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A comprehensive and systematic review of the load balancing mechanisms in the Internet of Things

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Abstract

The Internet of Things (IoT) is a network of different objects that refers to an environment in which intelligent devices around us can connect to the Internet and exchange information together. A large number of generated events from IoT objects causes overhead on the network. Therefore, to optimize the usage of IoT network, it is essential to provide solutions for network problems including scalability, routing, reliability, security, energy conservation, network lifetime, congestion, heterogeneity, and quality of service (QoS). In this regard, load balancing as an efficient method takes a significant role in distributing loads among different routes. Imbalance traffic load across the network causes high latency in some routes and loss of data packets and decreases packet delivery ratio. Although load balancing has a critical importance in the IoT, there is still a lack of an organized and comprehensive review about analyzing and examining its remarkable methods. Therefore, this paper by adopting a systematic manner aims to address this gap. In this research, the load balancing methods are categorized into two main categories including centralized and distributed and their merits and demerits are specified. Moreover, vital parameters, the challenges, and open issues in this scope are also discussed. Thus, future authors will be able to develop more effective load balancing mechanisms.

Keywords Internet of Things · Load balancing · IoT · Systematic review · SLR · Survey

1 Introduction

Recently, the Internet of Things (IoT) has become a significant research subject that provides possibilities to communicate among a variety of objects without any human interference [1, 2]. The IoT transforms physical objects into intelligent objects by using the enabling technologies like Internet protocols [3], Wireless Sensor Networks (WSN) [4], pervasive and ubiquitous computing [5], applications [6], and communication technologies [7]. Aggregating [8], composition [9, 10], processing [11], analyzing [12], and mining [13] of data are essential methods for extracting valuable information for enabling ubiquitous and intelligent services. Recently, the IoT concept is extended and evolved to many others fields like the Internet of Every Things (IoET), Internet of Vehicle Things (IoVT), Internet of Social Things (IoST), and Fog of Everything (FoE) [14]. These innovative concepts can help to identify the underline technologies, communication protocols, and data privacy to be used for any particular aim in an IoT environment. One of the most critical challenges of the IoT is the bottleneck (or heavy traffic) on a particular area or some data paths. It is because during the exploitation of IoT scenarios a large number of events are generated by IoT devices over a while [15, 16].

Load balancing is an efficient method to balance the workload and extend the lifetime of objects in the design of IoT [17]. Local information of the network is used to apply a load balancing technique in which data traffic among multiple paths is distributed [18]. Generally, an efficient load balancing technique improves the performance of large-scale computing applications and systems; also it prevents overload [19]. Optimizing consumption of the

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server-side resources [20], minimizing the request processing time [21], and improving the scalability [22] of the distributed system are the other aims of the load balancing technique.

Load balancing plays a fundamental role in IoT, but there is not any systematic work available in case of collecting and evaluating the chosen techniques. Hence, the main aim of this study is thoroughly reviewing the load balancing methods in the IoT. In this regard, the existing mechanisms are identified, collected, classified, and analyzed in a systematic manner. The aims of this research are in the following:

- Discussing the challenges of the load balancing methods in the IoT.
- Presenting a detailed assessment and classification of the examined methods, as well as emphasizing their main characteristics.
- Specifying critical areas for evolving load balancing methods in upcoming research.

The remaining of this study is organized in this way. Section 2 presents the background of IoT, load balancing and related surveys. The research methodology is clarified in Sect. 3. Also, Sect. 4 describes the selected load balancing methods in two categories. Section 5 shows the results and comparison of techniques. Section 6 outlines the open issues. Finally, Sect. 7 concludes this research.

2 Background

In this section, the common description of IoT and load balancing are defined. First, an overview of the concept of IoT is presented. Then, the layered architecture of the IoT is described. In the following, the main idea of load balancing in IoT is defined.

2.1 The common description of IoT

In 1999, Kevin Ashton introduced the concept of IoT in the context of supply chain management for the first time [23]. Nevertheless, nowadays, the definition of IoT comprehensively covers broad application fields such as transport [24], utilities [25], healthcare [26, 27], smart cities [28], and monitoring [29, 30]. In addition, it can be adopted effectively in various cases. For instance, IoT can enable the gathering of valuable data by leveraging sensor devices [31], and as another illustration, it can be claimed that IoT devices can be utilized as the efficient common agents for transmitting data [32], and so other examples. Nevertheless, IoT devices discussed in the above-mentioned work have some restrictions in the range of transmitting, processing, battery energy, and memory terms [33]. Evolving the technology leads to changing the definition of "Things" though the key goal of IoT which intends to assemble a computer sense information free from human involvement does not change [34]. The IoT provides the possibility of connecting anyplace, anytime, with anyone, any services, and anything [3, 35]. The description mentioned above is indicated in the International Telecommunication Union (ITU) vision of IoT as well [36]. Being able to hold an enormous number of nodes and the capability of working in the IP-based networks, IoT is applicable to various scopes [37, 38]. In the IoT environment, in order to attain a goal, all involved nodes can communicate and cooperate with each other [39]. The IoT critically needs an architecture with flexible layers which enables it to interconnect an enormous number of heterogeneous objects via the Internet [40]. Although the number of proposed architectures for IoT booms day by day, none of them has the capability to be introduced as a reference model [41]. The principal model of IoT architecture has three layers [42, 43] including application, network, and perception layers respectively. Meanwhile, researchers by adding extra abstraction to the architecture of IoT have suggested some other models recently [37]. Two common architectures of IoT are illustrated in Fig. 1. The 5-layer model utilized by some research like [44–46] is similar to the TCP/IP layers. Objects or perception layer is the first layer of the 5-layer architecture model which refers to the IoT devices and physical sensors that is responsible for collecting and processing information [47]. Wireless Fidelity (Wi-Fi), Third Generation (3G) of wireless mobile telecommunications technology, Global System for Mobile communications (GSM), Universal Mobile Telecommunications System (UMTS), Radio Frequency Identification (RFID), and infrared are some of the important technologies for transferring the created data in the object layer to the above layer [48]. Object abstraction is responsible for transferring produced data from the previous layer (objects) to the next layer (management of services) via secure

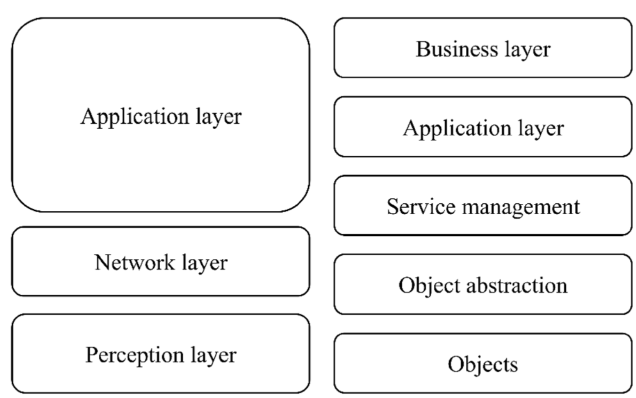


Fig. 1 The IoT architecture: three-layer and five-layer models

channels [49]. This layer provides a common way to address different objects. Service management layer has been known as a pairing (middleware) layer which is in charge of pairing service with the requester using names and addresses. It provides the possibility of working with heterogeneous objects platform-independently for the programmers of the IoT applications [50]. The application layer is in charge of providing the requested services by users [51]. Business layer aims at designing a business model, flowcharts, graphs and so forth respects to the data has been given by the application layer. In other words, it manages the services and activities of the IoT system thoroughly [52].

2.2 Load balancing in the IoT

Load balancing is one of the essential techniques in distributed systems which intends to allocate proper resources to tasks for optimizing the use of resources [53]. The role of the load balancing issue in distributed computing is correlated with the number of physical objects employed for exchanging data [54]. Vehicles, devices, and buildings are the most common objects in IoT that different sensors are embedded into them [55]. In distributed computing, the technology of load balancing is usually adopted to evolve the effectiveness of the whole network [56]. Load balancing distributes the load among the same type of numerous resources. It is capable of being implemented in physical devices or software [19]. Load balancing can be classified into various methods such as dynamic, static or a combination of them [57]. In another point of view, there can be centralized and distributed methods [22].

