Received 16 April 2024; accepted 3 May 2024. Date of publication 20 May 2024; date of current version 31 May 2024.
Digital Object Identifier 10.1109/OJCOMS.2024.3400981

A Review of Service Selection Strategies in Mobile IoT Networks

ABDESSALEM MOHAMED HADJKOUIDER[1], CHAKER ABDELAZIZ KERRACHE[2], AHMED KORICHI[1], YESIN SAHRAOUI[3], CARLOS T. CALAFATE[4] (Senior Member, IEEE), SAHRAOUI DHELIM[5], AND ASMA ADNANE[6]

[1]Department of Computer Science and Information Technology, Kasdi Merbah University of Ouargla, Ouargla 30000, Algeria
[2]CLaboratoire d'Informatique et de Mathématiques, Université Amar Telidji de Laghouat, Laghouat 03000, Algeria
[3]National Higher School of Artificial Intelligence, Algiers 16000, Algeria
[4]Computer Engineering Department (DISCA), Universitat Politècnica de València, 46022 Valencia, Spain
[5]School of Computer Science, University College Dublin, Dublin 4, D04 V1W8 Ireland
[6]Computer Science Department, Loughborough University, LE11 3TU Loughborough, U.K.
CORRESPONDING AUTHOR: C. A. KERRACHE (e-mail: ch.kerrache@lagh-univ.dz)

This work was supported in part by MCIN/AEI/10.13039/501100011033 under Project TED2021-130890B-C22 and Project PID2021-122580NB-100; in part by the European Union NextGenerationEU/PRTR; and in part by the "ERDF A way of making Europe."

ABSTRACT With the proliferation of service-oriented architectures, the ubiquity of mobile networks, and an expanding spectrum of services available to users, the service selection process has become paramount in designing and implementing contemporary applications. Service selection strategies in mobile networks involve choosing the optimal services from many available options based on QoS (quality of service), bandwidth, and mobility, ultimately augmenting network efficiency and user experience. Nonetheless, particular challenges can impact the efficacy of these strategies. This paper presents a comprehensive *survey of service selection strategies in mobile networks, transitioning from traditional approaches to emerging techniques*, while also introducing a taxonomy classifying service selection methods based on criteria including mobile devices as service providers, architectural perspectives, computing devices allocation, evaluation metrics, and service selection methods. Additionally, We offer insights into the latest QoS-aware and energy-centric service selection methodologies, while addressing challenges related to battery life and energy efficiency, Quality of Service (QoS), security and privacy, as well as scalability and resource management. Additionally, we discuss prospective trajectories and future direction.

INDEX TERMS Service selection, mobile networks, QoS, IoT.

I. INTRODUCTION

MOBILE networks have become an integral part of our lives, connecting us to various services and applications wherever we go. From making calls and sending text messages to accessing the Internet and streaming media, mobile networks provide us with the means to stay connected and access information on the go Fig. 1. However, with the increasing complexity and diversity of services available, it has become crucial to have practical service selection mechanisms in place [1], [2], [3].

With the emergence and integration of the Internet of Things (IoT), mobile networks underwent substantial transformations, resulting in the growth of what are now known as mobile Internet of Things networks. This convergence has prepared the way for a wide range of applications, including smart homes and health monitoring, industrial automation, and environmental sensing, which benefit from mobile networks' increased connection and flexibility [4]. In the context of Mobile IoT, service selection is the process of selecting the most appropriate services from a pool of available options that best meet the specific needs and preferences of users or applications while taking into account various constraints and criteria, such as quality of service (QoS), energy efficiency, security, cost, and latency. This

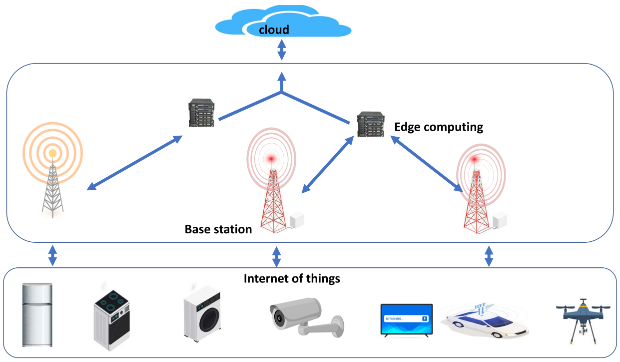

FIGURE 1. service IoT Networks.

selection procedure is critical for maximizing user experience and system performance in mobile situations when resources are limited and conditions can change rapidly [3].

A significant challenge in service selection in mobile IoT networks is determining the optimal services that fulfill users' needs, considering the diverse range of capabilities, variations in latency, performance attributes, and the extensive array of available services. These services span from fundamental voice and messaging functions to data-intensive applications like video streaming, Augmented Reality (AR), online gaming, and IoT-based applications such as smart homes, wearable devices, and industrial IoT [5]. To address these challenges, Service selection in mobile IoT networks has rapidly become an attractive topic for researchers and industries by leveraging various techniques, Decision-Making Algorithms [6], machine learning-based algorithms [7], and game theory models [8].

The introduction of fifth-generation 5G technology has further revolutionized service selection in mobile networks and played a crucial role in enabling wireless communication and connectivity for mobile devices, allowing people to stay connected and access a wide range of services on the go [9], [10].

On the other hand, The QoS requirements significantly influence the service selection process. which involves commonly used metrics in the service selection, such as latency, bandwidth, reliability, and cost [11]. Different algorithms and techniques have been applied to assist users in selecting suitable Services, given that specific features, limitations, and prices characterize every service [12], [13].

Furthermore, cloud computing has gained significant traction as a predominant computing paradigm, driven by the proliferation of wireless network applications and the apparent limitations in resources and storage capacity for end users. This paradigm offers extensive computing resources, continually evolving and enhancing the methodologies available to help consumers choose the most appropriate services [14], [15].

this paper aims to offer a comprehensive overview of service selection within mobile networks, focusing on the employed strategies.

TABLE 1. List of acronyms.

Acronym	Definition
5G	Fifth-Generation
AHP	Analytic Hierarchy Process
ANP	Analytic Network Process
API	Application Programming Interface
BS	Base Station
CC	Cloud Computing
CV	Consumer Vehicles
GA	Genetic Algorithm
ILP	Integer Linear Programming
IoT	Internet of Things
IoV	Internet of Vehicles
MANET	Mobile Ad-hoc Network
MCDM	Multi-Criteria Decision Making Methods
MEC	Mobile Edge Computing
ML	Machine Learning
PV	Provider Vehicle
QoE	Quality of Experience
QoS	Quality of Service
REST	REpresentational State Transfer
RFID	Radio Frequency Identification
SAW	Simple Additive Weighting
SLR	Systematic Literature Review
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution
UAV	Unmanned Aerial Vehicle
UAVNET	Unmanned Aerial Vehicle ad hoc Network
VANET	Vehicular Ad-hoc Network
WS	Web Service
WSN	Wireless Sensor Networks

The rest of this paper is organized as follows. Section II provides a brief background to understand the main concepts of service selection in the mobile environment. and Section III provides the Existing Service Selection Works. Section IV presents the Proposed taxonomy for service selection approaches in mobile networks. Service selection solutions' methods and techniques are presented in Section V. Section VI discusses The main challenges and future directions. Finally, we conclude in Section VII.

