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A detailed review of D2D cache in helper selection

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Abstract

With the rapid development of communication networks, the information interaction between heterogeneous networks such as the Internet of Things (IoT) and vehicle ad-hoc networks (VANETs) is becoming more and more common. In cellular networks, the proximity devices may share files directly without going through the eNBs, which is named Device-to-Device (D2D) communications. It has been considered as a potential technological component for the next generation of communication. The traditional centralized network architecture cannot accommodate such user demands due to heavy burden on the back-haul links and long latency. Cyber-social networks seamlessly integrate people's daily lives and social activities, which has a prominent contribution to the social relationship of mobile users in D2D communication. In this paper, we make an exhaustive review on the state-of-the-art research efforts on D2D caching. We first give an overview of D2D helper selection, including the network frame, computing method, and social-aware attribute. Next, a comprehensive survey of issues on D2D helper selection is presented. Finally, open research challenges and future directions are presented as well.

Keywords D2D cache · Cyber-social networks · D2D helper selection · Information diffusion and sharing

1 Introduction

With the rapid development of network communication technology, the relevance of the network and the social attributes of users have become increasingly close. How to seamlessly integrate cyber-social networks [102, 104] with people's daily life and social activities has become a hot topic in current network research. Device-to-device (D2D) communication [94] in the 5^{th} generation (5G) [6, 66] environment utilizes the mobile user's smartphone

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for information transfer. The social attributes of users have become an indispensable consideration in this field.

During the past several decades, mobile cellular networks have been steadily evolving from voice-only systems [15] to the current 4^{th} generation (4G) all-IP based LTE-Advanced network [23]. In order to solve the explosive growth of mobile data traffic, large-scale terminals, emerging services and various new business scenarios, the 5G mobile communication network has been proposed, which has become a hot topic in academia and industry. As a next-generation wireless mobile communication network [81], 5G will be mainly used to meet the mobile communication needs after 2020. With the rapid development of the mobile Internet and the growing demand for IoT services, 5G needs to provide low cost, low cost power, strong security and high reliability [60, 85, 86]. As one of the key technologies of 5G communication, D2D communication is proposed to enable devices to communicate directly, which provides a bottom layer for cellular networks to improve spectral efficiency (SE). Under the control of a small base station (SBS), user equipment (UEs) can use cellular resources instead of transmitting data to each other over a direct link through SBS. Therefore, it implements physical proximity communication, thereby saving power while significantly improving spectral efficiency.

In dealing with system caching issues, hyper-heterogeneous networks (HetNets) [9, 79, 80] have been proposed to solve the problem of large cellular users. This requires deploying a large number of SBS and introducing caching capabilities to SBS to address bottlenecks in a large number of network requirements. Therefore, SBS can prefetch content during off-peak hours. SBS provides services directly to local users during peak hours. However, such deployments can result in significant cost overhead. How to deliver content at the lowest download/access time cost and meet user requirements in the future. D2D caching is considered as a potential solution to this problem.

In this article, we provide a brief survey on some works that have already been done to enable the integration of D2D helper selection, and explore several research challenges. Other surveys focus on the discussion of energy consumption and minimization of latency in d2d networks. In this article, we discuss the discussion in this article based on how the helper is chosen. Due to the different perspectives of the discussion, we can get different performance results. The major contributions in this paper are three parts: 1) To categorize the existing D2D helper selection strategies into three classes: network-based helper selection, computing-based helper selection and social-aware-based helper selection. 2) To review on previous works following the proposed taxonomy. 3) To discuss the performance metrics and challenges associated with D2D caching.

The classification of our D2D helper selection design method is shown in Figure 1. To improve the readability of this article, Table 1 summarizes the acronyms used in this article.

The rest of this paper is organized as follow. Section 2 presents an overview on the history and current research progresses of D2D helper selection in network architecture. Section 3 focuses on the research of D2D helper selection in computing method. A D2D helper selection based on social-aware attribute is proposed in Section 4. The open challenges and future directions are shown in Section 5. Finally, conclusions are drawn in Section 6.

2 D2D helper selection in network architecture

In this section, we present the current research advances in D2D helper selection in the network architecture for wireless communication system. In particular, we provide Table 2