An efficient and proper load balancing can lead to reducing the response time, the number of involved resources, packet loss ratio, overload and so on. Moreover, it can increase scalability, reliability, packet delivery ratio, network lifetime as well [58, 59]. Aiming to identify the better mechanism for load balancing problem and to distinguish its pros and cons, the load balancing mechanisms should be evaluated and compared to each other. Thus, several factors are needed to assess a load balancing mechanism by them. These factors are known as the qualitative parameters [18]. Different papers adopt different qualitative parameters like latency, energy consumption, packet delivery ratio, scalability, and so forth [60–62].

2.3 Related surveys

A survey work of the load balancing methods in the WSN has been offered by Wajgi and Thakur [63] in which the selected techniques have been studied based on energy requirements. They have focused on several issues such as heterogeneous network, cluster properties, and mobility. Also, the advantages, disadvantages and main features of each method are explained. Moreover, suggestions for further studies are offered. However, the paper has been written in a non-systematic way, and it is only surveyed cluster-based methods.

A study in order to review the load balancing techniques in the distributed systems has been proposed by Raghava and Singh [64]. They have discussed methods in two groups including static and dynamic. Also, the selected techniques have been compared whit regards to some important factors such as reliability, stability, response time, and complexity. Furthermore, the advantages and weaknesses of each method have been presented. However, the paper selection method is unclear, and future works are not checked.

Sreenivas et al. [65] have surveyed the load balancing methods in cloud computing. Some parameters such as performance, scalability, and overhead are considered to investigate the techniques. Also, some load balancing challenging problems in cloud environments are explained. However, this study does not specify the weaknesses of each technique.

Also, Milani and Navimipour [19] have examined the popular load balancing methods in cloud environments. They have classified and discussed the methods in two categories including dynamic and hybrid methods. Also, the weaknesses and advantages of each technique have been specified. Furthermore, a side by side analysis of the discussed methods regarding some parameters like response time, makespan, migration time, scalability, resource utilization, and throughput has presented. Finally, some suggestions for future work are provided. However, static load balancing techniques are ignored.

Kaur et al. [66] have surveyed the scheduling and load balancing techniques in the cloud environment. In their study, essential parameters such as CPU utilization, cost, energy consumption, and SLA Violations have been considered to analyze the existing methods. The advantages and weaknesses of each method and future works in this field have not been checked. Furthermore, the paper selection method is unclear.

Moreover, a review of load balancing techniques in Low Power and Lossy (RPL) networks has been offered by Sebastian and Sivagurunathan [67]. In this study, some challenges such as instability of the network, hot spot and bottleneck problems, packet delivery ratio, network load, and thundering herd problem are considered to investigate the selected techniques. Also, this study provides recommendations for future work, but few papers without any classification have been studied.

Load balancing methods in the Software Defined Networks (SDN) have been surveyed by Neghabi et al. [18] in which the methods are classified into two core classes comprising deterministic and non-deterministic methods. The used scheme, advantages and weaknesses of each technique are specified. Additionally, the discussed techniques are compared based on some parameters such as the percentage of matched deadline flow, overhead, response time, packet loss ratio, energy consumption, utilization, latency, peak load ratio, root mean squared error, throughput, migration cost, overload ratio, and execution time. Notwithstanding the high quality of the paper, the published articles in 2018 have not been investigated in this research.

Ahmad and Khan [68] have offered a systematic study of current techniques and tools for load balancing in cloud computing. In this regard, some important metrics such as throughput, scalability, fault tolerance, and reaction time are considered to assess methods and comparing them with each other. However, this paper has ignored the published articles between 2016 and 2018.

Finally, a review work of load balancing algorithms in cloud environment has been proposed (Hota et al. [69] in which the algorithms have been discussed in three different classes such as metaheuristic, heuristic, and hybrid with regards to the type of adopted algorithm. The benefits, limitations and optimization measures of each algorithm have been presented. However, the recently published papers have been ignored.

Table 1 presented a summary of the studied surveys in which the parameters such as review type, publication year, paper selection process, classification, main topic, future work, and covered years of each study are depicted. It is clear that just two papers have used the SLR method for study the load balancing methods and also just one paper has been done in the field of IoT. Therefore, our paper is the first study that reviews the load balancing methods in the IoT using SLR method. Briefly, the drawbacks of most of the preceding surveys are as follows:

- Most of the articles are about load balancing in cloud computing.
- The methods are reviewed without any classification.
- Some articles have not presented hints for future work.
- The method of paper selection for review is not clear.
- Most of them do not include recently published papers.

3 Research methodology

This paper follows the Systematic Literature Review (SLR) strategy of collecting and classifying the articles of the load balancing in the IoT and investigating them. The SLR is a method of finding, assessing, interpreting, and synthesizing the available studies relevant to a specific research topic area and reporting the findings [70]. In this regard, to conduct the search process, Google Scholar[1] is selected as the main search engine, and the following search strings are used to find relevant articles.

("IoT" OR "Internet of Things") AND ("load balancing" OR "load balanced" OR "workload balanced" OR "workload balancing")

Also, to achieve the main objective of this study, five key questions are considered as follows:

- *RQ1* What is the significance of load balancing in the IoT?
- *RQ2* What are the challenging problems in load balancing in the IoT?
- *RQ3* Which parameters are vital to assess the load balancing techniques?
- *RQ4* Which of the popular simulation tools are applied for load balancing in IoT?
- *RQ5* Which issues in the load balancing area in the IoT remain unaddressed?

The search is accomplished in September 2018, without a specific time limitation and based on the article title. As a result, 35 articles are found which are specified in Fig. 2. The taxonomy of the papers by various publishers is demonstrated in Fig. 3. Besides, Fig. 4 shows the distribution of the papers in each publisher over time. As shown in Fig. 5, 64% of the articles belongs to journal articles, 26% of the papers are conference articles, 5% are related to the thesis, and 5% of the articles are working reports. Then in order to choose high-quality publications and articles, all other types of studies are ignored, including survey studies, reports, working articles, and non-English articles. So, 13 articles are removed from the initial search result. Finally, in order to further analysis, 19 proper articles, which have directly focused on load balancing in the IoT and improved some of the desired parameters, are selected. The dispersion of the chosen studies by their publication year is shown in Fig. 6. The number of published articles in each publisher is specified in Fig. 7. Also, an outline of the article selection process is depicted in Fig. 8. Finally, the detail information about the selected articles are represented in Table 2.

4 Load balancing techniques in IoT

This section discusses the selected load balancing techniques in the IoT which are classified into two main classes including distributed and centralized. The selected techniques are compared with each other considering some important qualitative parameters such as fault tolerant, energy consumption, heterogeneity, latency, overhead,

[1] www.scholar.google.com.

Table 1 Related surveys in the field of load balancing

Research	Review type	Publication year	Paper selection process	Classification	Main topic	Future work	Covered years
[63]	Survey	2012	Not clear	No	Cloud	Presented	2003–2011
[64]	Survey	2012	Not clear	Yes	Distributed systems	Not presented	2000–2011
[65]	Survey	2014	Clear	Yes	Cloud	Presented	2010–2012
[19]	SLR	2016	Clear	Yes	Cloud	Presented	2010–2015
[66]	Survey	2017	Not clear	Yes	Cloud	Not presented	2010–2015
[67]	Survey	2018	Not clear	No	IoT	Presented	2012–2018
[18]	SLR	2018	Clear	Yes	SDN	Presented	2013–2017
[68]	Survey	2019	Not clear	Yes	Cloud	Presented	2008–2016
Our study	SLR	–	Clear	Yes	IoT	Presented	2009–2019

packet delivery ratio, packet loss ratio, network lifetime, reliability, and scalability. Therefore, at first, a brief discussion of these parameters is provided.

