and more stability in the network.	Does not support mobile networks
[190]	Optimizes the LEACH protocol utilizing the ant colony algorithm (AC) and the particle swarm algorithm to reduce the energy consumption of WSN data transmission and improve data transmission routing (PSO).	Mathematical Simulation Model and Experimental Environment	Improved in performance AI-LEACH routing protocol, and balancing between the data transmission and network energy consumption.	The results of practical experiment are few.

Table 12. Enhancement technics energy in WSN for IoT applications – Continued (4).

Ref	Strategies used for energy conservation in WSN	Network simulator	Advantages	Disadvantages
[191]	The wireless sensors network is connected together using fuzzy clustering, and the initial value of the cluster heads is estimated using the particle swarm optimization technique (PSO).	NS2	Improve energy consumption, packet delivery ratio and network throughput maximum longevity of the network.	Does not achieve load balancing, and not support heterogeneous WSNs
[192]	By using employee bee agents for investigation, the stagnation in the intensification process of ACO is tried to prevent, and similarly. ABC is resolved by dividing the exploitation process into two levels by incorporating the employee bee phase for the primary level of exploitation.	Matlab	Matlab simulation, Practical experiments. Improve in residual energy, and throughput.	Few improvements in results compared to previous protocols.
[193]	The fitness function and particle-encoding scheme used in the algorithm's development are effective. Several factors take into account for the proposed PSO approach's energy efficiency.	Matlab	Increasing the amount of energy residual in all nodes, improve the network lifetime, and the number of data packets received by the base station	Does not achieve load balancing, and not support heterogeneous WSNs
[194]	Sensor nodes must communicate huge amounts of data, easily creating packets, which can cause the sink to prematurely exhaust. Mobile wireless sensor networks were created to alleviate the energy consumption constraint that has been discovered. The suggested data collection system for mobile sinks is based on an artificial bee colony.	Matlab	Enhancement data collection, choose the optimum path for the mobile sink, increase network lifetime and improve the reliability of the network.	There is no mechanism to compress the data or avoid duplication before it is collected by the mobile sink.
[195]	The GADA-LEACH proposed technique uses an evolving genetic algorithm to enhance CH selection in the established LEACH routing protocol in the wireless sensor network.	Matlab	Different scenarios to find results with changing in number of nodes and initial energy per node, improve in network life time	Not achieves load balancing, does not support mobile nodes, and does not take resuiel energy in fitness function computation.

Table 12. Enhancement technics energy in WSN for IoT applications – Continued (5).

Ref	Strategies used for energy conservation in WSN	Network simulator	Advantages	Disadvantages
[196]	The Energy efficient Clustering Hierarchy (GAECH) algorithm, a new clustering technique that uses a novel fitness function to boost FND, HND, and LND, is proposed. The fitness function in GAECH creates well-balanced clusters when taking into account a cluster's primary characteristics, which again lengthens the network's lifetime and stability period.	Matlab	Less energy consumption, with each cluster's energy load well balanced.	Does not take residual energy in fitness function computation. All scenarios do not take into account the change in the number of nodes.
[197]	Provides a cluster head election strategy based on a genetic algorithm for centralized clustering algorithms that has superior load balancing to the conventional clustering algorithm.	Matlab	Increase in network lifetime, load balance is better. Taking the distance and energy remaining at each node into consideration when calculating the fit-ness function.	The type of simulator used to obtain the results was not mentioned The proposed model is not well explained and the results shown are few
[198]	Provides a strategy for maintaining energy efficiency in WSNs that uses Multi-Objective Based Clustering and Sailfish Optimizer (SFO) guided routing.	Matlab	compared to other existing protocols, improve in energy consumption, packet delivery ratio, and throughput, and increase in network lifetime.	
[200]	Using an upgraded Artificial Bee Colony (ABC) algorithm, it chooses the cluster head and optimizes fuzzy C-means clustering to discover the best clustering technique Energy, density, location for the network cluster head, and other corresponding characteristics are integrated into the efficient upgraded ABC method.	Matlab	Enhancement in energy consumption, improvement in balancing, improve energy efficiency, extended network life, increase network stability period and network throughput.	Does not support mobile nodes.

6. CONCLUSIONS

The most common topology technique, particularly in WSNs, is clustering. Even though IoT networks have specific features that make clustering difficult, such as

heterogeneity and mobility, several established methodologies for WSN clustering may be applicable to IoT networks. The study on a wireless sensor network protocol based on hierarchical clusters that consume less energy has been evaluated and summarized in this paper concerning the required power. Most existing hierarchical protocols focus on improving the network lifetime and resource use, particularly when it comes to vital resources like battery power. Researchers have already conducted numerous experiments that demonstrate how effectively clustering boosts the stability and longevity of wireless sensor networks. However, it also causes an imbalance in the nodes' energy consumption. The energy constraint of a node is quite important when designing any protocol for WSN. In this study, we evaluated the applicability of existing WSN clustering approaches to IoT networks and thoroughly reviewed them. The survey is based on each of the common clustering goals (such as load balancing and decreasing energy consumption), as well as the network characteristics affecting the effectiveness of IoT clustering (e.g., mobility). The classification of the well-known clustering research demonstrates that clustering cannot only fulfill various other performance objectives in addition to its primary goal of reducing energy usage. This paper also demonstrated that, despite the difficulty of clustering ad hoc IoT networks due to their high dynamicity and heterogeneity, existing clustering approaches can help to better satisfy their quality-related criteria. These needs include QoS and fault tolerance. Each protocol mentioned in this paper has individual advantages and disadvantages. In order to balance energy conservation among sensor nodes, various multi-hop-based data transmission techniques have been taken into account. In addition, we analyzed current clustering-based methods and concentrated on contemporary networking and computing concepts that are connected with IoT (such as Blockchain, SDN, NFV, Fog/Edge, and 5G). Our extensive study demonstrates that clustering can significantly help in the better management of scalability-related design issues in these computing fields, from dynamic systems to service management and resource management.

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