II. BACKGROUND

We introduce in this section concepts and paradigms essential for readers to comprehend the proposed topic. Then, we proceed to review the main applications of service selection. Table 1 presents a comprehensive compilation of acronyms utilized in this research article to enhance the overall legibility and comprehension of the study.

A. USEFUL CONCEPT DEFINITIONS

- *Service selection:* Choosing the most suitable services from a pool of candidates is called service selection. This process relies on non-functional features, commonly known as Quality of Service (QoS) metrics, which include price, reliability, security, and reaction time. The quality of service selection may fluctuate over time due to its operation within a limited environment. Therefore, the system for selecting services must be flexible enough to accommodate consumer preferences. Consequently, it is feasible to substitute a service with an alternative that provides equivalent features and comparable or improved Quality of Service (QoS) during its lifespan [16].
- *Service discovery:* IoT service discovery and selection entail the thorough examination of services provided by IoT devices to pinpoint the most suitable options. This method takes into account the limitations inherent in IoT systems as well as the expectations of users, with the aim of improving the quality of service (QoS) [17].
- *Quality of Service (QoS):* QoS: It is the ability to achieve the desired level of performance regarding a set of parameters, such as cost, bandwidth, latency, delay, packet loss ratio, jitter, and throughput, among others. The QoS places greater emphasis on the considerations and criteria involved in the selection of services. The QoS traits are recognized and employed during service selection to enhance the discovery process and choose the best appropriate services from a pool of potential options [18].
- *Internet of Things (IoT):* The term IoT is semantically related to two words, "Internet" and "Things," where the Internet is known as the global system that uses TCP/IP protocol suite to interconnect different computer networks, while Things refer to any objects that surround us and have the capability to sense and collect data about its environment. Therefore, IoT can be defined as a global system based on an IP suite, in which objects equipped with sensors, radio frequency identification (RFID) tags, or bar-codes have a unique identity, operate in an innovative environment, and are seamlessly integrated into the information network by using intelligent interfaces [19]. IoT relies on a wide range of materials, network infrastructure, communication protocols, Internet services, and computing technologies [20]
- *Cloud Computing (CC):* CC refers to a specific approach for managing adjustable and scalable infrastructures. This involves utilizing remote servers to define data centers, deployed centrally on a worldwide scale [21]. According to Sunyaev et al. [22], the cloud computing platform provides various on-demand services categorized by usage tranches. These services include processing power, storage, development environments, bandwidth, and others.
- *Edge Computing (EC):* EC is a paradigm that extends the capabilities of CC to edge nodes, such as smart sensors, smartphones, smart vehicles, and edge servers. This paradigm enables computation and storage to be performed at the nearest level, typically within the Base Station of cellular mobile networks [23]. Edge devices connect to cloud data centers via the core network only when advanced processing is required [24]. Edge computing enhances the capabilities of cloud computing by facilitating the execution of computational tasks at the edge nodes. This approach is particularly beneficial for real-time applications and services that require low latency and high bandwidth. By distributing computation and storage closer to where data is generated and consumed, edge computing reduces network congestion and improves overall system performance.
- *Mobile Ad hoc NETwork (MANET):* MANET refers to a wireless network in which mobile devices establish communication without relying on a fixed infrastructure or centralized resources [25]. The devices can operate in either stationary or mobile configurations, enabling the formation, reconfiguration, and self-repair of networks in a dynamic or ad-hoc manner. MANETs have the potential to provide users with access to information and offer a more cost-effective alternative compared to conventional networking technologies. They can be used in scenarios where fixed network infrastructure is impractical, impaired, or impossible [26]. Some advantages of MANETs over fixed-topology networks include flexibility, scalability, and cheaper management expenses [27].
- *Vehicular Ad hoc NETwork (VANET):* VANET is a specific type of Mobile Ad-Hoc Network (MANET) designed for communication between vehicles in motion. It is established by employing the fundamental concepts of MANETs within the context of vehicular environments [28]. VANET is a decentralized wireless network that allows various mobile cars and connected devices to establish communication and exchange valuable information with each other [29].
- *Unmanned Aerial Vehicle (UAV):* a UAV refers to an aircraft without a human pilot. Instead, it is operated manually by an individual situated on the ground or autonomously by utilizing a software program [30]. UAV networks facilitate the interconnection of many UAVs. According to Kerrache et al. [31], these networks possess a wide range of potential applications, including but not limited to military surveillance, search and rescue missions, and various other uses. In an ad-hoc UAV network, a subset of UAVs is connected to the ground base stations, while all UAVs collectively establish an ad-hoc network. In this particular system, UAVs can establish communication channels with both other UAVs and the ground base stations [1].
- *Wireless Sensor Networks (WSNs):* WSNs are composed of numerous miniature devices that can communicate

with one another while operating under constrained power resources. These wireless sensors are strategically placed in a specific environment to detect and monitor various environmental phenomena [32]. Due to the limited power resources of sensor nodes, the data collected from the designated environment is transmitted directly to the base station.

B. STANDARDS AND TECHNOLOGIES

Various protocols and standards in IoT mobile networks enable devices to communicate seamlessly with the Internet. Support critical public safety functions. These standards are critical to the expanding environment of mobile networks, ensuring that devices communicate consistently, securely, and efficiently in an increasingly connected world. These standards include:

- **NB-IoT Standardization**: NB-IoT, a fundamental technology for the Internet of Things (IoT), was standardized in 3GPP Release 13 (LTE Advanced Pro). This standardization was an important milestone, showcasing the 3GPP's ability to quickly react to emerging market needs. NB-IoT is one of several technologies geared at addressing the IoT industry, demonstrating 3GPP's commitment to providing a diverse portfolio of technologies for operators to use based on their market requirements (3GPP) [33].
- **Advances in 5G for IoT**: The evolution to 5G Advanced (5G Advanced) involves important advancements with 3GPP versions 17 and 18, which focus on increasing radio access network features such as MIMO enhancements and dynamic spectrum sharing. These enhancements are critical for enabling new IoT use cases because they improve the network's ability to manage high mobility scenarios, increase robustness, and reduce user equipment power consumption. Release 17 includes substantial enhancements in beamforming, multiple-input and multiple-output (MIMO) operations, user equipment power reductions, and positioning [34]. These improvements aim to raise network performance and support ultra-reliable, low-latency communication (URLLC), which is critical for time-sensitive IoT applications such as industrial automation and remote-control applications.
- **3GPP's Role in IoT Standards**: 3GPP has helped shape IoT standards by developing a "portfolio of technologies" that includes NB-IoT, eMTC (also known as LTE Cat M1), and EC-GSM-IoT. These technologies support a wide range of IoT applications, including enhanced mobile broadband (eMBB) and ultra-reliable and low-latency communications (URLLC), which are critical for the next generation of IoT deployments. The standardization efforts include enhancements spanning numerous releases, with a focus on improving positioning, power efficiency, and compatibility for new IoT applications. With each release, 3GPP refines and expands IoT capabilities, guaranteeing that mobile networks can meet the diverse and changing needs of global IoT deployments (3GPP).
  Proximity Services (ProSe) over 3GPP networks is vital because ProSe is a key standard enabling direct connection between devices in LTE (Long Term Evolution) and beyond. ProSe, as specified by 3GPP, allows devices in close proximity to connect directly with one another via the LTE network, skipping the core network. This feature is notably useful for public safety applications, as it allows first responders to communicate in places where the network is overcrowded or non-existent [35]. It also creates chances for new commercial services and Internet of Things applications that benefit from direct device-to-device connectivity.

