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Service composition approaches in IoT: A systematic review

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ABSTRACT

The Internet of Things (IoT) signifies to an overall system of interconnected physical Things utilizing existing correspondence conventions. One critical inquiry remains in what manner can make and communicate the management of provided services for smart devices by an assortment of protest things that substituted and joined capably. Service composition process permits the interaction between user requirements and smart objects of IoT environment. Leveraging on the service discovery procedure can be influenced on finding the desired services. Consequently, choosing suitable services is the main challenge that covers functionality and required quality to combine several services as the integrated composite service in the IoT. The service composition process has been broadly considered with regards to web suppliers and business processes in the IoT. Currently, the IoT environment identifies the dynamic relationship topics on physical processes that are combined as the enhanced web services heterogeneously. This paper focuses on several service composition approaches that are applied in the IoT environment based on the Systematic Literature Review (SLR) method. The aim of this study is to analytically and statistically categorize and analyze the current research techniques on the service composition in the IoT (published between 2012 and 2017). A technical taxonomy is presented for the service composition approaches according to content of the existing studies that are selected with SLR method in this review with respect to functional and non-functional aspects in service composition approaches. The functional aspect emphasizes on verifying the behavior of service composition approach and the non-functional aspect considers the Quality of Service (QoS) in IoT environment. The approaches are compared with each other according to some technical aspects such as system correctness factors in functional properties approaches, and (QoS) factors, presented algorithms, and existing platforms in non-functional approaches. The advantages and disadvantages of each selected approach discussed as well as providing some hints for solving their weaknesses. A brief contribution to this literature is as follows: (1) Presenting a SLR method for the service composition approaches in IoT, (2) Addressing a discussion of the main challenges, (3) Providing the future research directions and open perspectives.

1. Introduction

The Internet of Things (IoT) perspective has carried out numerous new changing items to the marketing, healthcare and e-life systems (Muralidharan et al., 2018; Terroso-Saenz et al., 2018; Kim et al., 2017; Gubbi et al., 2013). Sensors and correspondence abilities have been included into numerous customary gadgets, controllers, and foundations that can make smart and logical choices (Pereira et al., 2017; Ngu et al., 2017). Nowadays, IoT is relied upon to have important life-care and business processes to add the personal satisfactions and to develop the world's economy (White et al., 2017; Jang et al., 2018).

Cloud services can provide simplifying interaction of the smart things with capable composite services (Alodib, 2016). Service-based applications support both Quality of Service (QoS) and functional properties in the cloud service composition with respect to Service Level Agreements (SLAs) that refer to contracts between users and the cloud service providers to guarantee the QoS criteria. However, providing required users' requests is a challengeable issue to apply the interaction of smart things. Since IoT infrastructure has a dynamic and heterogeneous structure, composition of the existing cloud services cannot coordinate the QoS factors and the SLAs. Cloud service providers can suggest a heterogeneous set of IoT objects as web services that can be collected by a service coordinator to deliver a suitable composite service to the end users (Baker et al., 2017). One of the main challenges of the IoT smart objects is service composition. For example, some smart things, sensors and actuators are composited together to achieve

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a suitable composited service for user's requests. The service composition approach has a uniform way to consider user requirements based on heterogeneous requests, providers and business procedures (Pan et al., 2017; Wang et al., 2017a; Rodríguez-Mier et al., 2017). Various principles have been utilized as a part of true arrangements to help the service composition (Chung and Bichler, 2005; Alonso et al., 2004). In this way, original composition models as the new necessities of the IoT environments are estimated. Also, IoT applications perform service computing for gaining better services by means of composition of existing smart object services for service oriented applications in the IoT environment.

Thus, the key objective of this research is to conduct a comprehensive study where the parameters of the service composition can be easily selected to achieve the best service composition in IoT (Shokrollahi and Shams, 2017). To the best of our vision, this study provides a systematic review that gives knowledge about the service composition approach for smart objects. There are some technical survey and review papers on various parts of service composition that don't concentrate on smart objects of the IoT systematically (Al-Fuqaha et al., 2015; Li et al., 2015). To fill this weakness, we present a Systematic Literature Review (SLR) method and overview opportunities of the service composition approaches in IoT. This overview helps researchers to have an overall conception of this field and for experts to do consequent examinations. The key commitments of this study are highlighted as follows:

- Introducing a comprehensive and the SLR analysis of the service composition approaches in IoT.
- Designing a technical taxonomy to classify the service composition approaches in IoT environments.
- Providing a discussion and comparison of the main challenges for the service composition in IoT.
- Emphasizing the future research challenges and open issues in IoT.

The structure of this review study is designed as follows: The background and related work illustration demonstrated in Section 2. Section 3 provides a research selection method and motivation based on the SLR method. Section 4, overviews the service composition approaches in IoT systematically and categorizes them. In addition, this section presents a technical taxonomy and comparison of the approaches for selected papers. In Section 5, we describe the service composition approaches in IoT that have not been investigated systematically up to now as an exploration of new challenges. Finally, Section 6 shows the conclusion as well as the paper limitations.

2. Background

This section presents a brief explanation of the background and related review studies in IoT and service composition approaches.

2.1. Preliminaries

Nowadays, the IoT grow into more and more prevalent and suitable for user's interactions, which compose service technologies heterogeneously (Shadroo and Rahmani, 2018). Typically, the IoT smart devices are embedded heterogeneously and dynamically with the dependability functions related to their QoS for each atomic service (Souri et al., 2018). Each atomic service is related to the IoT device that provides the functionality of the service (Huo and Wang, 2016). In most cases, a single service is not sufficient to perform user's complex requirements. Also, a single IoT service cannot satisfy the compound user's requests, because some of the complex services are offered by a set of IoT devices. In that case, composite service is needed. A composite service orchestrates a set of single services to one to solve a complex goal successfully in a way that adds value to the delivered composited services. The most well-known example of a composite service is the travel planner that invokes a flight, hotel and car booking service in sequence. The service composition approach in IoT is the self-motivated connection of the complex business processes with the suitable atomic service technologies (Li et al., 2012). In addition, service providers suggest a huge number of atomic services that are collected with a suitable broker for representing a mixed-virtualized candidate service to users (Souri et al., 2018).

Due to the resources restrictions of a single provider to response the requested service, performing a user task cannot be managed by only one service provider; hence growing the number of needed providers is essential that consequently increases the complexity of the mentioned scenario. In broker-based services and service composition models which require cooperation between several IoT service providers, the stated problem is naturally appeared (Rahmani et al., 2017). Fundamentally, a user's demand is sent to the service provider to get a suitable response. Therefore, service composition is an indispensable concern in an IoT environment, wherein a solitary provider is not adequate to satisfy user's request (Baker et al., 2017). Since web service is operating in a highly varying environment, the QoS criteria and measures for candidate web services oscillate continuously. Hence, impressive SLAs are applied to satisfy users' requests with respect to their required QoS factors by cloud service providers. In order to find whether a composite service can meet the SLA, it is necessary to check the QoS of the users' requests by collecting of single services QoS criteria. The QoS of the composite services is related to composition patterns. As illustrated in Fig. 1, there are four composition models: sequential (a), parallel (b), probabilistic (c), and circular (d). Calculating the QoS of the sequential pattern provides a basis for calculating of other patterns. The aggregation functions are different for various QoS criteria and depend on the composition pattern.

Each service composition approach has some key QoS factors for considering best composited service between recommended candidate services. The declared QoS factors will be compared and analyzed in each analysis subsection. Five important QoS factors have been defined as follows (Alodib, 2016; Anastasi et al., 2017):

- **Availability:** Service composition availability can be mentioned in the smart devices, middleware layer and application layer in the IoT for presenting various services at anytime and anywhere according to the user tasks.
- **Response time:** length of the time taken for a composite service to respond to a user task.

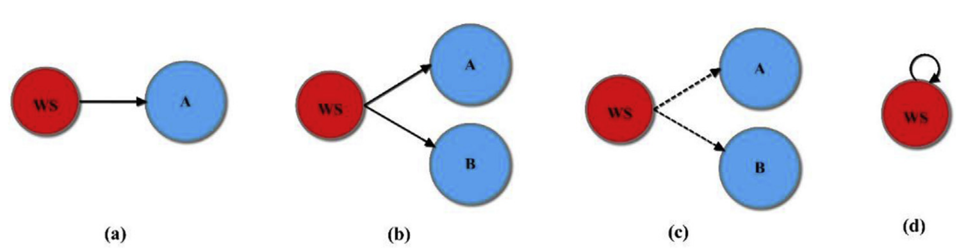

Fig. 1. The pattern of the composite services a) Sequential b) Parallel c) Probabilistic d) Circular.