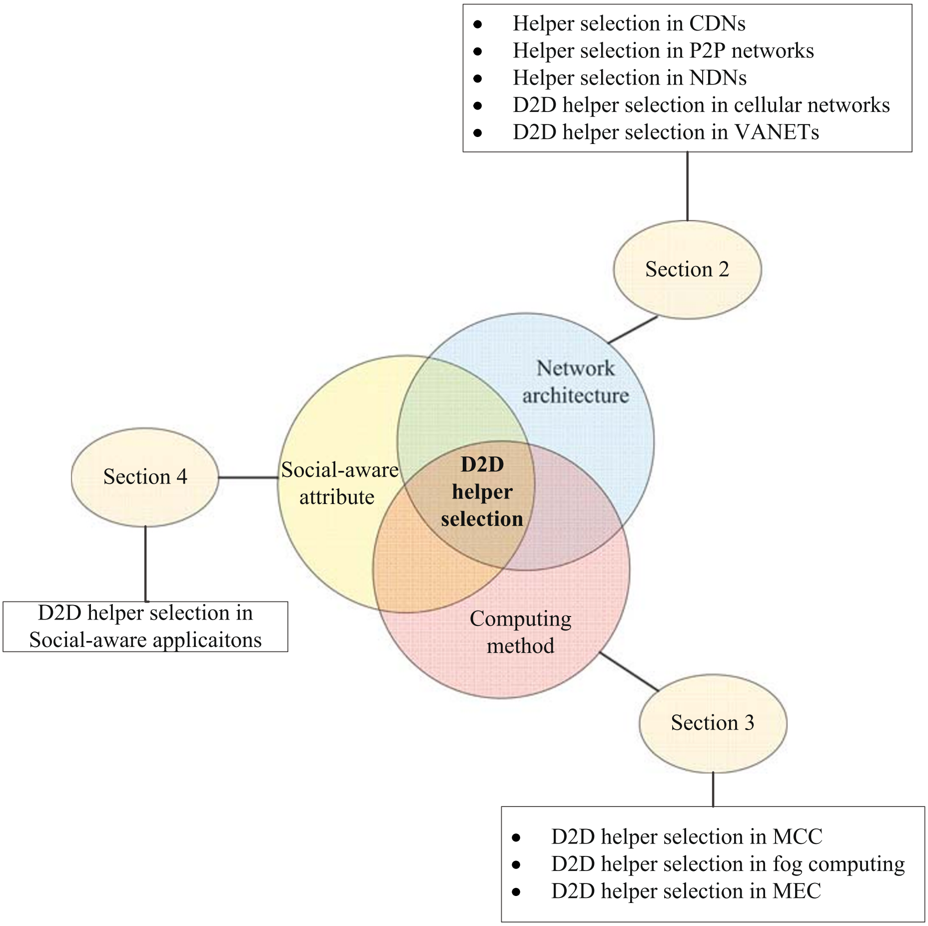

Figure 1 The classification of D2D helper selection design method

to compare the existing work. From the table, using the network architecture to select the optimal helper can provide a node cache solution for D2D caching technology.

2.1 Helper Selection In Content Delivery Networks

We first discuss the helper selection in Content Delivery Networks or Content Distribution Networks (CDNs) [42, 58]. Compared to traditional networks, content in the CDNs is pre-cached to a proxy server closer to the user. In this way, mobile users can easily obtain the necessary information resources from the surroundings. The CDNs architecture is shown in Figure 2. In such a network architecture, we usually select a proxy server as the helper. which proxy server should be selected as the helper is a problem for minimize energy consumption in the networks.

Researches on the CDNs helper selection problem focus on three aspects: energy, file size and caching algorithms. In energy research articles such as Mathew et al. [58], Mathew et al.

Table 1 Summary of abbreviations

4G	4^{th} generation
SE	Spectral efficiency
SBSs	Small base stations
UEs	User equipments
HetNets	Heterogeneous networks
CDNs	Content delivery networks or content distribution networks
P2P	Peer-to-Peer
NDNs	Name data networks
ICNs	Information centric networks
EPC	Evolved packet core
RAN	Radio access network
MSNs	mobile social networks
D2D	Device-to-device
V-D2D	Vehicle Device-to-Device
IoT	Internet of Things
VANETs	Vehicular ad-hoc networks
RSU	Road side unit
V2V	Vehicle-to-vehicle
V2I	Vehicle-to-infrastructure
LTE	Long term evolution
VITP	Vehicular information transport protocol
CC	Cloud computing
MCC	Mobile cloud computing
VCC	Vehicular cloud computing
CCFF	Cognitive caching approach for the future fog
MEC	Mobile edge computing
UDN	ultra-dense networks

propose online and offline algorithms to reduce network energy consumption. However, cache consumption is caused by many factors, and it is only the optimal helper that energy consumption cannot find cached content.

In terms of file size, Kangasharju et al. [42] cache content using nodes with limited storage capacity. The helper is selected by traversing, and the real Internet topology data is used for comparison. The disadvantage is that the network overhead is correspondingly larger due to the traversal approach to finding helper nodes. Video data often requires consistency of data. The literature [67, 89] discuss and analyze the buffering of video data. Xie et al. [89] discuss and analyzed the user performance, user interest in content and video popularity dynamic mode. However, no better results were obtained. Shanmugam et al. [67] use a low-speed backhaul but high storage capacity assistant to cache video files. Considering that such mobile users are not general. Therefore, such a network node is actually equivalent to a simplified SBS device.

In terms of caching algorithms, Mokhtarian et al. [61] design a variety of caching algorithms: The based on recently used baselines to meet demand; The adaptive entry control algorithm to reduce the peak upstream traffic of the server.