FIGURE 2. Service Selection Applications.

C. APPLICATIONS RELYING ON SERVICES SELECTION

-The service selection process is even more challenging. Selecting the best service that matches the end user's functionality and quality requirements is necessary. It involves determining the most suitable service that fulfills the user's requirements and optimizing the network resources to provide the desired level of quality and performance within various contexts, such as software development, cloud computing, service-oriented architectures, Internet of Things (IoT), Healthcare Systems, Network Management, E-commerce, Web Services, etc. Fig. 2 presents the Service Selection Applications.

- **Cloud Computing(CC)**: Within cloud computing, it is common for companies to encounter the need to make informed decisions regarding selecting cloud services. These services include a range of offerings, including but not limited to storage, computing power, and databases [36]. The primary objective of such decision-making efforts is to identify the most suitable cloud services that match the organization's specific goals, considering aspects such as performance, cost, security, and other important considerations. Service selection approaches assist organizations in making well-informed judgments regarding the choice of cloud service providers and the selection of service plans [37].

- **Internet of Things (IoT)**: Service selection is essential in IoT systems where various devices and sensors need to interact with each other to provide many services such as cameras, actuators, mobiles, homes, hospitals, etc., where this Technique helps choose the most appropriate services for data processing, storage, and analysis in IoT applications [38].
- **Healthcare Systems**: In healthcare, service selection strategies can be employed to choose suitable medical services to optimize patient care effectively. These strategies assist healthcare clinicians and administrators select the most appropriate services, treatments, and patient interventions. Such techniques include Health Information Systems, Emergency Medical Services, Personalized Medicine, Medical Imaging and Diagnosis, Telemedicine Services, etc. [39], [40].
- **Web Services(WS)**: Service selection is choosing the most suitable Web service from a pool of available services to fulfill a specific activity or demand, known as service selection. Different components of the services are evaluated during this phase to ensure the services satisfy the customer's demands. These aspects consist of metrics for Quality of Service (QoS), security, cost, etc. Based on the factors above, various Web services are evaluated and compared during the selection process, and select the best service for consumer demands [41], [42].
- **Smart cities**: Smart cities use sophisticated technology to enhance the overall well-being and standard of living of their citizens. Smart cities use high-tech to improve residents' lives. The challenge in this environment is finding and selecting data and services in this architecture to enhance citizen lives and nurture new innovative companies. These services include transportation, energy and environment, health and social service, crime and disaster prevention, education, demographics, logistics urban development and facility management, culture, tourism, and city administration [43], [44].
- **E-commerce**: E-commerce involves online purchases and sales. It is available on computers, tablets, smartphones, and other smart devices in various markets. E-commerce sells books, plane tickets, etc. E-commerce platforms use many services to manage product catalogs, payments, orders, customer support, and more. The service selection process is when the consumer selects the most suitable service from the available options. Therefore, choosing the best service requires applying methods and techniques. This process creates a comprehensive and competitive online platform [45].

III. EXISTING SERVICE SELECTION WORKS

This section reviews the existing service selection surveys in various fields. In addition, we present contributions and discuss the related work of Service selection in mobile networks in the second subsection.

A. EXISTING SERVICE SELECTION SURVEYS

Within the scope of mobile network service selection, the imperative to make informed decisions spans across an array of diverse domains, underscoring its pervasive significance in the realm of contemporary telecommunications. This multifaceted decision-making process is intrinsic to the effective utilization of mobile network services and contributes significantly to the evolving landscape of mobile communication technologies. A few reviews have surveyed the service selection problem in different environments; previous surveys related to this issue are summarized below (See Table 2). In this subsection, we discuss the existing literature on service selection. Authors [46] provide a review of the literature on QoS-aware dynamic Web service selection. It covers current QoS models and related calculation methods, examines and evaluates current service selection strategies and approaches, and highlights several weaknesses of existing algorithms. The work suggests several future study possibilities, such as trusted service selection. This survey also notes the difficulties of developing Web service applications and the need for in-depth research. By using a new classification method, the authors [47] surveyed, classified, and analyzed various service selection algorithms in the Internet of Things (IoT) environment under Quality of Service (QoS) constraints. The study identifies two main problems that need to be addressed by the research community to propose a suitable solution for the service selection problem: (i)Identifying the methods to design an appropriate IoT environment and determining the methodology for implementing the proposed solution. (ii) highlights the importance of an evaluation step for assessing the efficiency and effectiveness of the proposed solution. The authors [16] propose a taxonomy to categorize and compare different service discovery and selection techniques in IoT. The authors discuss the main challenges associated with service discovery and selection in IoT and how they differ from traditional service management approaches. It also explores the key factors that need to be considered when evaluating the quality of service (QoS) and quality of experience (QoE) for cloud services in IoT and how these can be measured and optimized. The authors [48] aim to Present a Systematic Literature Review (SLR) and study the current IoT service selection approaches where they Describe the main challenges of the IoT service selection and Provide an exact evaluation of discussed mechanisms using some important QoS metrics. Sun et al. [14] provide a comprehensive

TABLE 2. Comparison of the reviewed works about service selection.

Ref.	Year	Domain	Approach criteria
Han et al. [46]	2011	Web service	Analyze and discuss the strategies of services selection systematically
Abosaif et al. [47]	2020	Internet of Things (IoT)	Classify and analyze algorithms for service selection under QoS constraints.
Li et al. [48]	2020	Internet of Things (IoT)	Centralized, decentralized, and hybrid taxonomy
Achir et al. [16]	2022	Internet of Things (IoT)	Description methods, selection algorithms, and architectural aspects
Sun et al. [14]	2014	Cloud services	Analyze the five perspectives: decision-making techniques, data, parameters representation models, and characteristics of Cloud services.
Bouzary et al. [49]	2018	Cloud services	Selection criteria, objective function, algorithms, mapping approaches, and correlation awareness
Manqele et al. [50]	2017	Dynamic environments	Based on multi-agent approach, QoS, ontology, and functional requirements
Mhakur et al. [15]	2022	Cloud services	Eight dimensions considered: context, decision-making methods, cloud service performance parameters, purposes, simulation/language tools, datasets, domain, and experimental methods
Hosseinzadeh et al. [2]	2020	Cloud service, web service	MCDM-based service selection, classification service selection techniques according to the applied MCDM methods
thakur et al. [51]	2023	Cloud services,Internet of Things (IoT)	Description and investigation the Quality of Service based Cloud Service Composition (QoSCSC) from the perception of AI
Ghafouri et al. [52]	2022	Web Service	Classify the QoS prediction methods to select best service in web
Our work	2024	Internet of Things (IoT), Vanet,UAV	Decision-making and description methods, categories for service selection, provide a Taxonomy of service selection approaches in mobile networks