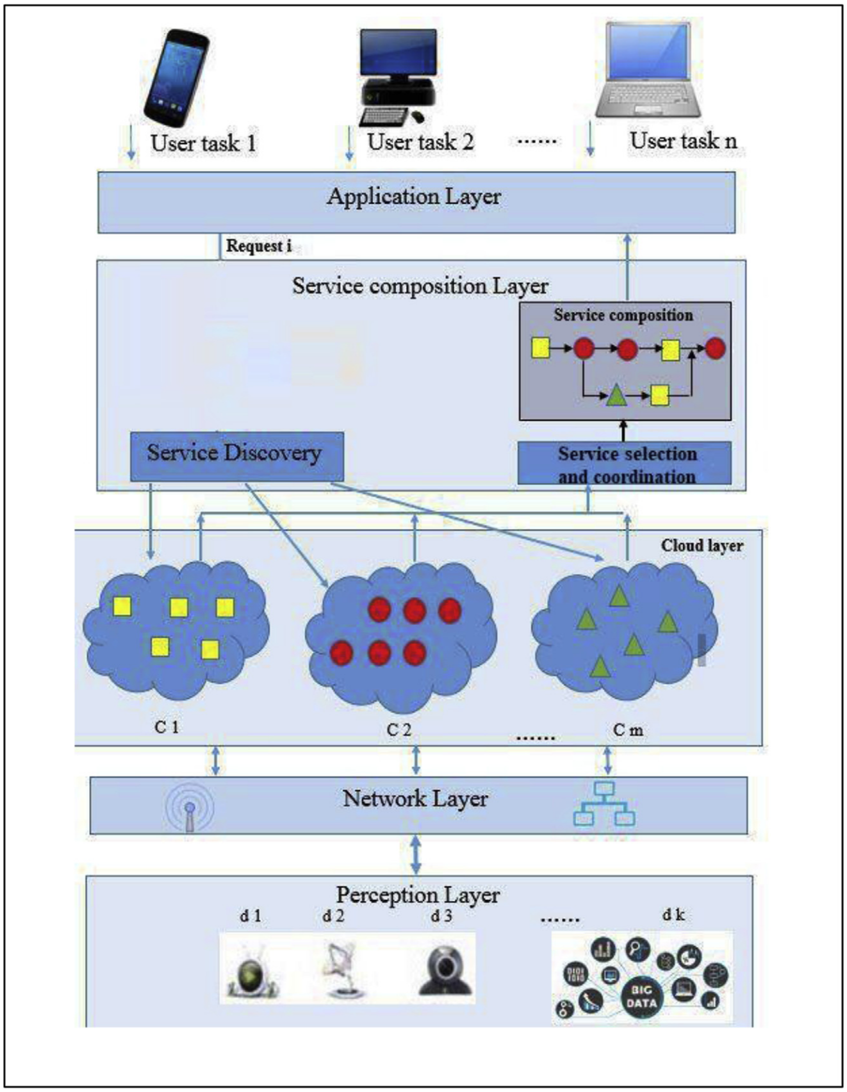

Fig. 2. Service composition in IoT.

- **Scalability:** The scalability factor shows the ability to add new operations and smart devices as the service nodes for user tasks without decreasing the quality of current services.
- **Cost:** the total price has to be paid by the service requester to achieve the best composite service.
- **Reliability:** The objective of reliability denotes to achieve the successful service delivery based on its specifications in the IoT.

Fig. 2 illustrates a brief description of the service composition in the IoT architecture. This architecture consists of five layers which are explained as follows:

1) The perception layer includes sensors and smart devices to collect the data from the IoT environment.
2) The network layer provides connecting to other servers, smart thing such as sensors and network devices. The other important feature of this layer is processing and transferring the data gathered from the perception layer.
3) The cloud layer provides various sub-services by several private or public clouds.
4) The service composition layer is responsible for composing a number of sub-services together regarding the user's functional and non-functional requirements. This layer deals with coordinating the delivered requests to send them for discovering available and proper sub-services due to user's demands from one or more clouds in the cloud layer and finally the selected sub-services are combined together to compose the desired composited service which be delivered through the application layer.
5) The application layer drives particular composited services to the end users according to their requests.

2.2. Related work

Now, some literature review studies are discussed as follows: Jatoth et al. (2017) presented a systematic literature-based review for Quality of Service (QoS)-aware service composition approaches according to computational intelligence mechanisms in the cloud. They classified the existing methods to three categories that include heuristic, non-heuristic and meta-heuristic approaches. The main weakness of this review is that the taxonomy classification represented the applied algorithms only for cloud environments. Also, the suggested technical questions have not been specified deeply for getting the technical comparison on the QoS-aware service composition in cloud computing.

Han et al. (2016) presented a survey on service composition of Internet Protocol (IP) smart objects. In this study, a comprehensive analysis was comprised based on different factors such as smart objects techniques, service modeling, target platforms, target applications and composite service approaches for the IPs of IoT. The main defect of this research is that there is not any SLR method on the integration of the existing studies. The authors did not analyze the evaluation factors such as response time, cost, availability, and scalability in this survey.

A survey of IoT fundamental techniques was provided by Li, Xu and Zhao (Li et al., 2015). Their presented review is classified to the fundamental techniques in forms of sensing layer, network layer, service layer and the interface layer. This literature review categorizes IoT technologies according to well-known standards that include communication, RFID, Data encoding, sensors, electronic code and network management. Some open issues and study directions were illustrated in this literature based on standardization, technical challenges and security and privacy factors. The main advantage of this survey is providing comprehensive open issues and challenges in the IoT. The main defect of this survey is that they did not clear the compatibility of each strategy in the IoT applications. Also, Ray (2018) presented a survey on IoT domains in terms of RFID, SOA, WSN, healthcare, cloud, social computing, and security. The evaluation parameters such as availability, cost, energy consumption, time and reliability were not compared and discussed in this survey and only some tools and methodologies were presented in this literature.

Navimipour et al. (Navimipour and Vakili, 2017) presented a comprehensive review of the service composition approaches in cloud computing based on the algorithmic classification including framework-based, heuristic-based and agent-based approaches. The variety of the paper selection is considered just by journal papers from 2012 to 2016 according to the QoS parameters, without any technical discussion and comparison. Also, Jula et al. (2014) addressed an SLR-based method for the cloud service composition approaches based on some key questions that can be divided the research to five important categories including classical algorithms, combinatorial algorithms, machine-based algorithms, structures and frameworks algorithms. The authors performed the QoS parameters for comparing the proposed algorithms with individual dataset types for the published studies from 2009 to December 2013. Of course, there is not any taxonomy and paper selection based on SLR method in this study. Also, they provided the comparison of service composition approaches just in a cloud environment.

Table 1 depicts a summary of the related reviewed studies on the IoT/service composition topics based on SLR and survey papers. In this table, review type, the main topic, publication year and covered years are illustrated for each study. Just three review literature have applied the SLR on the service composition approaches in cloud computing. Up to now, there is no a systematic survey that evaluates service composition approach in IoT environments.

Due to the existing review studies, the following weaknesses suggest that we provide a comprehensive literature review to cover these deficiencies as follows:

- The existing studies do not present any analytical comparison and taxonomy for service composition in IoT.
- Some reviews do not consider exactly the service composition techniques.
- Some studies don't analyze the evaluation parameters on service composition techniques in IoT.
- The organization of the presented studies does not have the systematic structure. Therefore, the paper selection process is unclear.

3. Research selection method

This section demonstrates an SLR-based review as a research study evaluation and important valuation for classifying the service composition approaches in IoT (Jatoth et al., 2017; Jafarnejad Ghomi et al., 2017; Effatparvar et al., 2016). Usually, the SLR process includes an explanation of finding the research studies collection (Charband and Jafari Navimipour, 2016; Souri and Rahmani, 2014; Shojaiemehr et al., 2018).

By adding substitutes and other synonyms of the key essential elements, the following exploration string was defined (Navimipour and Vakili, 2017; Souri and Rahmani, 2014; Aznoli and Navimipour, 2017; Souri et al., 2014; Jamshidi et al., 2013; Kitchenham et al., 2010):

- ("Service composition" OR "Service selection" OR "Smart objects" OR "Smart things" OR "Web processing service" OR "Web of objects" OR "Service decomposition") AND ("IoT" OR "Internet of Things")

This systematic review provides a comprehensive response to the following Analytical Questions (AQ) according to the goals and scope of the proposed research:

- AQ1: What service composition approaches are applied in IoT?
- AQ2: What target platforms are selected for service composition in IoT?
- AQ3: What measurement environments are applied to evaluate the service composition in IoT?
- AQ4: What popular modeling tools are used for service composition in IoT?
- AQ5: What evaluation factors are applied in service composition in IoT?
- AQ6: What are the current algorithms support the service composition in IoT?
- AQ7: What are the open perspectives and future challenges of service composition in IoT?

Fig. 3 displays the distribution of the research papers over time according to some scientific publishers based on the review process and article citations such as IEEE, Elsevier, Springer, ACM, Wiley and Taylor & Francis. In this classification, some electronic databases such as Science Direct and IEEE Xplorer are used in the SLR method according to Table 2.

After providing the technical questions, we apply the inclusion/exclusion criteria for the final research selection. With respect to the number of published studies, we just analyze the journal articles and conference papers that indexed in WoS and ISI proceedings as the important and peer-reviewed papers for the service composition approaches in IoT. Finally, the 42 peer-reviewed papers were considered for further analysis to response our technical questions that the details content is provided in section 4.

Fig. 4 illustrates the selection criteria and evaluation framework of

Table 1
Some related studies in service composition in Cloud and IoT.

Research	Review type	Main topic	Publication year	Covered years
Jula, Sundararajan and Othman (Jula et al., 2014)	SLR	Service composition in cloud	2014	2009–Dec 2013
Navimipour and Vakili (Navimipour and Vakili, 2017)	SLR	Service composition in cloud	2017	2012–2016
Jatoth, Gangadharan and Buyya (Jatoth et al., 2017)	SLR	Service composition in cloud	2017	2005–May 2015
Li, Xu and Zhao (Li et al., 2015)	Survey	IoT	2015	–
Han, Khan, Lee, Crespi and Glitho (Han et al., 2016)	Survey	IoT	2015	–
Ray (Ray, 2018)	Survey	IoT	2016	–

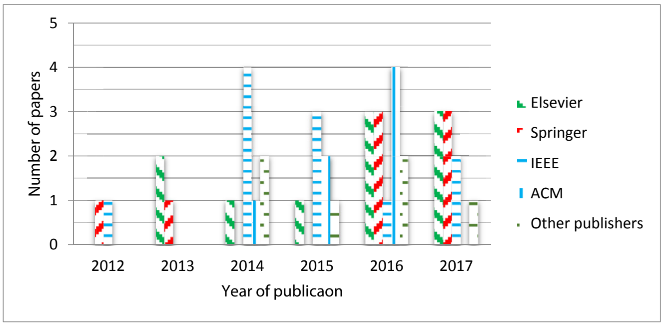

Fig. 3. Distribution of research papers by Publisher.

Table 2
Electronic databases used in article selection.