- *Energy consumption* It is a critical issue in designing of IoT scenarios where objects are powered with limited energy resources. An efficient load balancing method can improve energy consumption [18].
- *Fault tolerant* Due to the possibility of occurring failure in any computing sites, it is considered as one of the vital factors in load balancing which may increase the implementation cost and response time exponentially [80].
- *Heterogeneity* It is one of the challenging problems in developing load balancing techniques. The objects of the IoT may be different from each other in terms of sensing range, computing power, and amount of energy [89].
- *Latency* The amount of taken time for the server to process a given request. It can be considered as both communications latency and computing latency [90].
- *Overhead* It is defined as the amount of overhead involved while applying a load balancing method [22].
- *Packet delivery ratio* It is described as the ratio of successfully received data packets to the entire principle packet produced by the objects [60].
- *Packet loss ratio* The transmitted data packet may be lost before it reaches the destination. The packet loss ratio indicates the percentage of data packets lost regarding data packets sent [91, 92].
- *Network lifetime* It specifies the time duration from the time when the method began until the energy of a % of the nodes is drained [93].
- *Reliability* It indicates that which method is more reliable in case if some host failure is occurred [94].
- *Scalability* This parameter determines how the system can perform load balancing method with a limited number of hosts or servers [95].

4.1 Centralized techniques

In the centralized techniques, there is a central control node that manages the compute load of nodes in the distributed system [79]. This central object stores the knowledge based on the entire network, and it can apply a static or dynamic method for load balancing [96]. These techniques can be utilized simply, managed easily, and repaired quickly in case of the failure [22]. First, some centralized techniques are discussed in the rest of this section. Then, the main advantages and weaknesses of each technique are summarized in Table 3.

Zhang et al. [85] have outlined a general framework for the Software-Defined-IoT (SD-IoT) which adopts a vertical control architecture and includes two key components including a basic control layer and main control layer. Moreover, they have designed an algorithm in the main control layer for choosing a controller as a leader to arrange and handle the main controllers, which contributes to balancing the load of the main controller. Furthermore, in the basic control layer, a dynamic load balancing algorithm according to the balanced delay has been suggested. This mechanism can decrease the latency and ensure the consistency of the messages between the main controllers. However, it suffers from high overhead.

A well-organized clustering algorithm is introduced by Al-Janabi and Al-Raweshidy [17] which has a full consideration of IoT load adjustment with the architecture of SDN. Aiming to analyze load balancing using Particle Swarm Optimization (PSO) [10, 97] clustering algorithm, a centralized SDN controller positioned over the cloud should adopt storage units and data centers as the cloud resources. This adoption is the initial idea of the proposed method. PSO is implemented by the SDN controller which regards some parameters such as communication cost, load balancing, and remained energy to provide a clustering table. In order to formulate cluster, some information like the members of the cluster and an optimal set of cluster

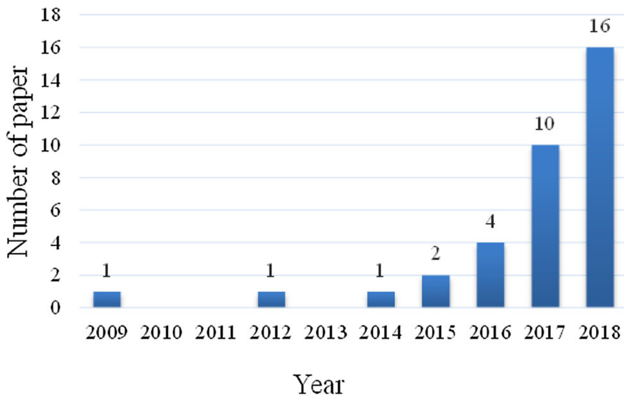


Fig. 2 Dispersion of the papers based on publication year

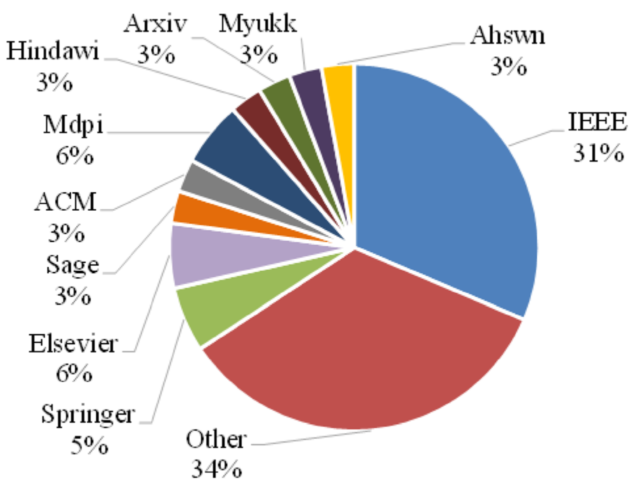


Fig. 3 Pie chart of published papers based on their publication

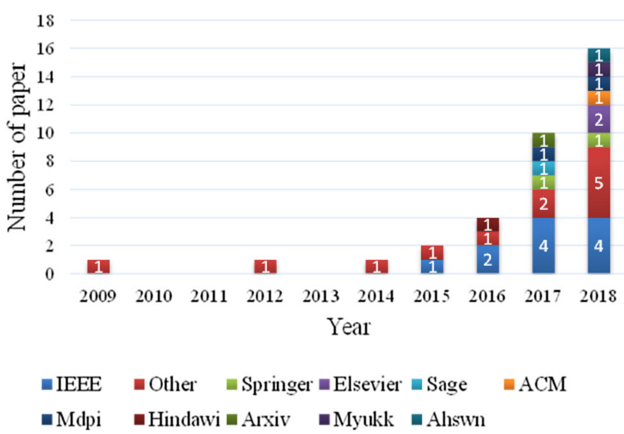


Fig. 4 Dispersion of the papers in each publication over time

heads are needed to be adopted. These data are stored in the clustering table. Although the proposed method is comparatively more effective in terms of flexibility, the volume of transmitted data to the sink, scalability, energy dissipation, and network lifetime, it does not take packet loss ratio and latency into consideration.

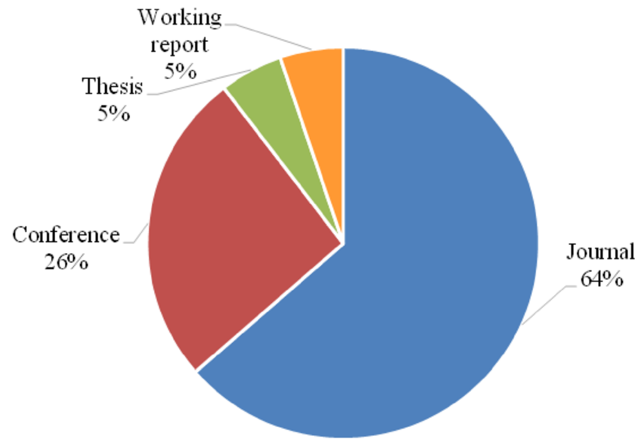


Fig. 5 Dispersion rate of published papers based on article type

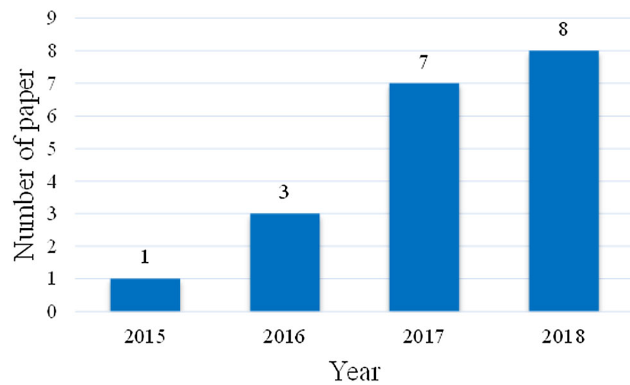


Fig. 6 Dispersion of the selected papers by publication year

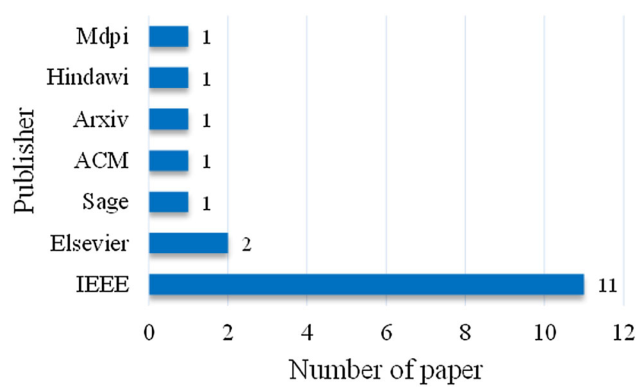


Fig. 7 The number of selected articles for each publication

Furthermore, Tsai and Moh [74] have examined the load balancing issue in Cloud Radio Access Network (CRAN). The proposed method aims to diminish the latency of IoT communications. Regarding real cellular network traffic features delivered by Nokia Research, authors in this paper investigate and assess eight real-world load balancing algorithms in CRAN field. The proposed method provides high performance, flexibility, and scalability which leads to enabling 5G to supply connectivity for a colossal number