survey of state-of-the-art Cloud service selection approaches, analyzing them from seven perspectives: context, purpose, data representation models, selection techniques, selection parameters, methods for quantifying qualitative parameters, and criteria weighting methods. The authors classified Cloud service selection approaches into three categories: MCDM-based, multi-criteria optimization-based, and logic-based. In [2], the authors have highlighted the extensive use of multi-criteria decision-making (MCDM) techniques in service selection, specifically in determining the weight of quality of service (QoS) factors and ranking services provided by different service providers. The authors present a comprehensive classification of service selection schemes based on Multiple Criteria Decision Making (MCDM) and discuss their adaptation and application in various contexts, including Web service selection, Web service composition, and cloud service selection. The primary objective is to assist decision-makers in assessing the relative importance of each Quality of Service (QoS) factor and the ranking of services offered by different service providers. Another work has presented an exhaustive survey of the optimal selection and composition of cloud-based services [49]. It begins with a summary of recent research in cloud manufacturing, followed by a discussion of the SCOS (Service Composition and Optimal Selection) issue. The authors discuss the difficulties associated with the authenticity and dependability of QoS values, the significance of user behavior data, and the need to move towards automated and integrated service composition. The survey also presents recent advancements in six main areas of cloud manufacturing, including architecture, business modes, enabling technologies, resource modeling and scheduling, service virtualization, and task description. A survey for service selection has been investigated in dynamic environments. Manqele et al. [50] have analyzed various service selection approaches in dynamic environments and propose a method for selecting the most effective one based on certain factors. The proposed approach was tested by manipulating the relevant services description of available services, and the method was evaluated based on response time, recall, and precision metrics. The experiments showed that the content-based algorithm returned more relevant services to the user and took a shorter time. The authors also discuss the QoS constraints that must be considered when selecting a service, such as reliability, response time, cost, throughput, integrity, and platform/API. The authors [15] introduced a systematic review of existing cloud service selection approaches and offered a taxonomy based on a thorough literature study according to eight dimensions: decision-making methods, context, purposes, cloud service performance parameters, simulation/language tools, domain, datasets, and validation methods. The authors identify nine crucial challenges in selecting cloud services that require additional research. Comparing the Analytic Hierarchy Process (AHP) and the Analytic Network Process (ANP), the study concludes that AHP is superior without feedback and dependencies. In contrast, ANP is ideal for complex decision-making involving interdependencies between criteria and alternatives.

B. SERVICE SELECTION IN MOBILE NETWORKS

This section discusses the existing literature on service selection in mobile networks (See Table 3). It reviews various approaches and techniques for improving the process of service selection in mobile networks, such as game theory models, machine learning, and fuzzy logic. The strengths and limitations of each approach are evaluated, providing insights into the evolution of service selection mechanisms. In the UAV context, a new Game Theoretic approach was proposed for *Selection Services in UAV Clouds* (GTSSUC) [53] to enable normal users to select the most suitable UAV-Service-Provider. The proposed approach considers the user requirements and the qualities of the UAV provider to find the most adequate provider. The simulation advocates for the proposed method's efficiency in both network QoS and service gain.

In the same context, Brahimi et al. [54] investigated a *Game Theory approach for Cloud Services*(GTCS)in MEC- and UAV-enabled networks, enabling ordinary end-users to select the most suitable UAV service provider based on specific features, limitations, and prices. Hadjkouider et al. [8] introduced a Stackelberg game-based solution for service discovery and selection in the context of UAV-based mobile edge computing. The proposed game is efficient in terms of price and QoS metrics. It allows clients to determine the most appropriate provider while efficiently considering consumer preferences and service constraints.

Two Linear Integer Problem (LIP)-based optimization techniques [55] are proposed for selecting the optimal set of UAVs: Energy Aware Selection of UAVs (EAS) focuses on minimizing energy consumption, while Delay Aware Selection of UAVs (DAS) aims to reduce response times. DAS is particularly effective for optimizing operation time, while EAS is geared towards minimizing energy consumption. In the context of Vehicular Ad hoc Networks (VANETs), Brik et al. [56] introduced a novel game theory-based approach for managing service provisioning in vehicular cloud computing. This approach takes into account the benefits of each player and allows Consumer Vehicles (CVs) to select the most suitable Provider Vehicle (PV) based on their probability of interaction. CVs can choose to either Consume (C) or Not Consume (NC), while PVs can decide whether to Offer (O) or Not Offer (NO). However, this approach operates exclusively on a Vehicle-to-Vehicle (V2V) architecture and does not consider Vehicle-to-Infrastructure (V2I) interactions.

In [57], authors introduced a flexible approach for selecting a vehicular cloud service provider based on a link stability metric and linguistic quantifiers. The system efficiently handles user preferences and reduces latency while considering consumer preferences and service provider features. The ranking was refined by defining two unique operators: Least Satisfactory Proportion (LSP) and Most Satisfactory Proportion (MSP). Additionally, the work presented in [58] proposed a multi-agent/multi-objective interaction game system to manage on-demand service provision in a vehicular cloud based on a game theoretic approach and a Quality of Experience (QoE) framework. Three game approaches were developed to help drivers minimize service costs and latency while maximizing their privacy. Furthermore, the authors investigated the QoE framework for service provision in a vehicular cloud for various types of users.

Zhang et al. [59] investigated a Stackelberg game-based approach to address the challenge of service pricing and selection for IoT applications offloading in a multi-MEC system. The proposed method comprises two stages: in the first stage, the cloud service broker sets service prices and load-balancing strategies to maximize revenue, while in the second stage, IoT users determine the number of their generated application requests. The method of backward induction is employed to solve the game, and the effectiveness of the proposed scheme is validated through simulation results. In the same context, Singh et al. [60], analyzed the issue of IoT service selection, considering the IoT framework as a composition of three major components: things, communication, and computing. Subsequently, the quality-of-service (QoS) parameters associated with each of these components are discussed. Furthermore, the authors investigate a framework that presents a hybrid strategy for selecting IoT-based services, which combines the Analytic Hierarchy Process (AHP) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) approaches.

Process management in resource-constrained WSNs is a crucial topic that warrants significant attention to intelligently select services with optimal QoS values and residual energy. In [61], authors proposed an energy-aware QoS-guaranteed workflow management mechanism, a novel QoS model, an efficient service selection schema, and an adaptation mechanism for balanced energy usage in WSNs using Linear Programming (LP). The study also addresses the necessity for runtime modifications of component services based on residual energy and explores the trade-off between execution process changes and network lifetime.

C. SERVICE DISCOVERY IN MOBILE IOT NETWORKS

Service discovery in the Internet of Things (IoT) is critical for rapidly discovering and accessing services across several IoT networks. Multiple approaches have been presented to

TABLE 3. Comparison of the different works about service selection in mobile networks.