Online database	URL Address
IEEE	http://ieeexplore.ieee.org/
ACM	http://dl.acm.org/
Science Direct	http://www.sciencedirect.com/
Springer	http://link.springer.com/
Taylor & Francis	http://www.tandfonline.com/
John Wiley	http://onlinelibrary.wiley.com/
Inderscience	http://www.inderscienceonline.com
Sage	http://journals.sagepub.com.com

the studies. The exclusion phase includes omitting book chapters, non-peer-reviewed researches, short papers, white papers and low-quality studies that do not present any scientific information and explanations. The inclusion directive is used to the mapping ultimate selected studies as follows:

- Studies published online from 2012 to 2017.
- Studies in the field of IoT.
- Studies offering a technical quality method in service composition in IoT.

The exclusion directive is applied to the mapping last selected studies as follows:

- Studies presenting survey and review papers.
- Studies not indexed in ISI.
- Studies not presented in an English context.
- Studies not peer-reviewed procedure. Regulation

4. Organization of the service composition in IoT

This section provides a technical review of the selected service composition approaches in IoT for specified studies according to the applied SLR method. Fig. 5 displays taxonomy of the service composition approaches according to content of the existing studies that are selected in the Section 3. Service composition approaches in the selected studies are classified in two main categories with focus on functional properties aspect and non-functional properties aspect. 1) The functional properties approach consists of formal-based approach that emphasizes on verifying the behavior of service composition approach by evaluating some factors such as correctness, reachability, deadlock and safety that are explained in section 4.1. 2) The second category consists of non-functional properties aspect of service composition that focuses on considering the QoS factors of composited services, regarding IoT architecture. This class including three groups:

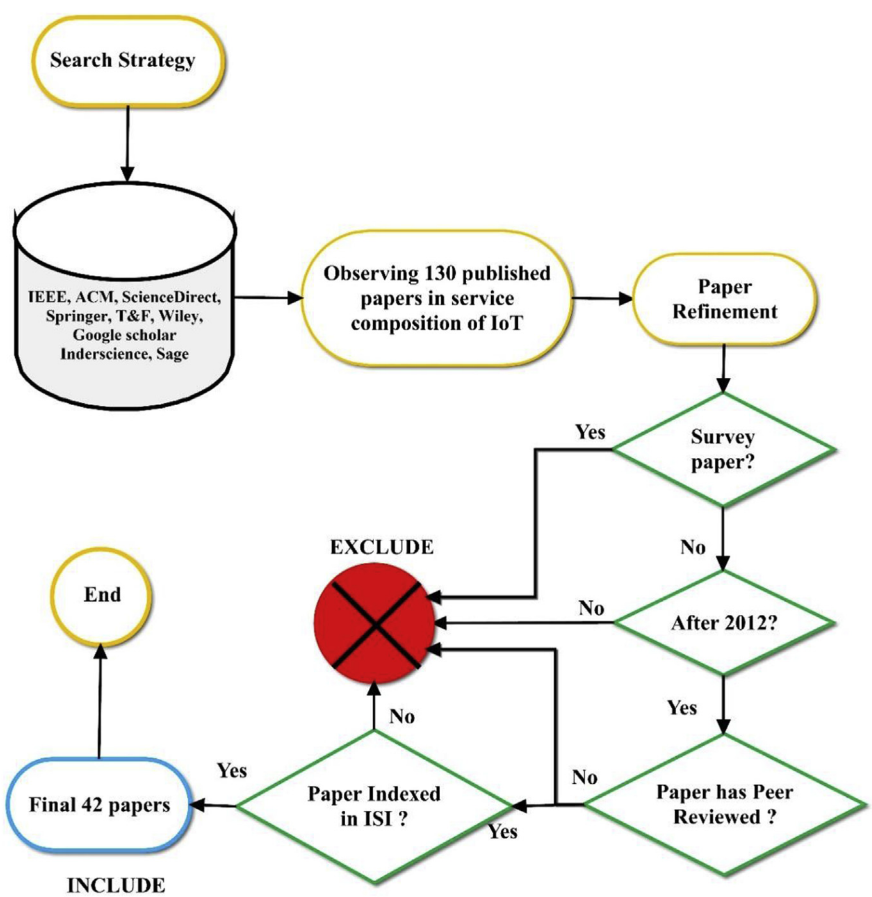

Fig. 4. The selection criteria and evaluation framework of research papers.

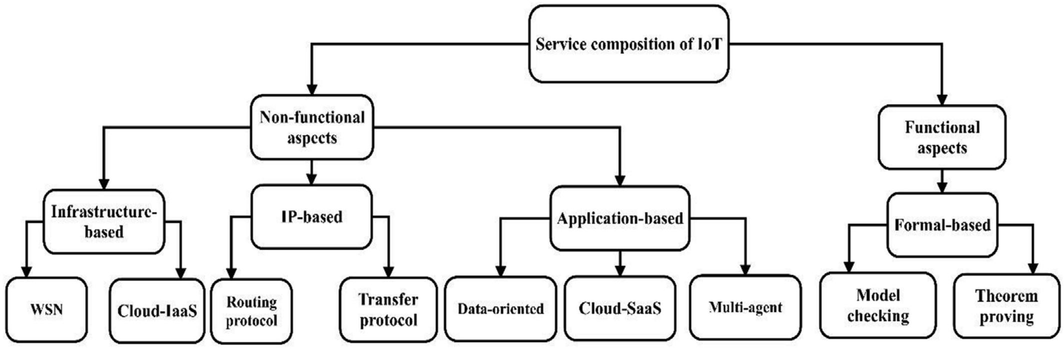

Fig. 5. The taxonomy of service composition approaches in IoT.

infrastructure-based, Internet Protocol (IP)-based and application-based service composition approaches in IoT. Each service composition approach includes a set of main categories.

1) Functional properties group as the first category includes only formal-based composition approaches.
   - The formal-based approach has two key modeling methods including model checking-based and theorem proving-based methods. Also, in the formal-based service composition approaches, the software layer is formulated based on some input/output service conversations. The existing satisfaction principles are checked in a state space exploration of the service nodes using formal approaches (Aziz, 2016). In the formal verification of service composition approaches, some functional properties such as reachability, fairness, correctness, and deadlock are evaluated based on satisfied experimental results.
2) Non-functional properties category as the second class, includes three groups of service composition attitudes.
   - The first group of studies is about the infrastructure-based service composition approach. In this approach, the energy consumption factor is the main challenge in composing the minimum service nodes to save the energy and decrease cost factors in the IoT environments (Cheng et al., 2017). The infrastructure-based approach consists of two classes, Cloud-IaaS and WSN-based studies. Cloud-IaaS category focuses on analyzing the cloud service composition metrics such as energy efficiency, resource management and latency of IoT infrastructures. Also, WSN-based studies refer to ability of smart sensors to navigate the service composition approach in IoT environment. The main metrics of this category include battery life of sensors, the amount of wasted energy and rising device temperature.
   - The second group of non-functional category is about IP-based approach that includes the routing and transfer protocols of service composition in IoT devices. Routing protocols illustrate some new routing algorithms to handle the service discovery and selection procedures. In addition, transfer protocols specify the fair connection contracts between smart objects and cloud services in IoT layers.
   - Finally, the application-based approach, as the last category of non-functional properties class, has three main fields including data-oriented, cloud-SaaS and multi-agent method (Souri et al., 2017). Data-oriented method refers to data processing and data management methodologies in IoT. Also, cloud-SaaS category includes selection and composition of software components such as e-booking travels, online shopping, and online reservation. Finally, multi-agent category implies on all of the new methods that apply agent methodology for the service composition in IoT environments. In IoT service composition approach, multi-agent methods have an emerging paradigm on the composite service selection according to some technical strategies such as reinforcement learning (Wang et al., 2017b), evolutionary computation and Nash equilibrium (Ma et al., 2017). The multi-agent approach permits some critical problems of a restricted approval service selection to perform agents with their individual choices and objectives.

4.1. Functional properties aspect of service composition

The functional properties aspect of service composition includes formal-based service composition approaches, which refers to evaluating the behavior of service composition method by verifying the properties such as correctness, reachability, deadlock, safety and liveness. To evaluate the correctness of a system behavior, the functional properties have been illustrated as follows:

- **Correctness** properties are related to checking the existing specification rules that should be satisfied in the state space of the system behavior.
- **Reachability** is a concept that refers to an assumed set of objective states can be reached preliminary from a fixed set of initial states.
- **Deadlock** is a condition that some existing paths are inactivated for some other parts of state space in a trapped status.
- **Safety** is a condition that a critical path will never occur in the total of system behavior.
- **Liveness** occurs when a system requires making a set of paths that eventually happens in parallel execution.

4.1.1. Formal-based service composition approaches

This subsection illustrates the formal verification-based approaches in IoT. In addition, we explore the selected approaches in the web services. Finally, the verification approaches will be compared with the structural properties such as the specified case studies, modeling and specification languages and verification tools. Formal verification approach has two main model-based approaches including model checking (Edmund et al., 1999; Baier and Katoen, 2008) and theorem proving (Cook, 1971) approaches.

Model checking as a formal verification technique, is one of the most powerful approaches for evaluating and verifying the hardware and software systems (Edmund et al., 1999; Ouchani and Debbabi, 2015; Zhang et al., 2014a; Souri et al., 2012). Some famous model checkers are developed such as NuSMV,[1] SPIN,[2] PAT[3] and UPPAAL[4] (Souri and Norouzi, 2015a; Safarkhanlou et al., 2015a). The action-based and state-based techniques are two key methods for modeling the behavior of systems. The action-based method demonstrates a Labeled Transition System (LTS) of the system activities that the states are

[1] http://nusmv.fbk.eu/.
[2] http://spinroot.com.
[3] http://pat.sce.ntu.edu.sg/.
[4] http://www.uppaal.org/.

considered by a name and edges named by an event (Baier and Katoen, 2008; McMillan, 1993). Also, the state-based method presents a Kripke Structure (KS) of the system behavior in which the states are labeled by a name regardless edge name with an atomic proposition. Generally, the current algorithms in the model checking method specify a reachable state space of the system behavior by means of Binary Decision Diagrams (BDD) (Al-Saqqar et al., 2015).