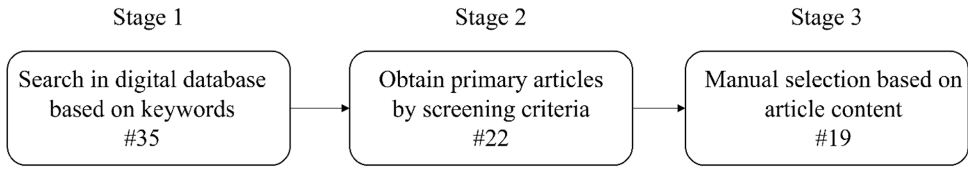


Fig. 8 The process of articles selection

Table 2 Information of the chosen studies

Publisher	Year	References	Conference/Journal name
IEEE	2015	[71]	International Symposium on Personal, Indoor, and Mobile Radio Communications
	2016	[72]	Intelligent Systems, Modelling, and Simulation
	2016	[73]	Internet of Things Journal
	2017	[74]	International Symposium on Signal Processing and Information Technology
	2017	[75]	Communications Workshops
	2017	[76]	Global Communications
	2017	[17]	International Symposium on Wireless Communication Systems
	2018	[77]	Network and Service Management
	2018	[78]	Transactions on Network Science and Engineering
	2018	[79]	Smart Internet of Things
	2018	[80]	IEEE Access
Elsevier	2018	[81]	Journal of Network and Computer Applications
	2018	[82]	Journal of Parallel and Distributed Computing
Sage	2017	[83]	Distributed Sensor Networks
ACM	2018	[84]	Mechatronic Systems and Robots
Arxiv	2017	[85]	Networking and Internet Architecture
Hindawi	2016	[86]	Sensors
Myukk	2018	[87]	Sensors and Materials
MDPI	2017	[88]	Applied Sciences

of IoT apparatuses expected for smart cities. Moreover, it can be utilized widely in other distributed systems. However, some vital parameters like packet loss ratio and overhead are not taken into account by this work.

As another work, the researchers in [81] by using simulated annealing algorithm [98–101] provided a service-oriented load balancing strategy based on SDN. The category and importance of demanded services by each end-device are taken into account by this research. Afterward, in an attempt to organize the transferal route in association with service function chains, this method utilizes the heuristic algorithm. Its goal is enhancing the performance of the whole network and reducing the load of each service function. The proposed method reduces the transmission time for data, provides low overhead, and accomplishes balancing of the load. However, it should be mentioned that this method must keep the balance between fixed-packets and non-fixed-packets to provide an efficient load balancing method. In other respects, the resources with the possibility of allocation will be decreased. Keeping this fact in mind that establishing a balance between fixed-packets and non-fixed-packets is not an easy process, this can be considered as a demerit of this research. Moreover, most of the vital factors of load balancing such as scalability, network lifetime, packet loss ratio, and so forth are not taken into consideration.

Moreover, regards to the Constrained Application Protocol (CoAP), Kwon et al. [87] have provided an architecture for Load Balanced Resource Directory (LB-RD). The proposed architecture utilizing a centralized resource discovery tactic in large-scale IoT local networks, to emphasize the issue of scalability. Exactly as a transitional agent, the LB-RD helps to establish the balance of traffic load between the resource directory and servers since the resource directory includes an enormous number of messages. With regards to the message loss rate and the number of lost messages, the proposed architecture outperforms the current RD methods. Although this method provides low overhead and high scalability, it does not take the network lifetime and latency into account.

Table 3 A comparison of the centralized techniques

References	Technique	Advantages	Disadvantages
[85]	Using vertical control architecture	• Decreased latency	• Suffers from high overhead
[17]	Using a clustering algorithm	• Increased scalability • Improved network lifetime • Increased packet delivery ratio • Considering heterogeneity • Decreased energy consumption	• Without considering latency and packet delivery ratio • The simulation environment in not mentioned
[74]	Providing a method for cloud radio access networks	• Decreased latency • Increased scalability • Increased reliability • Decreased energy consumption	• It ignores some of the important parameters such as packet loss ratio and overhead
[81]	Using a service-oriented strategy	• Decreased latency • Decreased overhead	• It does not evaluates packet loss ratio, scalability, and packet delivery ratio
[87]	Providing an architecture for the resource directory	• Decreased packet loss ratio • Decreased overhead • Increased scalability	• Without evaluating latency and network lifetime

4.2 Distributed techniques

In the distributed load balancing techniques, there is not any central control node responsible for monitoring the network and make accurate load balancing decision. Every node in the network can transfer the load to adjacent nodes with low loads [79]. In these techniques, the decisions of the nodes are made based on their own observed information about the system [102]. Also, each node can maintain a local knowledge base to guarantee the efficient distribution of loads in a static environment and re-distribution in a dynamic environment [96]. The distributed load balancing techniques in IoT are discussed in the following. Furthermore, Table 4 shows the most significant advantages and weaknesses of the discussed methods.

Yunlu et al. [71] have introduced a hybrid network based on Radio Frequency (RF) and Light Fidelity (Li-Fi) to provide appropriate services for customers. It should be mentioned that in an attempt to obtain a high rate for data, the vast amount of spectrum of visible light is adopted by Li-Fi and a seamless coverage is insured by the RF system. Regarding Evolutionary Game Theory (EGT) [103–105], authors have proposed a load balancing method for the Li-Fi/RF hybrid IoT network. The suggested algorithm allows customers to choose the access points and adjust their tactics autonomously. Hence, the adoption of the EGT algorithm may lead to mitigating the load of computation for the central unit in comparison with the conventional centralized algorithm. Since the offered technique provides the dynamic mechanism which enables the possibility of selecting access points by customers, they can be more satisfied with this method in comparison with the conventional centralized algorithms. Moreover, in comparison with the conventional centralized techniques, the suggested technique could mitigate the Central Unit (CU) computation complexity due to the fact that not only the CU also customers execute it. Besides, there is not any need for threshold optimization too. However, it suffers from low scalability and has two limitations including the need for a large number of iterations to reach a steady state and to allocate resources randomly. Therefore, the suggested method is not appropriate for real-time implementations.

As another work, Tseng [86] has proposed Multipath Load Balancing (MLB) routing to be adopted as an alternative to Zigbee's Ad Hoc On-Demand Distance Vector (AODV) routing. Although the heavy WSN data transmission traffic in mature IoT environments leads to bottleneck issues, there is not any load balancing strategy provided by Zigbee's AODV routing to tackle with that traffic. Conversely, adopting MLB provides the possibility of selecting the adjacent nodes with the minimum amount of load which results in coping with bottlenecks. The proposed method outperforms multipath version AODV and Zigbee's AODV in terms of packet loss rate, routing