Ref.	Year	Technology	Technique used	Attributes	Dynamicity/Static (D/S)	Environment	Architecture
Hadjkouider [8]	2023	UAVs	Stackelberg game	Qos, price	D	MEC	Decentralized
Bousbaa [53]	2021	UAVs	Nash Equilibrium game	Delay, cost	D,S	Cloud Computing	Hyrarchical
Brahimi [54]	2023	UAVs	Nash Equilibrium game	Throughput,Delay, cost, energy	D,S	MEC	Decentralized
Motlagh [55]	2016	UAVs	Nash Equilibrium game	Delay,energy	D,S	—	Hyrarchical
Brik [56]	2018	VANETs	Nash Equilibrium game	QoS , costs	D,S	Cloud Computing	Hybrid
Tamani [57]	2017	VANETs	Fuzzy quantified, Linguistic quantifiers	QoS, user preferences	D	Cloud Computing	Decentralized
Aloqaily [58]	2016	VANETs	Nash Equilibrium	Latency, cost , privacy	D	Cloud Computing	Hyrarchical
Yang [38]	2020	IoT	Algorithm	QoS	D	—	Decentralized
Zhang [59]	2020	IoT	Stackelberg game	Price	D,S	MEC	Decentralized
Demir [62]	2021	IoT	Algorithm(OptSel,PAMSer)	QoS , energy	D	—	Decentralized
Singh [60]	2020	IoT	MCDM method	Qos	D	—	Decentralized
Tong [61]	2017	WSN	Linear Programming (LP)	Qos,energy	S	—	Decentralized

improve the service discovery processes in IoT contexts. Demir et al. [62] introduced a service discovery technique called Peer-Assisted Multi-Service Discovery (PAMSer) that is designed to be both highly scalable and reliable. The system aims to identify and pick services that fulfill the specified Quality of Service (QoS) criteria. This algorithm utilizes a peer-to-peer (P2P) research discovery technique to give real-time quality of service (QoS) information for services. It eliminates the requirement for periodic monitoring of services or flooding of search query messages, as seen in current systems. Furthermore, a selection optimization algorithm called Optimal Selection (OptSel) is proposed to enhance the selection process. The authors propose a deep reinforcement learning-based approach for selecting and composing moving IoT services [63]. The primary focus is on optimizing the composition process through learning algorithms. The project seeks to address key difficulties in IoT service composition by focusing on improving accuracy, scalability, and efficiency. The suggested method is evaluated using a detailed comparison to a parallel flock-based service discovery algorithm, which provides useful insights into its accuracy and effectiveness. Furthermore, the study contributes to the formal modeling of crowdsourced moving services by employing a spatiotemporal model to ease service discovery and composition, minimizing dependency on traditional indexing processes. Through these efforts, the study hopes to advance the state-of-the-art in IoT service composition, opening up new options for future research and development in this field. The study [64] proposes a latent-based recommendation system optimized for the Social Internet of Things (SIoT). It uses multi-modal features to generate latent item graphs targeted at increasing service recommendations. Extensive experimental evaluations are carried out, using real-world datasets and performance metrics like MAE, RMSE, Precision, Recall, and NDCG. The results show that the suggested system outperforms the baseline approaches in terms of accuracy and precision. In addition, the experimental setup includes comparisons with existing methodologies, a complete examination of item graphs formed from multi-modal features, and sensitivity analysis on important hyperparameters, which provide extensive insights into the system's performance and robustness. In [65] authors present a configurable distributed network service discovery system that employs stateless scanning technology and random destination address approaches to improve efficiency. This text discusses the use of the operating system protocol stack to thoroughly examine and establish connections, resulting in more precise service discovery. Moreover, the paper provides a collection of patterns that may be used to convert user-customized service descriptions into standard syntax. This helps to simplify the process of integrating these descriptions into the scanning tool ecosystem. A service discovery solution specifically designed for distributed embedded systems based on edge choreography has been proposed [66]. This solution utilizes Raspberry Pi machines at the IoT edge layer. The application assesses the use of the CPU and the duration of delays in various methods of exchanging messages, emphasizing the influence of a regular expression interpreter on the efficiency of the system. This study presents illustrations of message body structure for different delivery patterns, highlighting the incorporation of new services with a limited understanding of meaning. The paper [67] introduces a Web service selection method specifically developed to facilitate the worldwide optimization of Quality of Service (QoS) and dynamic replanning. This algorithm utilizes location matrix coding and integrates user feedback to improve the precision of service selection. The study conducts a thorough evaluation to determine the efficacy of several QoS measurement methods and ranking algorithms. User satisfaction metrics are used as the criteria for evaluation. Simulation studies are performed to verify the effectiveness of QoS-aware service discovery in satisfying consumers' requirements. Moreover, the paper discusses the difficulties related to harmonizing the comprehension of QoS indicators among consumers and service providers, highlighting the significance of this comprehension in enhancing service quality and satisfaction. A specialized Graph Neural Network (GNN) method designed for service discovery [68] is presented in large-scale Social Internet of Things (SIoT) networks, using the social connections between devices. The suggested approach's usefulness in facilitating fast service discovery across SIoT networks is demonstrated by simulated tests done on real-world datasets, evaluating various embedding strategies and clustering methodologies. The authors present a new technique, as described in [69], that focuses on clustering objects to enable the grouping of entities that have similar services and capabilities, with the goal of promoting reciprocal collaboration. The suggested approach improves the efficiency of service search by clustering objects based on shared criteria and establishing relationships between service kinds and inter-object collaboration. This methodology enhances both the efficiency of service discovery and the effectiveness of community identification inside the Social Internet of Things (SIoT) ecosystem.

IV. PROPOSED TAXONOMY FOR SERVICE SELECTION APPROACHES IN MOBILE NETWORKS

The following section explains the proposed classification approach for service selection in mobile networks, as depicted in Fig. 3. Our taxonomy classifies the methods into five categories based on the state-of-the-art research approaches identified in our survey.

- The first category comprises mobile devices that function as service providers or sources. They may be equipped with various sensors (e.g., cameras, thermal sensors, LiDAR) to wirelessly collect and transmit data in real-time, such as UAV, VANET, MANET, and IoT applications.
- In the second category, architecture specifies the structure, behavior, and perspectives necessary to meet all technical and operational requirements while optimizing