Theorem proving as a formal verification technique that applies the mathematical logic and automated intellectual concepts. The theorem proving can verify properties that contain the fundamental theory and assumptions, rather than inaccessible properties.

Zhang et al. (Zhang and Chen, 2015) presented an event based theorem proving approach to evaluate the data consistency of the IoT resources. This approach is divided into three main concepts including data flow model, an interface model, and a data model based on interacting the physical devices. The soundness of the presented approach is evaluated with the Symmetric Circular Rule (SCR) that directly activates on the physical smart objects in the composition requests. Finally, the existing business process requests are specified as an industrial case study based on some logical properties which are evaluated in the formal labeling functions.

Li, Jin, Li, Zheng and Wei (Li et al., 2012) proposed a probabilistic-based model checking method for a reliable service composition approach according to Markov Decision Process (MDP) model. This approach is constructed by an Finite State Mahcine (FSM)-based model that focuses on the functional properties of the composition approach. With respect to the required non-functional properties of the service composition such as energy, cost and response time, the specified properties of the proposed composition approach are specified in forms of the probabilistic temporal logic formulas. The final structure is translated to the Labeled Transition System (LTS) model that is implemented using PRISM model checker. The experimental results depict that the proposed composition approach proves the reachability condition for functional properties and probability factor with minimum cost of the composite services.

Sarray et al. (2015) presented a Kripke Structure (KS)-based model checking method for a safe composition approach in the IoT multiple applications. This model uses the mealy machine as the synchronous perspective that is a finite automata for observing external input events in the composition process. Also, safety properties of the proposed composition approach are specified in forms of Computation Tree Logic (CTL) formulas. The final model is translated to the KS method that is implemented in NuSMV model checker.

In addition, the studies (Alodib, 2016) and (Yang et al., 2014) used Petri-net networks to verify the service composition approach in IoT. For example, Alodib (2016) proposed an SLA-based real-time monitoring model for composing services using the Petri-net networks. First, the proposed SLAs are mapped to the UML quality model. Then, the quality model is translated into the Petri specifications based on QoS-aware actions. The experimental results show that the feasibility of the real-time monitoring is considered with respect to the reachable state exploration graph in the Petri model.

4.1.2. Analysis of the reviewed formal-based service composition approaches

Table 3 explains the categorization of the above studies and the effective factors to analyze the composition approaches in IoT. The specified case studies in the formal-based composition approach include industrial systems, home-care systems, and commercial websites.

Table 4 explains a side by side valuation for the above studies using evaluation factors in IoT. The following factors include correctness property, reachability, deadlock, safety and liveness conditions. In the formal-based approaches, most research studies evaluated their proposed approach in the reachability and correctness property factors.

4.2. Non-functional properties aspect of service composition

Non-functional properties aspect of service composition emphasizes on considering and evaluating QoS factors of composited services, regarding IoT architecture. The important QoS factors consist of availability, response time, scalability, energy consumption, cost and reliability which were defined in section 2.1. This class includes three main groups including infrastructure-based, (IP)-based and application-based service composition approaches in IoT. Each service composition approach includes a set of main categories. Also, some important issues such as security play an important role in any service composition approaches (Dargahi et al., 2017).

4.2.1. Infrastructure-based service composition approaches

This subsection illustrates the infrastructure-based composition approaches in IoT. Finally, the composition approaches will be compared with some structural and evaluation factors.

Zhou et al. (2018) presented a service discovery chains and selection method based on energy efficiency in WSN smart objects. The presented method used the multi-objective genetic algorithm optimization to categorize the sensor devices based on their functionalities and their fitness to choose the greatest composite services. The experimental results are implemented with the simulation environment that shows the effectiveness of the proposed genetic algorithm to minimize the energy consumption in the suggested service composition method.

Baker, Asim, Tawfik, Aldawsari and Buyya (Baker et al., 2017) presented a new energy saving method to compose IoT-based cloud services that guarantee the power efficiency of the physical devices in composition approach with respect to the incorporating the minimum number of the existing services in the IoT environment. The main improvement of this research is using the geographical coordination method for selecting the best service composition approach according to the transitional relationships between the customer and the existing datacenters. The weakness of this research is that the authors do not use more potential topologies to evaluate their technical approach.

Rapti et al. (2015) proposed a decentralized service selection and composition approach based on the artificial potential fields to apply the high availability of the suitable services with respect to users' requests. In this research, the video and audio streams are mapped to the service components to achieve the gathering the sequence of service nodes. This composition approach provides the minimum waiting time for user requirements. Of course, this study has not any simulation and evaluation platform for the proposed approach.

Yu et al. (2016) presented a web of object service composition architecture based on the smart home-care systems. The presented architecture provides the web service data gathering using smart gateways. The composition method is based on the energy consumption factor that selects appropriate services. The authors used a real dataset for predicting the best service composition method using ANN and SVM algorithms.

Zhou et al. (Zhou and Ma, 2013) presented a QoS-aware service selection and composition approach based on backtracking algorithm in WSN IoT platform. First, the composition model is mapped to the WSN graph based on the service selection method. Then, the quality attributes are translated to the sequential workflow model for achieving to the best optimal service through a suitable cost. The offered approach is compared with integer programming and the genetic algorithm in simulation results. The weakness of the presented scenarios is sensible in this work. Also, the meta-heuristic algorithms show better capability in the service selection approach than non-heuristic algorithms in this research.

Huo and Wang (2016) proposed an artificial bee colony algorithm based on a cross-modified method to select the candidate composite services dynamically. This method provides a suitable response time and maximum accuracy than the other algorithms such as genetic

Table 3
Categorization of recent studies and other information in formal-based service composition approaches.

Research	Main idea	Case study	Advantage	Weakness	Specification	Category
(Zhang and Chen, 2015)	Event-based theorem proving approach	Industrial boiler station	• Low Time • High efficiency	• Low scalability	–	Theorem proving
(Li et al., 2012)	probabilistic-based model checking method	Fire alarm service	• Low complexity • Low time	• Low safety • Low liveness	PCTL	model checking
(Sarray et al., 2015)	Kripke Structure-based model checking method	Home-care temperature	• High reachability • Low time • Low cost	• High complexity	CTL	model checking
(Alodib, 2016)	SLA-based real-time monitoring model	Commercial websites	• High reachability • Low time	• Low safety • High cost	–	model checking
(Yang et al., 2014)	Petri-net based model checking method	Smart aquaculture system	• Low time	• Low safety • High complexity	–	model checking

Table 4
A side by side comparison of the existing correctness factors in the formal-based service composition approaches.

Research	Correctness property	Reachability	Deadlock	Safety	Liveness
(Zhang and Chen, 2015)	✓	✓	✗	✓	✓
(Li et al., 2012)	✓	✓	✓	✗	✗
(Sarray et al., 2015)	✓	✓	✓	✓	✗
(Alodib, 2016)	✓	✓	✗	✗	✗
(Yang et al., 2014)	✓	✓	✗	✗	✗

algorithm in chaotic and distinct solution space. The specified quality attributes are defined according to the IP case study to perform the best solution of the service selection and composition approach. The experimental results are simulated in MATLAB environment that shows the minimum response time and the mean convergence iteration for proposed algorithm. Of course, the main defect of this method is the absence of considering the serial optimization of the task nodes for examining the service composition approach.

Agirre et al. (2016) presented a QoS-based service reconfiguration method to compose the component-based distributed services in web sensor systems. This method provides four functionalities including monitoring infrastructure resources, monitoring component-based applications, reconfiguring flexible APIs, and composing a QoS-based method. The infrastructure resource management is achieved by the registry service status in the service selection level. The monitoring component-based applications specify the quality attributes to compose the existing services in service composition level.

Cherrier et al. (2014) proposed a behavioral-based crowd service composition in mobile cloud service. This approach has applied a heuristic algorithm for service composition approach. Some advantages of this research include low time minimum cost and low energy consumption. Finally, (Cuong et al., 2016) proposed a Bayesian classification technique to clarify service composition approach in IoT. The applied case study in this research is weather station system that is evaluated by a heuristic algorithm. The main advantage of this study is high reliability and low cost.

4.2.2. Analysis of the reviewed infrastructure-based approaches

Table 5 explains the categorization of the above studies and the effective factors to analyze the composition approaches in IoT. The specified case studies in the infrastructure-based composition approach include multimedia systems, marketing services, industrial systems, home-care systems and mobile applications.

Table 6 explains a side by side valuation for the above studies using evaluation factors in IoT. The following factors include availability, time, scalability, energy, cost and reliability. In the infrastructure-based approaches, most research studies evaluated their proposed approach in time and cost factors.

4.2.3. IP-based service composition approaches

This subsection illustrates the IP-based composition approaches in IoT. In addition, we review the selected approaches in the web services. Finally, the IP-based factors for each study will be compared.

Huang et al. (2014) proposed a service co-location composition approach to minimize the energy cost in internet protocols of IoT. This approach provides a comprehensive sensor node selection with a static routing table that computes the energy consumption of each node according to the determined weighted independent set algorithm. The composition of the selected sensor nodes is performed based on the minimum energy cost according to the routing table. The performance evaluation results show the minimum total saved energy cost ratio of the proposed approach with comparing the other simulated algorithms in linear, star and random flow-based program structures.

Ferrera et al. (2017) presented an agent-based service composition method for infrastructure layer in the IoT environments. This method provides a dynamic service discovery and selection approach based on some key features including event subscribing, naming, addressability and scalability. The proposed composition method is implemented using IoT-PIC graphical interface platform to configure the attractiveness of the selected services. The implementation results show the benchmark evaluation of the proposed method with high perceptivity, efficiency, and dependability for three main evaluation factors including request response time, page response time, and connection establishment time.