Table 4 A comparison of the distributed techniques

Reference	Technique	Advantages	Disadvantages
[71]	Using light fidelity and radio frequency	• Increased packet delivery ratio • Decreased overhead	• Low scalability • The simulation environment is not mentioned
[86]	Developing a multipath load balancing routing	• Increased scalability • Increased packet delivery ratio • Decreased packet loss ratio • Increased fault tolerance • Increased reliability	• Without evaluating energy consumption
[72]	Providing a method for narrowband cellular IoT systems	• Increased packet delivery ratio • Decreased packet loss ratio • High throughput	• Increased energy consumption
[73]	Providing a method for IoT traffic over LTE	• Low packet loss ratio • Decreased overhead • Decreased latency • Decreased energy consumption • Increased scalability	• Without evaluating network lifetime and packet delivery ratio • The simulation environment is not mentioned
[75]	Using multi-technology and load balancer	• Increased reliability • Decreased overhead • Increased packet delivery ratio • Decreased latency • Considering heterogeneity	• Increased energy consumption
[88]	An energy-efficient adaptive scheduler	• Increased scalability • Decreased latency • Considering heterogeneity • Decreased energy consumption	• Without evaluating network lifetime and packet delivery ratio
[83]	A suitable technique for the IoT over satellite networks	• Decreased packet loss ratio • Decreased latency • Increased scalability • Decreased overhead	• Lack of proper algorithms for predicting the traffic suitable for IoT and satellite environments
[77]	Providing a traffic load balancing technique among brokers	• Increased packet delivery ratio • Decreased overhead • Decreased energy consumption • Decreased latency • Increased reliability	• The network aspects of QoS such as scalability and network lifetime are ignoring • The simulation environment is not mentioned

Table 4 (continued)

Reference	Technique	Advantages	Disadvantages
[76]	A method for IoT communications within the e-health environment	• Decreased energy consumption • Increased network lifetime • Decreased packet loss ratio • Increased reliability • Decreased latency	• Not very suitable for the big environment • Lack of evaluation of overhead
[80]	A method for RPL-based network	• Decreased energy consumption • Decreased overhead • Increased packet delivery ratio • Decreased packet loss ratio • Improved network lifetime	• Without considering fault tolerance
[84]	Providing an energy-aware technique using event rate	• Improved network lifetime • Decreased energy consumption	• Lack of investigating the scalability, overhead, and fault tolerance
[79]	Providing a method for the Internet of Battlefield Things	• Decreased overhead • Decreased latency • Increased reliability • Considering heterogeneity	• Lack of energy consumption evaluation
[82]	Fog-supported architecture	• Decreased latency • Increased scalability • Decreased energy consumption • Considering heterogeneity	• Without evaluating packet delivery ratio and packet loss ratio
[78]	Using fog computing network	• Increased scalability • Decreased latency • Increased packet delivery ratio	• The simulation environment is not mentioned • Lack of evaluating energy consumption and network lifetime

connectivity ratio in not only the grid but random uniform topologies. Although the proposed method supplies better load balancing and more acceptable routing solution for applications in IoT environment, it does not consider energy in its design.

Whenever an enormous number of objects attempt to access a base station at the same time, an overcrowding problem arises on the control channel in narrowband cellular IoT systems. Hence, the researchers in [72] have suggested a new load balancing method for a control channel in those kinds of systems. The proposed scheme has outlined proper configuration for allocating the dynamic channels, also stages for load balancing of the control channel that considers coverage class. Although the proposed scheme diminishes the number of transmissions for the random access procedure and enhances packet delivery ratio, it suffers from high battery consumption.

Also, Wang et al. [73] by adopting Discontinuous Reception (DRX) technique [106–108] offered a methodology for session management which is appropriate for IoT traffic over Long Term Evolution (LTE). The proposed methodology first analyzes the extreme effect of DRX parameters by Markov Chain. Then, an IoT-aware adaptive DRX algorithm at the client and an optimal uplink scheduler design are introduced. Both of them adjust the balance among delay, signal load, and power consumption. The authors supply an adaptive DRX algorithm at Evolved Node B (eNB) related to clustering with high-priority which provides high scalability. As a result, it has the possibility of scaling to various customers without causing high power consumption and high signal overhead. However, the proposed method suffers from high complexity. Moreover, some essential factors such as network lifetime, packet delivery ratio, etc. are ignored.

Kotagi et al. [75] aiming to enhance the throughput of IoT networks have provided an adaptive routing using multi-technology and load balancer. The proposed method adopts a Parallel Opportunistic Routing (POR). Besides, source gateways are enabled to choose the next hop for dynamic data routing according to the Load Factor Index (LFI) of its nearby gateways. Balancing the load among gateways is guaranteed by this routing strategy. The proposed method could enhance the packet delivery ratio, reliability as well as throughput; also, it could mitigate the overhead; nevertheless, it suffers from high energy consumption.

An energy-efficient adaptive scheduler for vehicular fog computing has been proposed by Naranjo et al. [88] in which the fog data center data streams requested by vehicular clients have been studied. Also, a holistic vehicular fog computing architecture has been offered that has focused on the fog data centers. The authors have formulated the problem analytically and resolved the suggested method over a simplified case study. This mechanism is scalable and reduces energy consumption. However, some essential factors such as network lifetime, packet delivery ratio, etc. have not been evaluated.

As another research, Liu et al. [83] by utilizing Dijkstra algorithm [109–111] suggested a new routing scheme for load balancing suitable for the IoT over satellite networks. In order to allocate the traffic flows of IoT in an optimal manner, authors have combined the global and local strategies. Moreover, they have adopted some features of Low Earth Orbit (LEO) satellite networks such as predictability and regularity for avoiding bottleneck by dispersing the load of traffic. In comparison to single-strategy schemes, the proposed algorithm can impressively mitigate the possibility of occurring the bottleneck, reduce the packet loss ratio, communication overhead, average queuing delay, and average end-to-end delay. Furthermore, it provides better performance in terms of traffic distribution and route oscillation. However, it suffers from the lack of proper algorithms for predicting the traffic suitable for IoT and satellite environments.

Aiming to balance the traffic loads among brokers, the average delay needs to be reduced. Thus, Sun and Ansari [77] have proposed a method which is responsible for re-cache or re-allocate the popular resources from the brokers with a heavy load into the brokers with a light load. The results indicate that the suggested method offers outstanding performance in terms of reliability, latency, overhead, energy consumption, and content delivery ratio. However, the lack of scalability and high network lifetime is still sensible.

Furthermore, Hamrioui and Lorenz [76] have proposed a new load balancing technique for IoT communications within e-health environment which tends to adjust the functioning of the transport layer to the features of IoT communications whenever adopted for the applications of e-health. Since the proposed algorithm takes the network changes, object factors and the situation of links into consideration, it is an adaptive and self-organized algorithm that is raised according to the combination of IoT communication factors in the process of flow control maintained by Transmission Control Protocol (TCP). The proposed algorithm by augmenting the reliability of data enhances the QoS of IoT communications. Moreover, it improves the energy saving and network lifetime and reduces packet loss ratio. Nevertheless, it does not take overhead, scalability, and fault tolerance into consideration.

Also, Taghizadeh et al. [80] by concentrating on network lifetime and packet loss have tried to cope with the problems of Routing Protocol for Low Power and Lossy Networks (RPL) under dynamic and heavy load. Since the traditional RPL is not able to tackle with the dynamic and heavy load, authors have proposed a load balancing protocol which is aware of context, named CLRPL. This protocol for choosing a parent for the current node, first, takes the status of a parent-chain into account, then, chooses the last parent of the chain to fulfill the purpose. As CLRPL prevents the imposing of many amounts of overload on the network, it can balance the network load and overcomes RPL remarkably. Although the proposed method has increased the network lifetime and decreased the packet loss ratio, overhead, and energy consumption, it has not considered fault tolerance which is one of the vital parameters in the load balancing issue. Occurring the failure can contribute to exponentially augmenting response time and the cost of implementation. Thus, handling it may lead to a successful load balancing strategy.

Furthermore, Santiago et al. [84] have proposed a method which adopts the Nested Un-weighted Pair Group Method with event rate (UPGM) [112, 113] to handle the energy-aware load balancing issue. The proposed method enhances both the lifetime of the devices and the lifetime of the parent nodes cum network. Hence, it can save a remarkable amount of energy. However, this research has ignored investigating scalability, overhead, and fault tolerance.

Wang et al. in [79] have provided a new architecture for combat cloud-fog network suitable for the Internet of

Battlefield Things (IoBT) using generalized diffusion algorithm [114, 115]. In an attempt to mitigate latency and boost reliability, the proposed architecture appends a layer of fog computing which supplies edge network apparatus adjacent to the customers in the "combat-cloud" network. However, there is an extreme need for implementing distributed computing in the proposed architecture due to the weak computing ability of the fog apparatus. Hence, in this paper authors have investigated the problem of the distributed computing load balancing in the fog computing layer. Although the proposed strategy could mitigate latency and overhead and enrich the stability and reliability, it did not take energy consumption into account.