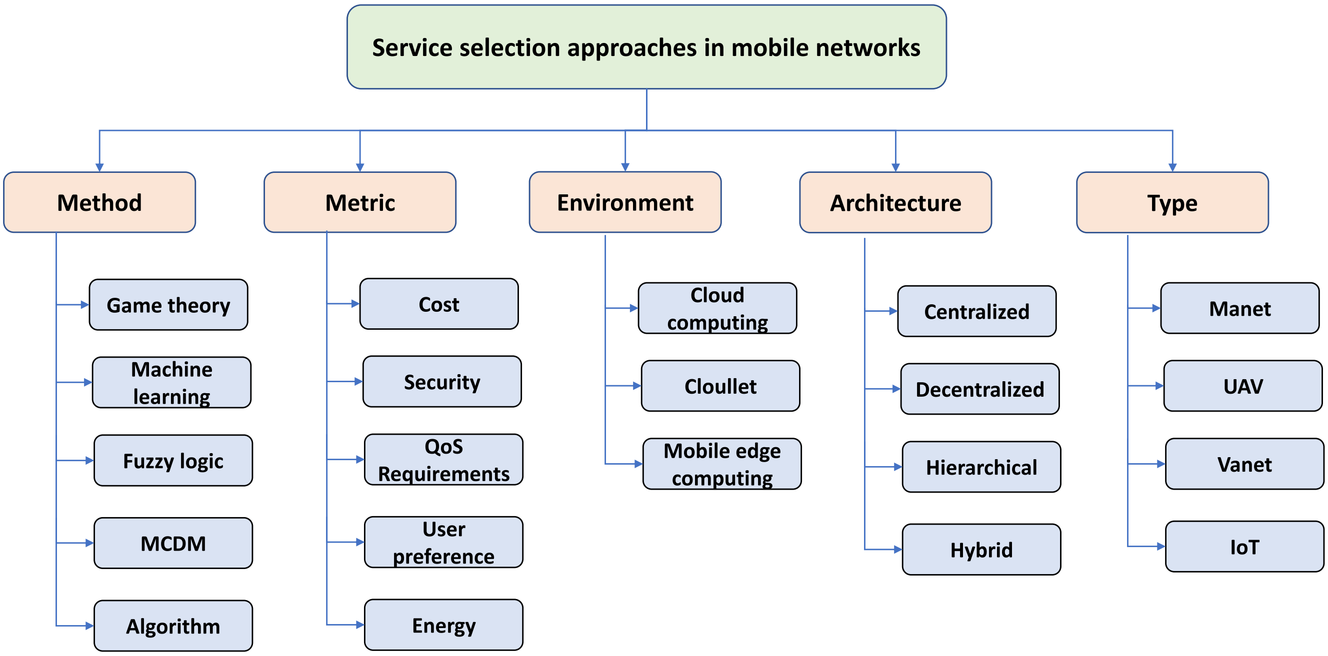

FIGURE 3. Taxonomy of service selection approaches in mobile networks.

TABLE 4. Summary of service selection methods in mobile networks.

Method	Goal	Pros	Cons	Types
Multi-Criteria Decision Making (MCDM) [6]	To evaluate and prioritize services based on multiple criteria.	– Allows for a systematic comparison of services. – Can consider a wide range of criteria.	- Can be complex to implement. – Requires accurate weighting of criteria.	– Analytic Hierarchy Process (AHP) – Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) – Multi-Attribute Utility Theory (MAUT)
Machine Learning Algorithms [7]	To predict service performance and make selection decisions based on data.	– Can improve with more data over time. – Adapts to changing patterns in user behavior and network conditions.	– Requires significant amounts of data for training. – May be complex to understand and explain.	– Neural Networks – Decision Trees – Reinforcement Learning
Game Theory [70]	To analyze and predict interactions between decision-makers for optimal service selection.	– Provides insights into competitive and cooperative scenarios. – Can lead to equitable resource distribution.	– Theoretical and may not always reflect real-world complexities. – Requires comprehensive understanding of all players' strategies.	– Cooperative games – Non-cooperative games.
Fuzzy Logic [71]	To make better informed service selection decisions under conditions of uncertainty, vagueness, or imprecision	– Flexibility and intuitive decision making optimization and control	– Complexity in implementation – Computationally intensive	– Takagi-Sugeno Fuzzy model – Fuzzy Multi-Criteria Decision Making
Algorithms based	To combine multiple services to meet complex user requirements	– Allows for flexible and customized service offerings. – Can leverage the best features of each service	– Composition can be complex to orchestrate. – May introduce latency or compatibility issues.	– Genetic Algorithms (GAs). – Dynamic Programming. – Greedy Algorithms.

common quality attributes such as performance and security. It illustrates how processes interact with one another and how network components are distributed. The architecture structure comprises centralized, decentralized, hierarchical, and hybrid elements.

- The third category describes computing devices that allocate computing resources, such as servers, storage systems, and databases, to provide services, applications, and data storage. The properties above encompass scalability and flexibility,

such as cloud computing, edge computing, and cloudlet.
- The metrics in The fourth category refer to the specific criteria or parameters employed in assessing and selecting various mobile services or applications. These indicators assist consumers and service providers in making well-informed decisions regarding selecting services that align with their requirements and preferences, such as cost, security, and user preference.
- The fifth category identifies service selection methods that encompass a range of techniques and tactics employed to ascertain the most suitable service or application for fulfilling a specified task or function. Given the restricted resources and connectivity alternatives available on mobile devices, efficient service selection is paramount to offer an excellent user experience. These methods include Game Theory, Machine Learning, Fuzzy Logic, and MCDM (Multi-Criteria Decision Making). Fig. 3

V. SERVICE SELECTION SOLUTIONS' METHODS AND APPROACH

A. SERVICE SELECTION' METHODS

The techniques of Service selection methods in mobile IoT networks, such as Game Theory, Machine Learning, Fuzzy Logic, and Multi-Criteria Decision Making (MCDM), have been applied in the context of mobile IoT networks. We discuss this issue below for detailed experimental results and case studies.

- **Game Theory:** Game Theory is employed to represent interactions among different agents in a network, where each actor strives to maximize its own utility. Within the realm of mobile IoT networks, these agents encompass devices, services, or users. Game Theory enables the examination of strategic choices in situations involving competition or cooperation, especially in cases with scarce resources, where gadgets or services vie for these restricted resources [70]. Game-theoretic approaches frequently result in equilibrium solutions, where no actor may gain a benefit by unilaterally changing their strategy. These equilibrium points ensure that resource allocation and service selection are optimized fairly and equally. Implementations sometimes involve the use of auction-based models or cooperative gaming scenarios to allocate resources and provide services efficiently. These advanced techniques improve decision-making processes in mobile IoT networks, guaranteeing equitable allocation of resources and optimizing overall network performance.
- **Machine Learning:** Machine Learning: By employing machine learning methodologies, it becomes feasible to predict the most advantageous services for IoT (Internet of Things) devices through the examination of previous information [72]. This predictive methodology is extremely beneficial in adjusting to changing network circumstances and user needs. Training machine learning models on historical data can lead to high accuracy in predicting service requirements, enabling efficient allocation of services through dynamic optimization. Different machine learning techniques, like as neural networks, decision trees, and reinforcement learning, are used as centralized methods for allocating services in real-time. These algorithms take into account both network conditions and device behavior. In addition, techniques such as federated learning or distillation, which function based on teacher-student paradigms, successfully tackle issues related to scalability and flexibility [73]. These innovative methodologies enable systems to constantly optimize the distribution of services, ensuring the effective use of resources and enhancing overall system performance.
- **Fuzzy Logic:** Fuzzy Logic deals with the process of thinking that is characterized by being approximate rather than strictly rigid and precise [74]. Fuzzy Logic is highly beneficial in mobile IoT networks for making decisions when faced with ambiguity and inaccurate information, which is common owing to the dynamic nature of these networks. Fuzzy Logic systems are highly effective in managing ambiguity and uncertainties that are naturally present in IoT situations. They provide strong decision-making processes for selecting services. Fuzzy Logic implementations may use fuzzy rule-based systems that assess different factors, such as battery life, network bandwidth, and service latency, in order to find the most suitable service options [71]. By integrating Fuzzy Logic into decision-making procedures, mobile IoT networks may proficiently handle ambiguous circumstances, guaranteeing adaptable and effective service selection customized to the current network dynamics. Possible implementations could involve the utilization of fuzzy rule-based systems to select services depending on factors like as battery life, network bandwidth, and service latency.
- **MCDM:** Multi-criteria decision-making (MCDM) approaches are essential for assessing and resolving conflicts between numerous criteria in decision-making processes. In the context of mobile IoT networks, these criteria often include aspects like as service quality, cost, energy consumption, and latency [60]. MCDM methodologies, such as the Analytic Hierarchy Process (AHP) or Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), have demonstrated their efficacy in systematically assessing and prioritizing many criteria to pick the best appropriate services for IoT devices. MCDM is utilized in the selection of IoT services for smart cities, where many criteria such as service response time, dependability, and energy efficiency need to be carefully evaluated. By utilizing Multiple Criteria Decision Making (MCDM) procedures, decision-makers may effectively navigate