Pallec et al. (2016) provided a routing protocol-based service composition approach in IoT. The proposed approach provides a self-directed recommendation system for available smart services to support end-users' requirements. This study uses a classification method to recommend the available smart services based on Typed Attributed Graphs (TAG) to interact the existing physical interfaces. The main weakness of this study is that the simulation or implementation developments are not considered to evaluate the proposed approach.

Kleinfeld et al. (2014) developed a mashup real-time platform (a mixture or fusion of disparate elements of smart devices) called Glue-Things to compose the web services in the IoT. The Glue-Things is a platform that supports the object connectivity of the smart applications for the IoT devices with low expansion and incorporation effort. The three main layers of this platform include device, service and transfer layers that user can manage and aggregate the existing data streams in a graphical interface using a workflow editor.

Di Salle et al. (Di Salle et al., 2016) presented a service composition approach based on transfer protocol in IoT. The authors provided a new architecture with five layers including application layer, network layer, web layer, glue thing layer and data layer. These layers have a high capability to connect smart devices with each other. The connection between the presented layers is provided with 3G or 4G networks. Of course, this study has not mentioned any simulation and implementation development for the presented architecture.

Table 5
Categorization of recent studies and other information in infrastructure-based service composition approaches.

Research	Main idea	Case study	Advantage	Weakness	Algorithm type	Category
(Zhou et al., 2018)	Energy-aware service discovery chains	Fire alarm service	• Low Energy • Low time • High availability	• High complexity • Low scalability	Meta-Heuristic	WSN
(Baker et al., 2017)	Energy-aware cloud service composition	Energy-based weather	• High availability • high scalability	• High time • High cost	Non-Heuristic	Cloud IaaS
(Rapti et al., 2015)	Decentralized artificial potential fields	Artificial potential systems	• Low time • High availability • Low cost	• High complexity • Low scalability	Heuristic	Cloud IaaS
(Yu et al., 2016)	Smart home-care service composition	Home-care systems	• Low time • Low cost	• Low Scalability • High complexity • Low availability	Non-Heuristic	Cloud IaaS
(Cherrier et al., 2014)	Behavioral-based crowd service composition	Mobile application	• Low time • High availability • Low energy • Low cost	• Low scalability	Non-Heuristic	Cloud IaaS
(Zhou and Ma, 2013)	QoS-aware service selection	Business process systems	• Low cost • Low time • High availability	• Low reliability • High complexity	Heuristic	WSN
(Huo and Wang, 2016)	cross-modified method	Online shopping service	• Low time • High availability • High scalability	• High energy • High complexity • Low scalability	Meta-Heuristic	Cloud IaaS
(Agirre et al., 2016)	QoS-based service reconfiguration method	Cyber-physical systems	• Low time • High availability • Low cost	• High energy • High complexity • Low scalability	Non-Heuristic	Cloud IaaS
(Cuong et al., 2016)	Bayesian classification technique	Weather station system	• Low time • High reliability • Low cost	• High energy • High complexity • Low scalability	Non-Heuristic	Cloud IaaS

Table 6
A side by side comparison of the existing QoS factors in the infrastructure-based service composition approaches.

Research	Availability	Time	Scalability	Energy	Cost	Reliability
(Zhou et al., 2018)	✓	✓	✗	✓	✓	✗
(Baker et al., 2017)	✓	✗	✓	✗	✗	✗
(Rapti et al., 2015)	✓	✓	✗	✗	✓	✗
(Yu et al., 2016)	✗	✓	✗	✗	✓	✗
(Cherrier et al., 2014)	✓	✓	✗	✓	✓	✓
(Zhou and Ma, 2013)	✓	✓	✓	✓	✓	✗
(Huo and Wang, 2016)	✓	✓	✗	✗	✓	✓
(Agirre et al., 2016)	✓	✓	✗	✗	✓	✗
(Cuong et al., 2016)	✗	✓	✗	✗	✓	✓

4.2.3.1. Analysis of the reviewed IP-based approaches. Table 7 explains the categorization of the above studies and the effective factors to analyze the composition approaches in IoT. The specified case studies in the IP-based composition approach include multimedia systems, marketing services, industrial systems, home-care systems and mobile applications.

Table 8 explains a side by side valuation for the above studies using evaluation factors in IoT. The following factors include availability, time, scalability, energy, cost and reliability. In the IP-based approaches, most research studies evaluated their proposed approach in time and cost factors.

4.2.4. Application-based service composition approaches

This subsection illustrates the application-based service composition approaches. The application-based service composition approaches will be compared according to structural properties and QoS factors. Also, this approach is classified into three main areas including data-oriented, cloud-SaaS and multi-agent methods.

Table 7
Categorization of recent studies and other information in IP-based service composition approaches.

Research	Main idea	Case study	Advantage	Weakness	Algorithm type	Category
(Huang et al., 2014)	Service co-location composition	Home-care systems	• Low time • High availability • Low energy • Low cost	• Low Scalability • High complexity	Non-Heuristic	Routing protocol
(Ferrera et al., 2017)	Agent-based service composition	Network Management Protocol	• Low time • High availability • High scalability	• High energy	Heuristic	Transfer protocol
(Pallec et al., 2016)	Interface-based service composition	Video conference service	• Low time • High availability	• High complexity • Low scalability • High cost	Non-Heuristic	Routing protocol
(Kleinfeld et al., 2014)	Dynamic mixed and Mashup platform	Marketing services	• Low time • High availability	• High complexity • Low scalability • High cost	Non-Heuristic	Transfer protocol
(Di Salle et al., 2016)	High embedded smart platform	Business process models	• Low time • High scalability • Low cost	• Low availability • High complexity	Non-Heuristic	Transfer protocol

Table 8
A side by side comparison of the existing QoS factors in the IP-based service composition approaches.

Research	Availability	Time	Scalability	Energy	Cost	Reliability
(Huang et al., 2014)	✓	✓	✗	✓	✓	✗
(Ferrera et al., 2017)	✓	✓	✓	✗	✓	✗
(Pallec et al., 2016)	✓	✓	✗	✗	✗	✗
(Kleinfeld et al., 2014)	✓	✓	✗	✗	✗	✗
(Di Salle et al., 2016)	✗	✓	✓	✗	✓	✗

4.2.4.1. Data-oriented service composition approaches. Urbieta et al. (2017) proposed a semantic web service composition approach to cover the context-aware behavioral services based on data-flow and context-flow constraints. The authors designed the proposed behavioral services by integrated flow dependency graph in Business Process Execution Language (BPEL) model that are simulated by the automata Raspberry platform. The systematic results establish the possibility of the proposed method than the other benchmark mechanisms. The main weakness of this research is that the authors did not consider the QoS attributes for evaluating the service selection process.

Montori et al. (2017) proposed a monitoring-based service composition architecture called SenSquare[5] in IoT smart cities. This architecture is based on semantic-aware mobile crowd-sensing that predicts the user experiments based on available data streams for composing the suitable services in smart cities. This approach was implemented using data mining classification approach to evaluate the feasibility of the proposed service composition approach.

Ara et al. (2014) proposed a Web-of-Objects service selection and composition framework in the IoT application layer. The proposed framework provides a semantic functional service and application service function to support the user-centric request dynamically. The authors implemented their framework by JSP/Servlets based GUI and SPARQL as the existing databases platform.

Bonte et al. (2017) presented a context-aware web service composition approach to support the flexible knowledge extraction and real-time processing of the service requests. This approach is divided into four main layers including an input layer for receiving data streams from the IoT sensors, semantic explanation layer, follow decision layer and service layer. Only the response time factor is analyzed and compared as the main weakness of this research.

Liu et al. (2013) presented a canonical PSO-based service composition approach according to the QoS attributes in IoT web services. This approach addresses the best service selection method for component-based applications using a cooperative evolution strategy. The simulation results display that the fitness value of the composition approach is feasible and efficient. The main weakness of this research is that the authors did not consider the other non-functional properties such as response time with the various periods in the simulation results.

Also, Li et al. (2014) proposed a meta-heuristic service composition approach based on QoS attributes in IoT web applications. This approach is based on the multi-population genetic algorithm that provides the best selection capability to compose the suitable services. The proposed approach is presented as a warehouse alarm system that specified some important quality attributes such as response time, reliability, and cost of the service composition approach. The experimental setup is implemented in MATLAB toolkit that illustrated the effectiveness of the proposed approach dynamically.

Vidyasankar (2015), and Vidyasankar (2016) presented an application platform for service composition approach in IoT. More used algorithms of the related researches are based on framework algorithm. For example, Vidyasankar (2016) presented a transaction-based IoT service compositions framework to evaluate the correctness principle of the ACID properties.

Yen et al. (2017) Kuemper et al. (2013) presented API web application discovery approach to cover selecting and composing cloud services in IoT environment. The main advantage of these studies includes minimum response time.

Chen et al. (2014) proposed a security-based social commitment method to select and compose the web services in SOA based IoT environment. The authors considered a dynamic adaptive filtering technique for direct and indirect trust feedbacks to decrease the response time and trust preference. The filtering technique is based on the friendship similarity of the trust feedbacks by considering the weighted user satisfaction graph. The service composition approach is applied according to the utility rate of each service that the users receive from friendship similarity scores.

Chen et al. (2015) presented a RESTful web service composition approach based on distributed IoT device management. The presented approach uses a social network model to show the relationship between the IoT services and the upper layer applications. Also, this approach provides the dynamic collaboration between smart objects and user requirements heterogeneously. The suitable services are chosen with a hybrid service selection method by three dimensions factors including location-based, type-based and correlation-based service selection. The experimental results are applied to a real data set from a smart home care system such as dining room, kitchen, bedroom, office room and living room. The running time factor is evaluated for some critical scenarios. Of course, there is no evolutionary and complex algorithm for evaluating this approach in this study.

Chen et al. (2016a) presented a trust-based web service composition approach according to the security-based relationship between trust convergence and trust variability in the IoT devices. This approach uses a table-lookup strategy for addressing the dynamic attacks analysis. The presented approach demonstrates the feasibility of the trust values based on the response time of the composition method according to the cooperative and community factors in a smart city air pollution detection system as a technical case study.