A novel fog-supported smart city network architecture has been suggested by the authors in [82]. It is a multi-level architecture in which the applications are running on objects in the smart city environment. The objects include three types of communications, namely, primary, inter-primary, and secondary communication in order to handle applications while satisfies the QoS standards. The suggested architecture improves the efficiency of services and decreases latency and energy consumption. However, some important metrics such as packet loss ratio and packet delivery ratio have not been taken into account.

Finally, aiming at minimizing the average latency of data flows for IoT devices in the fog computing network, Fan and Ansari [78] have introduced the load balancing scheme. The proposed method by associating IoT tools to appropriate base stations or fog nodes regards not only the traffic load allocation but also computing load allocation. It results from this fact that the latency of a data flow comprises both computing latency and communication latency. In order to attain the optimal solution iteratively, a distributed algorithm is provided. The proposed method has presented an excellent performance in terms of optimality and the convergence. Moreover, it has provided good scalability, packet delivery ratio and low complexity, nevertheless it has ignored some vital factors such as network lifetime and energy consumption.

5 SLR findings

This section discusses and describes the obtained results in the previous section. The most popular load balancing techniques in IoT were reviewed in two categories including centralized techniques and distributed techniques. Table 5 summarizes the advantages and weaknesses of each technique. Also, Table 6 illustrates more metrics of each technique such as fitness function, simulation tool, the proposed method, article type, and data set.

5.1 Parameters observation

The selected techniques were analyzed and evaluated based on important parameters like energy consumption, fault tolerant, heterogeneity, latency, overhead, packet delivery ratio, packet loss ratio, network lifetime, reliability, and scalability. As shown in Fig. 9, researchers in their methods have high focus on improving some qualitative factors such as latency, overhead, and energy consumption. Also, it is obvious that some factors such as heterogeneity and fault tolerant have not been considered by most of the papers. Figure 10 shows the percentage of considered parameters in each category. In centralized techniques, 60% of the researchers have attempted to improve latency and scalability. Also, latency, overhead, and packet delivery ratio have the highest attention by the researchers in the distributed techniques.

In the centralized techniques, the load of each object in the distributed system is managed by applying a central control node, which causes a bottleneck in the central node. As a result, the reliability of the method is reduced. Although a centralized technique requires less time to analyze computation, it creates a significant overhead on the central node. Also, due to much failure possibility of the overloaded central node, these techniques do not have the proper and strong fault-tolerant capability. Furthermore, these techniques cannot be applied to dynamic and large-scale IoT networks, where global information cannot be attained in real time cases. On the other hand, distributed load balancing techniques offer better performance in case of scalability, network lifetime, and reliability. Since there is not any central node to make load balancing decision, desirable fault tolerance degree can be achieved. However, the objects in the distributed scheme may face relatively high computational costs which makes the load balancing processes difficult to control effectively and cause heavy loads on large systems.

5.2 Fitness function and proposed method observation

In this section, fitness function and the proposed method of all studied research have been observed. First, the proposed methods have been discussed in Sect. 5.2.1. Then, in Sect. 5.2.2 fitness functions have been investigated extensively.

5.2.1 Proposed method observation

Aiming to highlight the type of proposed methods, all of the examined papers are classified into two essential classes, heuristic-based and non-heuristic. In this regard,

Table 5 An outline of the discussed load balancing methods

Category	References	Qualitative parameters of IoT load balancing									
		Energy consumption	Fault-tolerant	Heterogeneity	Latency	Overhead	Packet delivery ratio	Packet loss ratio	Network lifetime	Reliability	Scalability
Centralized	[85]	–	–	–	↓	–	–	–	–	–	–
	[17]	↓	–	X	–	–	↑	–	↑	–	↑
	[74]	↓	–	–	↓	–	–	–	–	↑	↑
	[81]	–	–	–	↓	↓	–	–	–	–	–
	[87]	–	–	–	–	↓	–	↓	–	–	↑
Distributed	[71]	–	–	–	–	↓	↑	–	–	–	–
	[86]	–	↑	–	–	–	↑	↓	–	↑	↑
	[72]	–	–	–	–	–	↑	↓	–	–	–
	[73]	↓	–	–	↓	↓	–	↓	–	–	↑
	[75]	–	–	X	↓	↓	↑	–	–	↑	–
	[88]	↓	–	X	↓	–	–	–	–	–	↑
	[83]	–	–	–	↓	↓	–	↓	–	–	↑
	[77]	↓	–	–	↓	↓	↑	–	–	↑	–
	[76]	↓	–	–	↓	–	–	↓	↑	↑	–
	[80]	↓	–	–	–	↓	↑	↓	↑	–	–
	[84]	↓	–	–	–	–	–	–	↑	–	–
	[79]	–	–	X	↓	↓	–	–	–	↑	–
	[82]	↓	–	X	↓	–	–	–	–	–	↑
	[78]	–	–	–	↓	–	↑	–	–	–	↑

↑ = increased, ↓ = Decreased, and X = Supported

Table 6 Fitness functions, simulation tools, proposed methods and datasets which are adopted by each technique, and articles type

Category	References	Fitness function	Simulation tool	Proposed method explanation	Journal/conference	Dataset
Centralized	[85]	Not-clear	Mininet2.2	Non-heuristic	Journal	Not-mentioned
	[17]	Clear	Not-mentioned	Heuristic-based	Conference	Random
	[74]	Not-clear	CloudSim	Non-heuristic	Conference	Random
	[81]	Clear	C#	Heuristic-based	Journal-Q1	Random
	[87]	Not-clear	Matlab	Non-heuristic	Journal-Q3	Random
Distributed	[71]	Clear	Not-mentioned	Non-heuristic	Conference	Not-mentioned
	[86]	Clear	Ns2	Non-heuristic	Journal-Q2	Generated
	[72]	Clear	C	Non-heuristic	Conference	Generated
	[73]	Clear	Not-mentioned	Non-heuristic	Journal-Q1	Not-mentioned
	[75]	Clear	Java	Non-heuristic	Conference	Random
	[88]	Clear	Not-mentioned	Non-heuristic	Journal-Q2	Real dataset
	[83]	Clear	Ns2	Non-heuristic	Journal-Q2	Random
	[77]	Clear	Not-mentioned	Non-heuristic	Journal-Q1	Generated
	[76]	Clear	OMNET++	Non-heuristic	Conference	Generated
	[80]	Clear	Cooja	Non-heuristic	Journal-Q1	Generated
	[84]	Clear	Cooja	Non-heuristic	Conference	Generated
	[79]	Clear	Matlab	Non-heuristic	Conference	Generated
	[82]	Clear	iFogSim	Non-heuristic	Journal-Q1	Real dataset
	[78]	Clear	Not-mentioned	Non-heuristic	Journal-Q1	Random

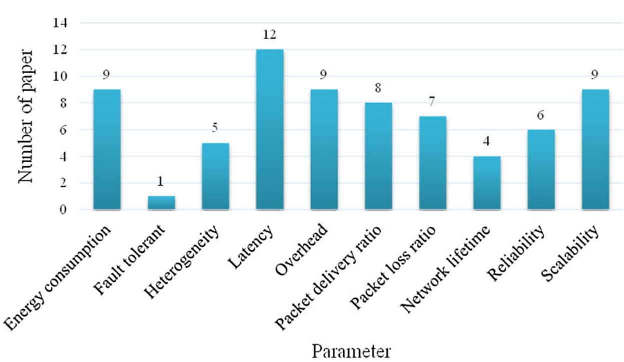


Fig. 9 Considered parameters in the discussed techniques

Fig. 11 specifies that 89% of the researchers have chosen non-heuristic methods in their suggested techniques.

5.2.2 Extensive investigation of the fitness function

In this subsection, the authors have inspected the fitness functions of the selected methods in two different viewpoints. Firstly, in order to inspect them in case of obvious explanation of fitness function, two major groups are considered, clear and not clear. As shown in Fig. 12, 84% of the researchers have explained their objective functions explicitly. The remain three papers [74, 85, 87] do not obviously describe their fitness functions.