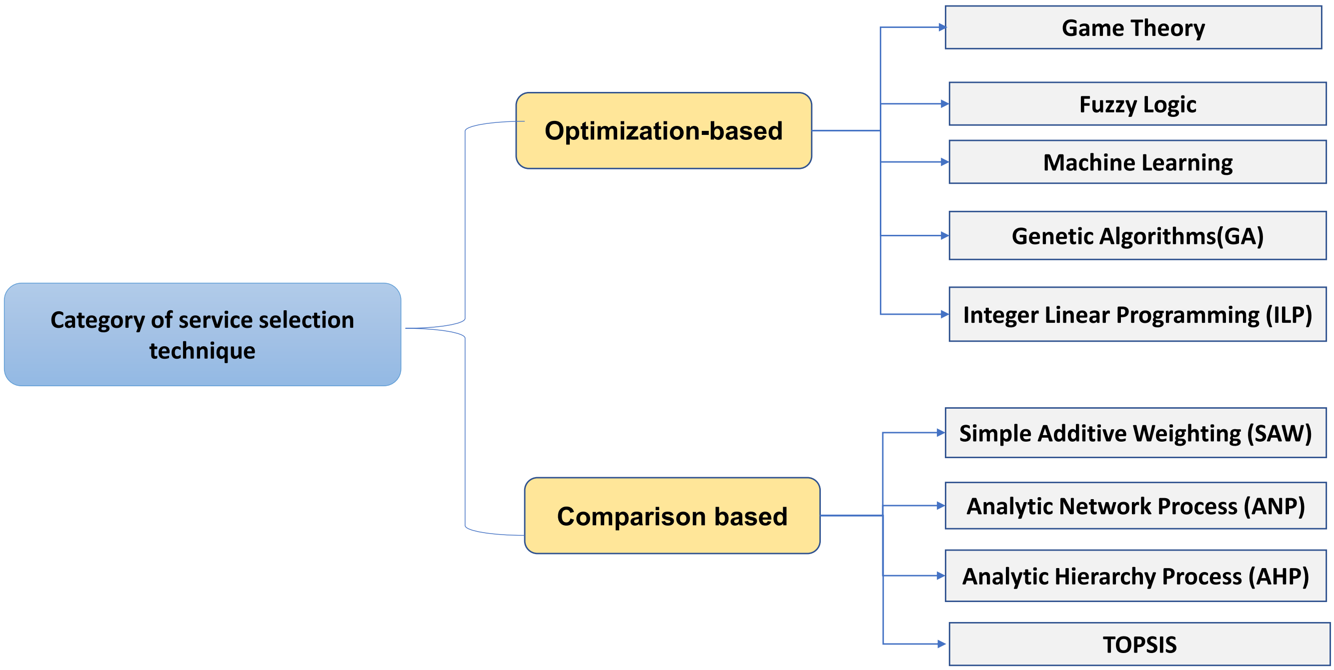

FIGURE 4. Service selection technique tree.

intricate decision landscapes, taking into account a wide range of criteria and making well-informed choices that are in line with their intended objectives.

The existing methods for service selection solutions can be categorized into two main groups, Fig. 4:

- Optimization-based techniques: In service selection, optimization-based techniques aim to find the optimal allocation or assignment of services to specific demands or requirements. The objective is to optimize a particular performance metric, such as minimizing cost, maximizing efficiency, or maximizing resource utilization. This involves employing techniques such as dynamic programming, integer programming, greedy algorithms, etc. The focus is on determining the best configuration or combination of services that satisfy the given constraints and optimize the defined objective [55].
- Comparison-based techniques: refers to a specific method of selecting services that involves comparing different services to identify the optimal combination that can effectively fulfill a given set of needs. These techniques consider various factors and criteria, such as cost, quality, reliability, customer satisfaction, and other relevant criteria. The focus is on identifying the best alternative(s) based on the overall performance across multiple criteria [75]. One of the most common comparison-based service selection approaches is Multiple Criteria Decision Making (MCDM) [76], which includes methods such as Analytic Hierarchy Process/Analytic Network Process (AHP/ANP), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), outranking, Multi-Attribute Utility Theory (MAUT), and Simple Additive Weighting (SAW), among others.

B. SERVICE SELECTION-BASED APPROACH

- **QoS-based service selection**: Quality of Service (QoS) involves implementing a mechanism that assigns varying priority levels to different applications, users, or data flows. This mechanism also ensures a specific performance for a given data flow. QoS-based service selection entails selecting the most suitable service by considering the user's quality of service (QoS) prerequisites and the range of services that are accessible. This methodology is employed within wireless networks to enhance the service rendered to users. The suggested method entails the reception of user requests and subsequent analysis of service patterns by identifying comparable services, locations, and the requisite data values. The primary objective of this initiative is to optimize the quality of service (QoS) advancements in the realm of mobile networks, as stated in reference [77].
- **Cost-based service selection**: Cost-aware service selection in mobile environments involves choosing services from various providers based on cost considerations. Wireless networks offer connectivity and data services for both personal and corporate use, thus necessitating a balance between cost and quality. Cost-aware service selection aims to find the most cost-effective solution for users, taking into account factors such as data usage patterns, coverage, dependability, scalability, and value-added services. Additionally, it requires knowledge of service providers' pricing and agreements. Conducting

research, comparing services, and analyzing cost-quality trade-offs within budget constraints can help users select a reliable and affordable service [78].