4.2.4.1.1. Analysis of the reviewed data-oriented service composition. Table 9 illustrates the categorization of the above studies and the effective factors to analyze the composition approaches in IoT. The specified case studies in the data-oriented composition approach include social networks, urban computing, mobile applications, smart cities and healthcare systems. Also, most research studies implemented their proposed approach with non-heuristic algorithms in the IoT.

Table 10 explains a side by side valuation for the above studies using evaluation factors in IoT. The following factors include availability, time, scalability, cost and reliability. Also, in the data-oriented approaches, most research studies evaluated their proposed approach in the time and availability conditions.

4.2.4.2. Cloud-SaaS service composition approaches. This subsection shows the cloud-SaaS service composition approaches in IoT. In addition, we review the selected approaches in the service composition according to QoS factors. Finally, the cloud-SaaS approaches will be compared.

Yang et al. (2016) proposed a dynamic service selection and composition framework based on the event-driven cloud manufacturing model. The proposed approach focuses on the big data platform of the resource allocation process based on syntactic composition methods. Of course, there is no implementation and simulation for evaluating this framework in the IoT cloud manufacturing environment.

Zhang et al. (2014b) presented an asynchronous BPEL framework to compose the RESTful web services. This framework is based on a

[5] https://github.com/alainrk.

Table 9
Categorization of recent studies and other information in data-oriented service composition approaches.

Research	Main idea	Case study	Advantage	Weakness	Algorithm type
(Urbieta et al., 2017)	context-aware behavioral services	Smart cities	• High scalability • Low time	• High cost • Low efficiency	Non-Heuristic
(Montori et al., 2017)	monitoring-based architecture	Mobile application	• Low time • High reliability	• Low availability • Low scalability	Non-Heuristic
(Ara et al., 2014)	Web-of-Objects framework	Urban computing	• High scalability • Low time • High availability	• High cost • High complexity	Non-Heuristic
(Bonte et al., 2017)	flexible knowledge extraction	e-Home Care	• High scalability • Low time • High availability	• High complexity	Non-Heuristic
(Vidyasankar, 2015)	Transaction-based framework	Healthcare system	• Low time	• High cost • Low scalability	Non-Heuristic
(Vidyasankar, 2016)	Consistency-based approach	Healthcare system	• Low time • High availability	• High cost • Low scalability	Non-Heuristic
(Liu et al., 2013)	canonical PSO-based	Web applications	• Low time • High reliability • High availability	• Low scalability • High complexity	Meta-Heuristic
(Li et al., 2014)	multi-population genetic algorithm	Warehouse alarm system	• Low time • Low cost	• Low scalability • High complexity	Meta-Heuristic
(Yen et al., 2017)	API service discovery	Web applications	• Low time	• Low scalability • High complexity • High cost	Non-Heuristic
(Kuemper et al., 2013)	API web application approach	Web applications	• Low time	• Low availability • High complexity	Non-Heuristic
(Chen et al., 2014)	Table-lookup strategy	Social networks	• High availability • Low time	• High cost • Low scalability	Heuristic
(Chen et al., 2015)	RESTful web service composition	Social networks	• High availability • Low time	• High cost • Low scalability	Non-Heuristic
(Chen et al., 2016a)	Trust-based web service composition	Social networks	• High availability • Low time	• High cost • Low scalability	Non-Heuristic
(Chen et al., 2016b)	Secure-aware social commitment	Social networks	• High scalability • Low time	• High cost • High complexity	Heuristic

Table 10
A side by side comparison of the existing QoS factors in the data-oriented service composition approach.

Research	Availability	Time	Security	Cost	Reliability	Syntactic/Semantic
(Urbieta et al., 2017)	✓	✓	✗	✗	✗	Semantic
(Montori et al., 2017)	✗	✓	✗	✓	✓	Semantic
(Ara et al., 2014)	✓	✓	✓	✗	✗	Semantic
(Bonte et al., 2017)	✓	✓	✓	✓	✗	Semantic
(Vidyasankar, 2015)	✓	✓	✗	✗	✗	Syntactic
(Vidyasankar, 2016)	✓	✓	✗	✗	✗	Syntactic
(Liu et al., 2013)	✓	✓	✗	✓	✓	Syntactic
(Li et al., 2014)	✗	✓	✗	✓	✓	Syntactic
(Yen et al., 2017)	✗	✓	✗	✗	✗	Syntactic
(Kuemper et al., 2013)	✗	✓	✗	✗	✗	Syntactic
(Chen et al., 2014)	✓	✓	✓	✗	✓	Syntactic
(Chen et al., 2015)	✓	✓	✓	✗	✓	Syntactic
(Chen et al., 2016a)	✗	✓	✓	✗	✗	Syntactic
(Chen et al., 2016b)	✓	✓	✓	✓	✗	Syntactic

centralized platform to connect between the client requests and service providers. The experimental evaluations show that the authors compared the presented framework with its synchronous framework. As the weakness, this research doesn't evaluates the proposed composition approach without considering other composition methods.

Palade et al. (2017) presented a semantic service registration, discovery, and composition framework in the middle-ware IoT environment. The experimental results are evaluated with a component-based workflow that the response time is compared for some technical scenarios. The main defect of this study is that the authors have not considered the scalability and heterogonous service nodes in their approach.

Finally, Liu et al. (2012) presented an architecture for cloud-based service composition in IoT environment. This study provided a lightweight semantic model to illustrate the context-aware web services in IoT heterogeneously. This architecture has three layers including intelligent service layer, service and provisioning management layer and an intelligent sensing layer. This study recommended an equivalent simplification technique based on formal methods to composition approach. The main weaknesses of this study are that high energy and high-cost problems.

4.2.4.2.1. Analysis of the reviewed cloud-SaaS service composition approaches. Table 11 explains the categorization of the above studies and the effective factors to analyze the composition approaches in IoT. The specified case studies in the cloud-SaaS composition approach include manufacturing systems, energy-based weather and web service workflow. All of the existing cloud-SaaS service composition approaches applied the non-heuristic algorithms in service composition methods.

Table 12 explains a side by side valuation for the above studies using evaluation factors in IoT. The following factors include time, security, energy, and reliability. In the cloud-SaaS approaches, most

Table 11
Categorization of recent studies and other information in cloud-SaaS service composition approaches.

Research	Main idea	Case study	Advantage	Weakness	Algorithm type
(Yang et al., 2016)	Dynamic event-driven approach	Manufacture system	• Low time • Low cost	• Low availability • Low scalability	Non-Heuristic
(Zhang et al., 2014b)	asynchronous RESTful framework	Web service workflow	• Low time • Low cost • High reliability	• Low availability • High complexity	Non-Heuristic
(Palade et al., 2017)	middle-ware dynamic framework	Smart cities	• Low time • Low energy	• High complexity • High cost	Non-Heuristic
(Liu et al., 2012)	Mobile API framework	Mobile application	• Low time • High security	• High cost • High energy	Non-Heuristic

Table 12
A side by side comparison of the existing QoS factors in cloud-SaaS service composition approaches.

Research	Time	Energy	Cost	Reliability	Syntactic/Semantic
(Yang et al., 2016)	✓	✗	✓	✗	Syntactic
(Zhang et al., 2014b)	✓	✗	✓	✓	Syntactic
(Palade et al., 2017)	✓	✓	✗	✗	Semantic
(Liu et al., 2012)	✓	✗	✗	✓	Semantic

research studies evaluated their proposed approach in the time factor.

4.2.4.3. Multi-agent service composition approaches. This subsection shows the multi-agent service composition approaches in IoT. In addition, we review the selected approaches in the service composition according to QoS factors. Finally, the multi-agent approaches will be compared.

Ko et al. (2016) presented a multi-agent service composition approach in an urban computing environment that discovers and selects possible service nodes according to the smart objects information. This approach is based on semantic attributes of the QoS properties for selecting the smart objects in IoT. The main benefit of this research is that the authors provided a Semantic Activity Description Model (SADM) to utilize the social aspects of the mobile devices in urban computing. This model has four main steps for processing the semantic-aware service composition approach including activity selector, task composer, task recommender, and execution coordinator. The authors evaluated the proposed approach by a real dataset based on the number of the user sessions and smartphones with Eclipse Java environment. The advantages of this study include high optimality and low computation time. On the other hand, this study suffers from low validity and low availability.

Wang et al. (2013) presented a hybrid service composition and delivery approach based on multi-agent methods in IoT. This approach addresses third-party business architecture for service providers to manage service orchestration models with dynamic IoT devices. The fundamental of this approach includes the open access interface between end-user and service, service lifecycle management, hybrid service composition and delivery, service enabler container and infrastructure support service. The main advantages of this study are reducing the deployment response time, decreasing discovery time and high efficiency in task processing time.

Also, Ciortea et al. (2016) proposed a decentralized agent-based service mashup selection and composition to support the API composition applications. This approach presented a dynamic open-source architecture to enable a realistic IoT application that navigates several smart IoT devices heterogeneously. This study has some main benefits such as low time, high scalability, but its weaknesses are high cost and high complexity.

In other studies, Wanigasekara (2015) and Wanigasekara et al. (2016) presented an agent-based service composition approach on the mobile applications according to semi lazy bandit mechanism. The time and scalability factors are improved in these studies.

4.2.4.3.1. Analysis of the reviewed multi-agent service composition approaches. Table 13 illustrates the categorization of the above studies and the effective factors to analyze the composition approaches in IoT. The specified case studies in the multi-agent composition approach include social networks, urban computing, and mobile applications. Also, most research papers implemented their proposed approach in the IoT platform. The applied methods in the above studies are based on heuristic algorithms.

Table 14 explains a side by side valuation for the above studies using QoS factors in IoT. The following factors include availability, time, scalability, cost and reliability. Also, in the multi-agent approaches, most research studies evaluated their proposed approach in the availability, time and cost conditions.