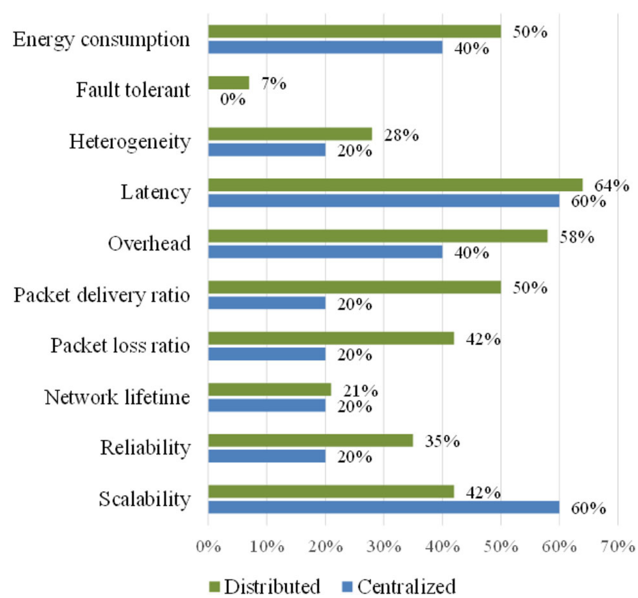


Fig. 10 Percentage of parameters in each category

As the second viewpoint, with a deep observation of fitness functions of the selected papers, authors have classified them into seven groups including energy-aware, cost-aware, context-aware, resource allocation-aware, traffic-aware, utilization-aware, and efficiency-aware. Figure 13 clearly depicts the classification. Energy-aware load balancing methods [17, 73, 76, 82, 84] intend to diminish the energy usage of the various layers of IoT. Moreover, some of the studied load balancing methods have been focused on reducing time cost including transmission cost [81] and delay cost [83]. Authors have placed them in a cost-aware load balancing group. Context-aware load balancing method [80, 88], has used a context-aware fitness function which has two essential features: (a) It takes the residual energy of the parent chain in the route in order to reach the root and integrates it with parent link and Expected Transmission Count. (b) It provides the circumstance of avoiding the obstacle of the thundering herd in the network. Aiming to enhance the effectiveness of efficiency-aware load balancing methods, some parameters such as bandwidth [71] and throughput [75] should be increased; moreover, latency [78, 79] should be decreased. The resource allocation-aware method [72] by focusing on resource allocation besides the load balancing can quickly and effectively accommodate the system loads. Also, the fitness function of the traffic-aware load balancing method [86] concentrates on the traffic load. Furthermore, the utilization-aware load balancing method [77] by taking the network utilization into consideration can diminish the average delay amongst the brokers.

5.3 Simulation tools observation

The researchers in their methods have used different simulation tools. As shown in Fig. 14, 28% of the researchers have not mentioned their used tools. Also, 11% of them have adopted Cooja, Matlab, and ns2 as their simulation tools. Moreover, other simulation tools such as mini-net, cloud-sim, Java, C#, and C are employed by 6% of papers.

5.4 Observation of articles type and data sets

Figure 15 shows the percentage of selected articles based on article type where 58% of the papers belong to journal articles group and 42% of them are related to conference articles group. Also, as shown in Fig. 16, 37% of the

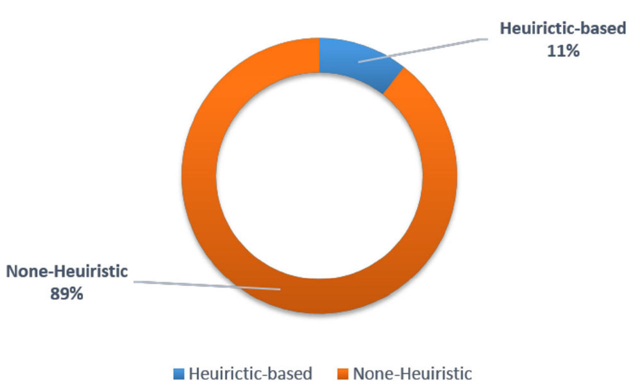


Fig. 11 Percentage of the adopted method in the discussed techniques

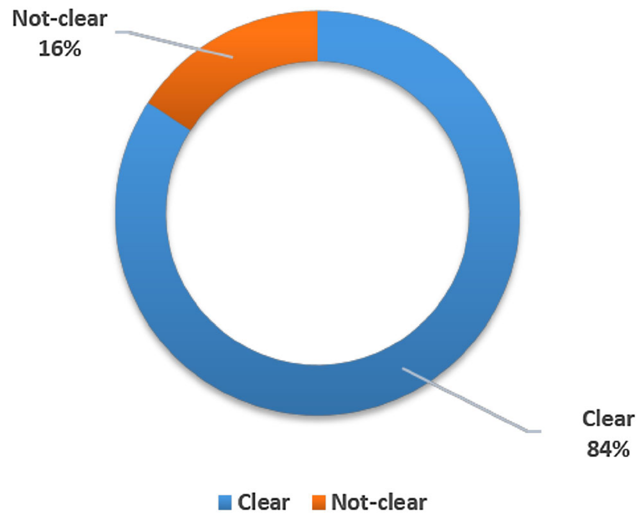


Fig. 12 Percentage of clear and not clear fitness functions in discussed techniques

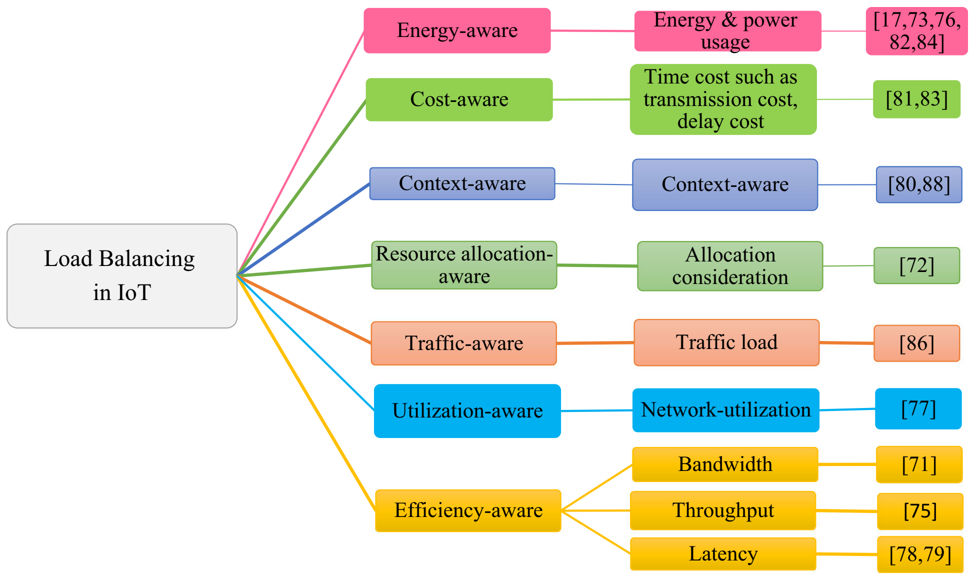
researchers have preferred to adopt randomly generated data, and 16% have not mentioned their data source. Moreover, 37% of the selected papers have utilized synthetically generated data and the remained 10% have used the real dataset.

6 Open issues

There are some vital issues about load balancing in IoT that are not investigated comprehensively and thoroughly up to now. Hence, this section aims to argue and discuss various open research issues in this scope. In this regard, it should be mentioned that some parameters like packet priorities and traffic patterns are ignored in almost all of the investigated papers. Consequently, adopting these factors in load balancing can be one of the efficient roadmaps for future researchers. According to the authors' exploration, there is not any single research which includes all QoS parameters and vital factors for load balancing problem. For instance, some methods apply packet loss ratio, network lifetime, and scalability whereas some other parameters such as overhead, latency, reliability, fault tolerance, and so forth are totally overlooked by them.