- **Energy consumption-based service selection:** The issue of limited battery capacity is becoming more relevant in energy consumption within mobile environments of service selection due to the advancements in mobile networks [79]. Conventional approaches endeavor to attain this goal by employing a straightforward method of selecting services based solely on their minimal reaction time. However, the challenge is determining the most optimal service for each activity to minimize the overall energy usage. Using these strategies can effectively minimize the reaction time of composite services, as demonstrated in the study by Feeney and Nilsson [80]. Consequently, adopting these methods can ensure the lowest possible standby energy consumption. In wireless networks, it is imperative to minimize standby energy consumption and optimize data transmission during favorable network circumstances to mitigate energy consumption associated with data transmission.
- **Security-based service selection**: In the current digital landscape, security-based services have emerged as pivotal components, prioritizing the safety and protection of various entities, particularly individuals. This paradigm emphasizes selecting services that bolster essential security elements [81], including authentication, trust, privacy, object access control, and data integrity. The selection process aims to ensure that chosen components, be they services or objects, align seamlessly with the security requirements defined by users and ongoing programs, thereby guaranteeing an optimal level of responsiveness [82]. A viable solution to enhancing security in service selection involves integrating pseudonym techniques [83]. This strategy offers a promising approach to address privacy concerns in the digital age. By leveraging pseudonyms, personalized services can be delivered without compromising the imperative of privacy preservation. This integration heralds a future where privacy and service quality can coexist harmoniously. The following case studies serve as illustrations [84]:
  – *Online retail:* Within the domain of e-commerce, online retailers are implementing pseudonym strategies to protect customer purchase records. Through the process of anonymizing transactional data, these systems guarantee the confidentiality and protection of sensitive consumer information.
  – *Healthcare services:* Healthcare providers are using pseudonyms for patient records, which allows for discreet treatment and medical care delivery while maintaining strict privacy regulations.
  Despite the effectiveness of pseudonym techniques in strengthening privacy, it's crucial to recognize their inherent vulnerabilities. Potential risks encompass linkability, inference attacks, data breaches, and additional cybersecurity threats like phishing attacks [85], all of which present substantial challenges in service selection. This necessitates vigilance against such malicious activities and the implementation of robust security measures to safeguard sensitive data and uphold service integrity.
- **Combined metrics based service selection**: This particular set of methodologies aims to identify the most appropriate services and objects by considering a range of characteristics [2]. The selection method is commonly employed to integrate services or products to construct a more intricate framework that enhances capabilities and overall performance. The various metrics under consideration encompass all network performance characteristics, including energy consumption, security, dependability, throughput, and other relevant factors. Therefore, the selection method requires establishing a harmonious balance between these specified metrics, which may occasionally conflict with each other, to determine the most advantageous services from the array of choices available. Regularly assessing metrics for each selectable element and maintaining their updates are crucial to ensure the utmost accuracy of outcomes throughout the selection process [86].

VI. CHALLENGES AND FUTURE RESEARCH DIRECTIONS

The service selection problem has been extensively explored by researchers, resulting in the proposal of several study approaches. However, it is imperative to acknowledge that specific unresolved challenges within academic and industrial domains require attention and resolution in the forthcoming period. This section focuses on the challenges and future research directions related to promoting and developing competent and efficient service selection solutions. Figure 5 presents the challenges and future research directions.

A. CHALLENGES

- Battery life and energy efficiency: battery capacity is a constraint for mobile devices. Extending battery life and enhancing energy efficiency continue to be significant obstacles. Discovering and selecting appropriate services from the geographically closest cloud data centers can reduce energy consumption in a mobile environment. Additionally, addressing this challenge involves optimizing service selection to utilize fewer device resources.
- Quality of Service (QoS): QoS presents several significant challenges. It is crucial to ensure efficient, reliable communication and provide users with a satisfactory and consistent level of service, especially in scenarios where there may be variations in network conditions, service providers, and user requirements.

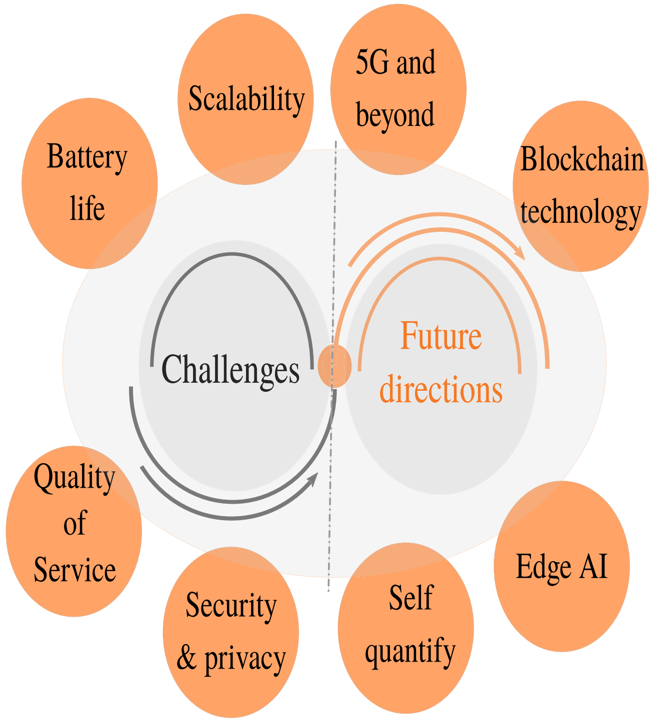

FIGURE 5. Challenges and future research directions.

- Security and privacy: security and privacy measures for service selection in mobile environments and networks are essential to safeguard the integrity and protection of data. It is a major concern for customers to ensure confidentiality, authentication, data integrity, and privacy when they require any service from a service provider. Several research efforts have been conducted to address security and confidentiality concerns and ensure secure service delivery.
- Scalability and resource management: It can be defined as managing the growing number of mobile devices and efficiently allocating resources. The system must be capable of accommodating new devices, services, or operations and handling increasing requests without compromising the quality and performance of existing services. Therefore, scalability refers to the ability to manage a large volume of connected devices in a mobile environment, which is considered a challenge for the network.

B. FUTURE RESEARCH DIRECTIONS

As the technological landscape evolves, several key domains emerge as potential focal points for academic and industry-based exploration:

- 5G and beyond: selecting a service provider and plan in the context of 5G (fifth generation) wireless technology involves considering various factors to ensure you get the best value and performance, and with increased connectivity compared to previous generations, which required offering faster data speeds and lower latency to minimize a gap between the possible transformation in terms of performance and efficiency and the emerging new service requirements.
- Edge AI: it revolutionizes service selection by imbuing it with intelligence, dynamism, and responsiveness to evolving conditions and user preferences. This integration enables the system to effectively optimize and select the most suitable service, while also analyzing and comparing the Quality of Service (QoS) offered by diverse providers. This capability proves especially valuable in scenarios necessitating real-time decision-making. Furthermore, Edge AI facilitates the customization of services based on preferences and content availability across multiple platforms, thereby enhancing the overall user experience.
- Self quantity: Self-quantification on mobile devices and apps can significantly influence personal data analytics and self-improvement, including service selection. It enhances decision-making and overall well-being through data collection and tracking, health and fitness tracking, data privacy and security, affordability, and guaranteed service availability.
- Blockchain technology: it is a chain of blocks in which transaction information is recorded and maintained in a distributed public ledger across several peer-to-peer-connected virtual computers. The selection of a provider is typically based on the values provided and customer feedback. These services are offered to various organizations and utilized by multiple consumers. This underscores the need for a trustworthy environment to evaluate the parametric values for service selection using blockchain technology.

VII. CONCLUSION

As a promising and dynamic field, service selection in mobile networks has garnered significant attention across various domains such as healthcare, education, e-commerce, transportation, etc., aiming to select the most suitable services for users based on multiple factors. However, the mobility of networks introduces a range of challenges that must be addressed to make the service selection process more seamless and efficient.

This paper reviews proposed solutions that leverage mobile networks for service selection, employing different techniques and application services while safeguarding privacy using pseudonym techniques. We categorize these solutions based on the metrics used, including QoS-based selection, cost-based, security-based, etc., and classify them into two main groups: optimization-based and comparison-based techniques. Through this classification, we identify the integration of some new technologies for service selection to better serve users' needs, such as deep learning and game theory, along with addressing recent research advancements. Finally, we highlight the main challenges and future research directions in this field, aiming to inspire further studies and engage researchers interested in advancing this area of research.

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