5. Discussion and comparison

Previous sections described the review process of the selected studies in service composition approaches of IoT. In this section, a statistical analysis of declared composition approaches in IoT is deliberated. Also, we present the analytical reports of the technical questions that plan in section 3 as follows:

Table 13
Categorization of recent studies and other information in multi-agent service composition approaches.

Research	Main idea	Case study	Advantage	Weakness	Algorithm type
(Ko et al., 2016)	User-centric service composition	Urban computing	• High availability • Low computation time	• low validity • low availability	Heuristic
(Wang et al., 2013)	Third-party service composition	Agriculture monitoring service	• Low deployment time • Low discovery time • High efficiency	• Low scalability • High complexity	Heuristic
(Ciortea et al., 2016)	Decentralized Service Mashups composition	Social networks	• Low time • High scalability	• High cost • High complexity	Heuristic
(Wanigasekara, 2015)	Semi Lazy Bandit Service composition	Mobile APIs	• Low time	• High cost • Low efficiency	Heuristic
(Wanigasekara et al., 2016)	Intelligent bandit hybrid composition	Mobile APIs	• Low time • High scalability	• High cost • High complexity	Heuristic

Table 14
A side by side comparison of the existing QoS factors in multi-agent service composition approaches.

Res.	Availability	Time	Scalability	Cost	Reliability	Syntactic/Semantic
(Ko et al., 2016)	✓	✓	✗	✓	✗	Semantic
(Ciortea et al., 2016)	✓	✓	✗	✗	✗	Syntactic
(Wanigasekara, 2015)	✗	✓	✓	✓	✗	Syntactic
(Wanigasekara et al., 2016)	✓	✓	✗	✓	✗	Syntactic
(Wang et al., 2013)	✗	✓	✗	✗	✓	Syntactic

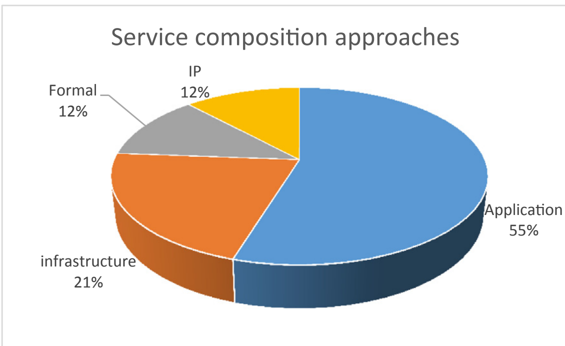

Fig. 6. Percentage of the presented service composition approaches in IoT.

- AQ1: What service composition approaches are applied for IoT?

Fig. 6 presents a comparison side of the service composition approaches up to now according to the proposed taxonomy in section 4. We categorized four service composition approaches that includes application-based, infrastructure-based, formal-based, and IP-based approaches. The application-based approach has the highest percentage of the composition usage by 55% in the literature. Of course, infrastructure-based service composition has 21%, formal-based has 12%, and IP-based has 12% usage for composing IoT services.

- AQ2: What target platforms are selected for service composition in IoT?

The target platform prepares an autonomous connection between the application and device layers of IoT. The perfect platform will coordinate with any associated hardware and appropriate applications for executing the IoT elements. According to Fig. 7, we observed that embedded platform has most usage with 41%, WSN platform has 24% and cloud platform has 21%.

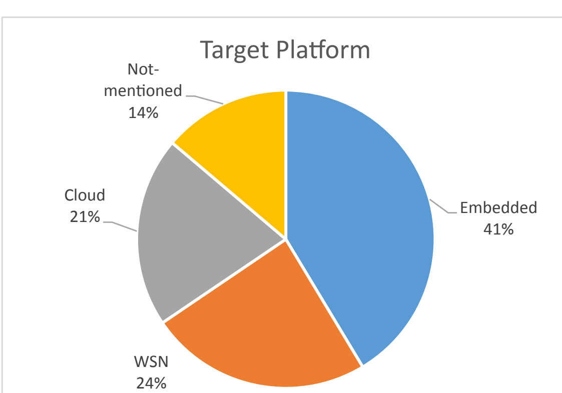

Fig. 7. Percentage of the target platforms for service composition approaches in IoT.

- AQ3: What measurement environments are applied to evaluate the service composition in IoT?

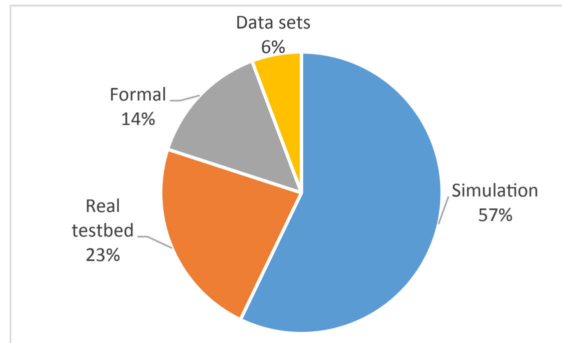

Fig. 8. Percentage of the presented measurement environments in the literature.

According to Fig. 8, we observed that the 57% of the research studies used simulation environment to evaluate the proposed case studies in the IoT platform. In addition, 23% of the studies implemented a real test-bed environment to apply the composition approach in the IoT environment. Also, we observed that 14% of the case studies proved their experiments using formal structures. Finally, we observed that 6% of the current papers used the analyzing methods such as prediction for evaluating their case studies using data sets.

- AQ4: What popular simulation and modeling tools are used for service composition approaches in IoT?

Fig. 9 shows the statistical percentage of the modeling and simulation tools that applied for this literature review. The Eclipse platform is the most percentage of using the simulation environment of case studies in service composition studies with 25%. The MATLAB toolkit has 25% of usage for modeling and simulation tool. Also, Petri-net environment is the most specification and simulation platform to prove the correctness of the formal-based service composition approaches.

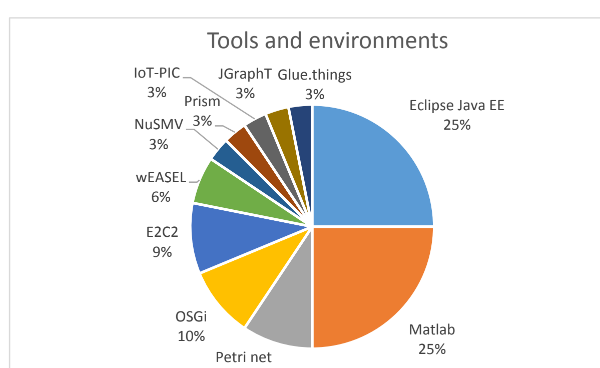

Fig. 9. Percentage of the presented popular tools and simulation environments in the literature.

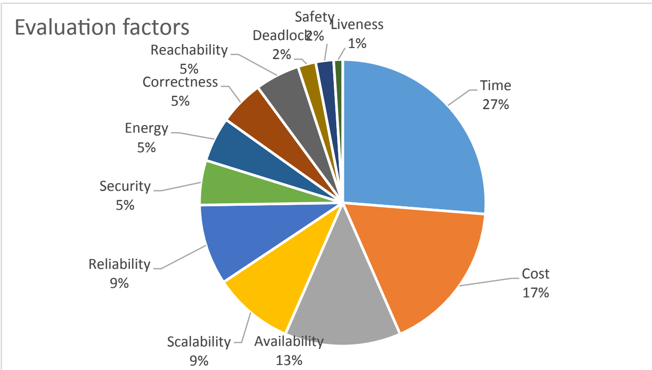

Fig. 10. Percentage of evaluation factors of service composition in the literature.

- AQ5: what evaluation factors are applied in service composition in IoT?

The non-functional properties as the evaluation factors are compared to the service composition approaches in Fig. 10. The statistical percentage of the evaluation factors presents that the response time factor has most usage in the evaluation of the composition approaches by 27%, the cost has 17%, availability has 13%, scalability 9%, reliability 9%, security 5%, energy 5%, correctness 5%, reachability 5%, deadlock 2%, safety 2% and liveness 1%.

- AQ6: What are the current algorithms used in service composition in IoT?

Due to the AQ6, the used algorithms in the service composition approaches are categorized into three groups. These groups and their statistic percentages are presented in Fig. 11. We observed that the highest percentage of research is done in non-heuristic algorithms.

Fig. 12 presents the distribution of the research papers per each service composition approach in IoT. According to this diagram, the application-based approach discovers most published papers in service composition in IoT by 15 journal articles and 8 conference papers. In addition, infrastructure-based approaches have a most published study with 6 journal articles.

Table 15 displays the distribution of the research papers per publication in the literature. In addition, country and quality rank of each journal illustrated. IEEE Transaction of Service Computing journal involved additional authors to the field of discovering the influence of refactoring on QoS-based service composition than any other journals. Most of the studies in the service composition are published in ICSE, ICWEW, ICSC, ICWS and other major conferences. Between 42 technical studies, 24 articles were published in major journals including TOSC, TODCS, IIoT, FGCS, and JNCA. A list of distribution of articles per publication is presented in Table 15.

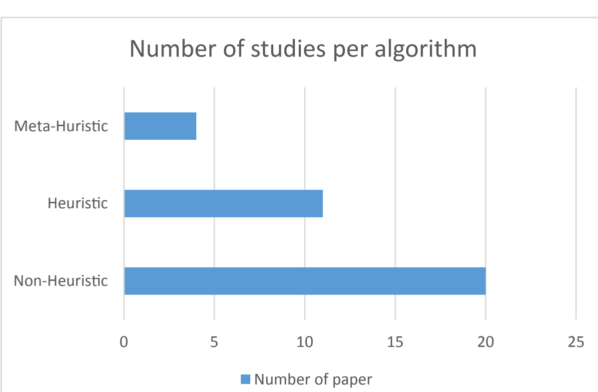

Fig. 11. A number of used algorithms in service composition approaches in IoT.