In order to make possible and feasible decisions considering resource releasing or reallocating, it is indispensable to emphasize the key performance factors of load balancing and allocating the resources and application development of those factors over time. Thus, aiming to consider much more QoS parameters, load balancing decision making needs to be extended. Also, it will be fascinating to inspect the adaptation with global QoS restrictions. Moreover, in most of the investigated strategies, energy saving and carbon emission were ignored by

Fig. 13 Classification of load balancing methods in IoT based on their fitness function



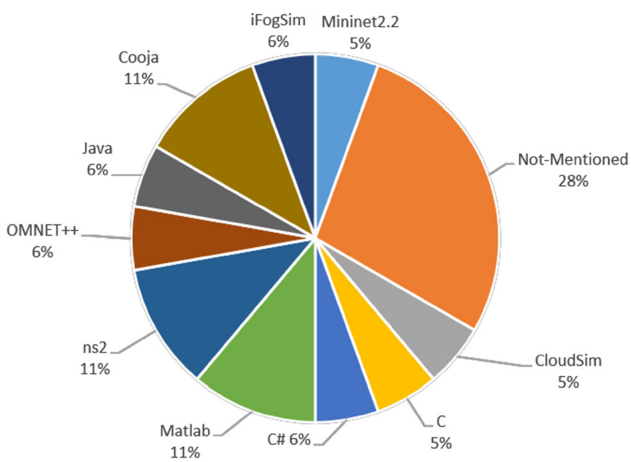


Fig. 14 Percentage of used simulation tool in discussed techniques

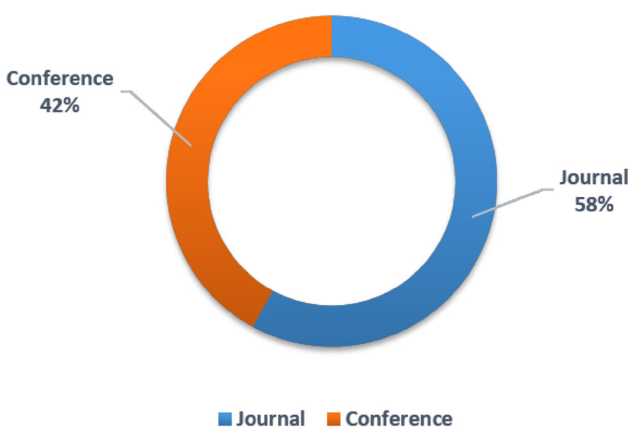


Fig. 15 Percentage of discussed articles based on article type

researchers. They have analyzed and inspected these factors separately. Additionally, to evolve the effectiveness

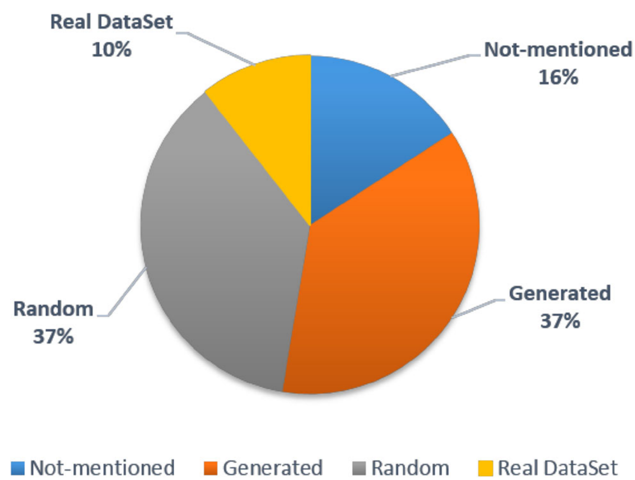


Fig. 16 Percentage of used datasets

and popularity of current load balancing strategies, adopting the factors mentioned above are suggested. Also, managing the cost is one of the common challenges in almost all types of processes and issues including load balancing problem. On the other hand, saving energy is one of the vital factors for providing cost efficiency. Besides, sometimes resources with lower cost can be selected for distributing the load. Thus, the process of load balancing could be improved, which leads to optimizing the process cost. Hence, a load balancing method which takes energy consumption, carbon emission, and cost of the process into account is tremendously desirable.

Furthermore, most of the investigated methods for evaluating their techniques use simulation process while some others do not utilize any simulation process. Also, adopting some appropriate simulators such as Cooja can be another interesting matter for future researchers. According to the observation of this paper, it can be seen that most of the researchers have not adopted proper simulation tools, which can be account as a limitation of the investigated papers. Consequently, future researchers should be aware of this issue. Adopting an appropriate simulation tool may increase the quality of their research.

Although the smart city concept has been recognized widely and applied in real-world scenarios, some challenging problems have become essential to achieve more progress. In this regard, enormous data collection and analysis, heterogeneity among IoT objects, information security, and cost of design and operation are important issues. An enormous amount of data are generated by smart objects that require large data storages. Thus, conventional data processing approaches and big data generation have become outdated for use in current smart city scenarios. Therefore, exploring and integrating big data analytics into smart city environments can be considered as an interesting open issue for future studies. Moreover, exploiting advantages of heterogeneous objects is another remarkable issue for upcoming studies. Generally, in order to offer timely and reliable services various sub-systems are integrated at the application layer. Aggregation at the application layer is notable for further investigation. Web-inspired WoT (Web of Things) notion has been developed as an ideal solution to integrate heterogeneous applications.

In addition to the simulation tools, there is not any data set observed in the investigated papers. Authors have adopted random or synthetic generated data as their data set. Gathering some proper and reference data set in this field can be so helpful for upcoming studies. Moreover, by examining the current papers in this scope, it can be concluded that some noteworthy concepts such as failure management and fault tolerance are ignored by almost all of them. Thus, adopting these two factors by existing methods will be a fascinating roadmap for future works.

In addition, considering heuristic-based strategies, adopting novel optimization algorithms can be extremely motivating for upcoming works. Researchers can use optimization algorithms including ant-lion optimizer algorithm [116], forest optimization algorithm [117], ant colony optimization algorithm [118], and PSO [119], to name but a few that can also be effective to load balancing issue. Other remarkable concepts for upcoming studies that get low consideration in existing load balancing methods are security and trust. In order to guarantee the validity and reliability of the contributed nodes in cooperating to attain an optimal load balancing, a secure trusted environment is extremely required. Thus, adding these factors to current methods can increase their efficiency.

7 Conclusion

This research has presented a SLR technique of load balancing strategies in the IoT environment. In this research authors first described and discussed the concept of both IoT systems and load balancing issue. Then the research methodology was introduced. According to some search queries, 19 important papers amongst the 35 studies have been selected and investigated thoroughly. Based on the SLR, it can be concluded that the years of 2015 and 2018 included the minimum and the maximum number of published papers respectively. Moreover, the maximum number of published studies with 58% including conference and journal papers belong to IEEE publisher (11 papers from total of 19 papers). The 19 selected papers have been classified into two essential classes including centralized methods with 5 papers and distributed methods with 14 papers. Also, the merits and demerits of the investigated papers have been specified. The challenges relevant to the load balancing issue in IoT systems have been examined through the state of the art strategies; hence, in this way, effective roadmaps in the field of load balancing can be introduced for future researchers. The consequences of investigation have proved that there is not any single research considered all parameters in the field of load balancing. Furthermore, open issues and future trends have been clarified and discussed through a comprehensive examination which points that managing carbon emission and energy depletion are ignored in most of the examined strategies. Also, some other parameters such as security, trust, and failure management have not taken into account in most of the current load balancing techniques. The essential aim of the load balancing issue in IoT, load balancing challenges, evaluation parameters, and open issues summarized in the answers to the research questions. Eventually, hope that outcomes of this research can show some effective and efficient roadmaps for upcoming works in this scope.

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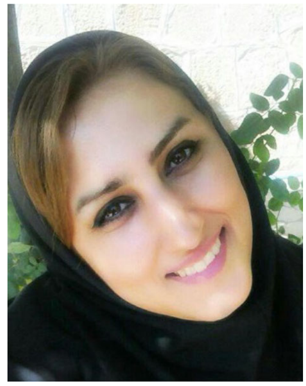

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