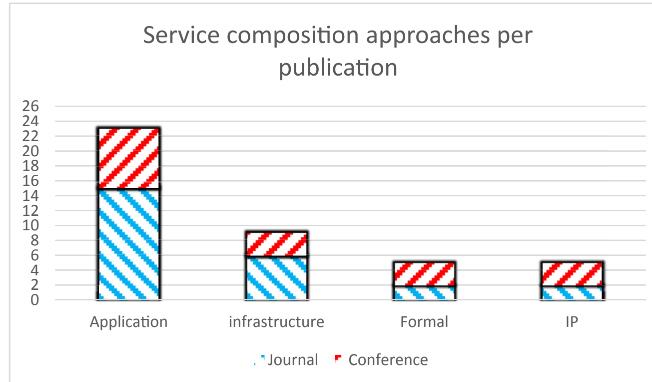

Fig. 12. The service composition approaches per publication.

5.1. Open issues

Typically, the service delivery speed, price and response time of services are impressive for consumers without considering the number of cloud providers and service location. Also, some important challenges effect on improving QoS factors in service composition approaches. Due to applying the SLR method on the data collection of the service composition approaches, the following research challenges as the open issues are presented that are not addressed exactly by the research studies as the AQ7.

- AQ7: What are the open perspectives and future challenges of service composition in IoT?

5.1.1. Trust and privacy

Trust management is a critical challenge for data access and data storage on IoT platforms. The trust-based similarity methods provide a safe interconnection between smart objects and user requests to support the political conclusions and permanency. The key challenge of this topic is that the smart objects should support a safe condition for the critical environment such as health-care systems. In addition, privacy issue is another main concern in IoT environment which emphasizes on protection of both users' and service providers' privacy precedencies. According to pervasive use of numerous diverse services, it can be imaginable to deliver purposely or unintentionally some critical and personal users' or even providers' information along with requested composited services to the others who are not authorized to access them. The main challenge of this matter is that a protection model for user's or service providers' privacy preferences should be offered for contribution for protecting the critical information in service composition process.

5.1.2. Energy

IoT devices are geographically distributed and computation in such distributed environment can be more energy efficient in comparison with the centralized cloud model. The association between battery life and coverage of sensors can be enhanced by distribution of load balancing in all of the nodes. By increasing energy and power consumption related to using the cloud datacenters, it has become a crucial environmental concern. The energy consumption problem particularly become a significant matter when data transferring into a cloud datacenter located anywhere far from the user physical location. Discovering and selecting appropriate services from nearest geographical cloud datacenters can decrease the level of energy consumption in IoT environment. Also, this challenge conducts to paying attention in service composition techniques and models that try to use

Table 15
List of distribution of the articles per Publications.

No	Publisher	Source	Q metric in 2017	Country	Number
1	IEEE	IEEE Internet of Things (IIoT)	Q1	United States	2
2	IEEE	IEEE Transactions on Services Computing (TOSC)	Q1	United States	2
3	IEEE	IEEE Transactions on Dependable and Secure Computing (TODCS)	Q1	United States	1
4	ACM	ACM Transactions on Internet Technology (ToIT)	Q1	United States	1
5	Elsevier	Journal of Innovation in Digital Ecosystems	Q1	United States	2
6	Elsevier	Future Generation Computer Systems (FGCS)	Q1	Netherlands	2
7	Elsevier	The Journal of China Universities of Posts and Telecommunications	Q1	China	1
8	Elsevier	Journal of Network and Computer Applications (JNCA)	Q1	United States	2
9	Elsevier	Manufacturing Letters	Q1	Netherlands	1
10	Springer	Journal of Supercomputing	Q1	Germany	1
11	Inderscience	International Journal of Ad Hoc and Ubiquitous Computing	Q1	United Kingdom	1
12	Springer	Annals Telecommunications	Q1	France	1
13	Springer	Knowledge Information Systems	Q1	Germany	1
14	Sage	International Journal of Distributed Sensor Networks	Q2	United States	2
15	Springer	Mobile Network Applications	Q2	Netherlands	1
16	Taylor and Francis	Automatika	Q2	United Kingdom	1
17	IEEE	China Communications	Q2	China	1
18	Inderscience	International Journal of Computational Intelligence Systems	Q3	United Kingdom	1

less number of clouds or IoT resources.

5.1.3. Context-aware computing

Context-aware processing would help the IoT with new data that can be utilized for new applications and getting a better knowledge establishment from the smart objects. Context-aware processing additionally recovers the first utilization of ontologies as wellsprings of learning, remaining a pending issue that is legally joining with the IoT smart objects. The main challenge of this topic is considered as an on-the-fly architecture to navigate the user interactions on the existing smart objects in IoT.

5.1.4. Interoperability

Interoperability (Arunkumar and Venkataraman, 2015; Rezaei et al., 2014) is one of the important factors to exchange data and resources between users, processes and smart objects in IoT. The main key challenge of interoperability that contributes to expose the full potential of the IoT is developing open-source frameworks in order to provide seamless connection Therefore, a set of standards should be defined globally to enable horizontal platforms with the abilities of communicability, operability, and programmability across devices, operating systems and applications without any concern about model or manufacturer or even industry. Some other remaining challenges of this are including developing scalable architectures to interact with heterogeneous smart objects and data centers, and also providing dynamic and adaptive interoperable architectures for ultra-large scale IoT applications. With respect to heterogeneity of diverse services in cloud centers and IoT environment, working on applicable frameworks, models and techniques for dynamic service composition systems in such platforms and architectures should be required to provide boundless connection.

5.1.5. Resource management

IoT nodes generally possess limited storage and computational power while their workloads are enormous. Therefore, efficient use and managing the smart devices is essential in the IoT environment. In general, resource management includes some issues like provisioning, scheduling, load balancing and service composition which can be leaded to more studies and efforts. In addition of allowing mobility of smart devices with relocation property to make optimal use of the available resources, another main challenging parts of resource management can be the service composition methods that should apply various services in an integrate manner to provide proper composited service for making efficient resource management.

5.1.6. Response time

Interaction between IoT smart devices can influence on response time of service discovery and selection processes to minimize delivery time for final composited service that is sent to the end user. Sensors convergence and smart objects negotiations are key factors that can effect on the time of final service composition procedure in the interaction between IoT devices.

5.1.7. Cost

Service providers have an interactive business with their own costumers to achieve cost effective supply chain for increasing composited service ordering. One of the most important challenges of this matter is that the IoT smart devices can have competitive behavior for selling smart services such as health-care monitoring, smart home-care monitoring, critical equipment industry monitoring and financial transactions management. With respect to today's business competition atmosphere and financial considerations, the cost factor is a crucial concern for users to select them as well as the service providers to provide them. Therefore, providing cost effective service composition methods which meet other required QoS factors should be considered in the studies.

5.1.8. Formal verification

The concept of the formal specification and verification describes a powerful mathematical proof to evaluate the correctness of the service composition approach as an NP-hard problem in IoT platforms (Souri and Jafari Navimipour, 2014; Keshanchi et al., 2017; Safarkhanlou et al., 2015b). Assessing the accuracy of the service composition process in the IoT critical systems such as healthcare systems is one of the main crucial challenges. In IoT, service nodes are specified as the middle layer between smart objects by a composition scenario and user's applications. In addition, a rule-based behavior is shown to navigate the smart objects in IoT. The existing rule-based behaviors have complex interactions between user requests (Safarkhanlou et al., 2015b). Therefore, analyzing the correctness of the complex communication among smart services and IoT platforms by means of formal verification approaches is a main challengeable topic (Souri and Norouzi, 2015b). Some critical issues are existed to establish the smart objects such as security (Souri and Hosseini, 2018), migration, data replication (Azari et al., 2018; Mesbahi et al., 2017) that have the complex behavior in IoT platforms (Rahmani et al., 2017). The main challenge of this area is finding an appropriate and powerful tool for modeling and verification of the service composition approach in IoT with a large number of the state space.

In this review, we performed a detailed research of the literature based on the finding of more than 80 authors and different works. However, with respect to the growing trend of studies and efforts in this field, it is not possible to confirm that all of the studies were considered, because the research finished in 2017.

6. Conclusion

This review presented an SLR-based research on service composition approaches in IoT. During this research, we contracted a comprehensive understanding addicted to the service composition and considerations on open issues to synthesize the collected data. In this literature, we presented the SLR-based method by applying the exploration query on 130 studies that were published between 2012 and 2017. Finally, we examined 42 studies that focused on the service composition in IoT environments. We observed that the most used composition approach for explaining service selection and the recommendation was application-based (55%). According to AQ2, we observed that embedded platform has most usage with 41%, WSN platform has 24% and cloud platform has 21%. Also, with respect to the AQ3, we observed that the 57% of the research studies used simulation environment to evaluate the proposed case studies in IoT platform. In addition, 22% of the studies implemented a real test-bed environment to apply the composition approach in IoT environment. For simulation and modeling tools, we observed that the Eclipse platform is the most percentage of using the simulation environment of case studies in service composition studies with 25% based on AQ4. The MATLAB toolkit has 25% of usage for modeling and simulation tool. Also, Petri-net environment is most specification and simulation platform to prove the correctness of the formal-based composition approaches. According to AQ5, The statistical percentage of the evaluation factors presents that the response time factor has most usage in the evaluation of the composition approaches by 27%, the cost has 17% and availability has 13%. Due to the SLR-based method, we may not have evaluated all of the existing studies. Therefore, some limitations of this literature include that the non-English and non-peer reviewed papers, book chapters, survey articles and editorial papers are omitted. We believe that this literature review addresses the conceptual features of the service composition approaches in IoT environment. Also, this overview helps the researchers and specialists to perform consequent examinations in general comprehension of this field. As the future work, we have recognized that there is an essential matter to assess further exploration at the evaluation, development, and proving complex service composition approaches in IoT. Also, some critical case studies such as trust and privacy mechanisms can be considered exactly and deeply in the QoS-aware service composition approaches with high security coverage.

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