Table 2 The comparison of D2D helper selection in network architecture

Integration	Papers	Algorithm	Communication	Simulation	Networking	Caching
CDNs	[58]	Online-Offline	Wi-Fi	MATLAB	Heterogeneous network	Location-based Caching
	[89]	Greedy-Global	Wi-Fi	MATLAB	Heterogeneous network	Multi-level Caching
	[67]	xLRU	femtocells	MATLAB	Heterogeneous network	Location-based Caching
P2P	[69]	FLAPS	Wi-Fi	PeerSim	Heterogeneous network	Fog-Caching
	[59]	P2PSD	Wi-Fi	MATLAB	IoT network	IoT-based Caching
	[13]	MPR	Wi-Fi	PeerSim	Cluster network	Multi-level Caching
ICNs	[8]	GCA	Wi-Fi	Icarus	ICNs	Greedy Caching
	[34]	Pre-caching	Wi-Fi	MATLAB	ICNs	Location-based Caching
	[68]	IR	Wi-Fi	ONE	MSNs	Popularity-based Caching
D2D	[21]	MAUU	LTE	–	D2D network	Location-based Caching
	[75]	RVV	LTE	–	D2D network	Location-based Caching
	[31]	Q-learning	LTE	–	MSNs	Popularity-based Caching
	[53]	Social-aware	LTE	–	D2D network	Social-aware Caching
VANETs	[12]	–	Wi-Fi	SUMO	Urban-VANETs	Multi-level Caching
	[50]	VITP	Wi-Fi	NS2	VANETs	Cooperative Caching
	[11]	–	Wi-Fi	SUMO	Urban-VANETs	Cooperative Caching

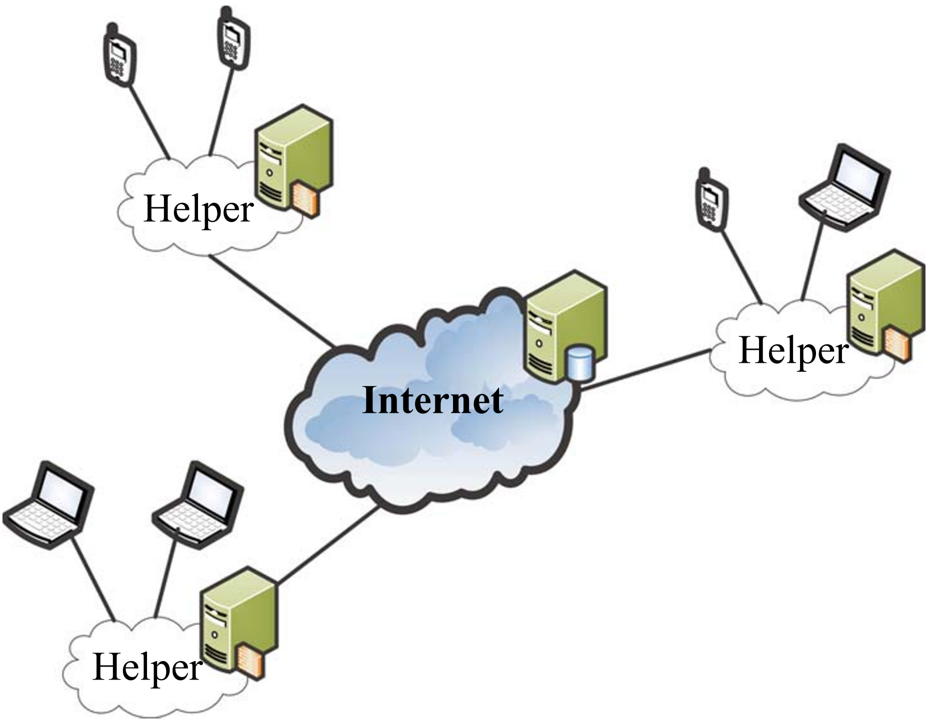

Figure 2 Helper selection in CDNs

2.2 Helper selection in peer-to-peer networks

Unlike the centralized CDNs architecture, peer-to-peer (P2P) networks [51] is a distributed application architecture. The P2P networks architecture is shown in Figure 3. Therefore, all nodes in the P2P networks in fact can be selected as helpers.

Due to the relationship between nodes, there is no extensive research, mainly focusing on the node memory and combining with other methods. Moeini et al. [59] designed an unstructured p2p routing mode when considering node memory is limited. This mode implements network caching through static and dynamic switching, which increases certain network overhead. In terms of P2P networks extension, Shojafar et al. [69] introduced fog computing into the P2P networks, and uses edge computing to adaptively discover point-to-point and point-to-point minimum jump routes.

2.3 Helper selection in name data networks

The CDNs and P2P network architecture, which we discussed, can not fully meet the demand of the D2D helper selection [62]. This is mainly due to the fact that D2D communication in 5G environment belongs to a non-IP network. In Named Data Networks (NDNs) [46] and Information Center Networks (ICNs) [2, 91], users can get data they need directly from neighboring users. The NDNs architecture is shown in Figure 4. Therefore, the device through which the information flow passes in the NDNs can be regarded as helper.

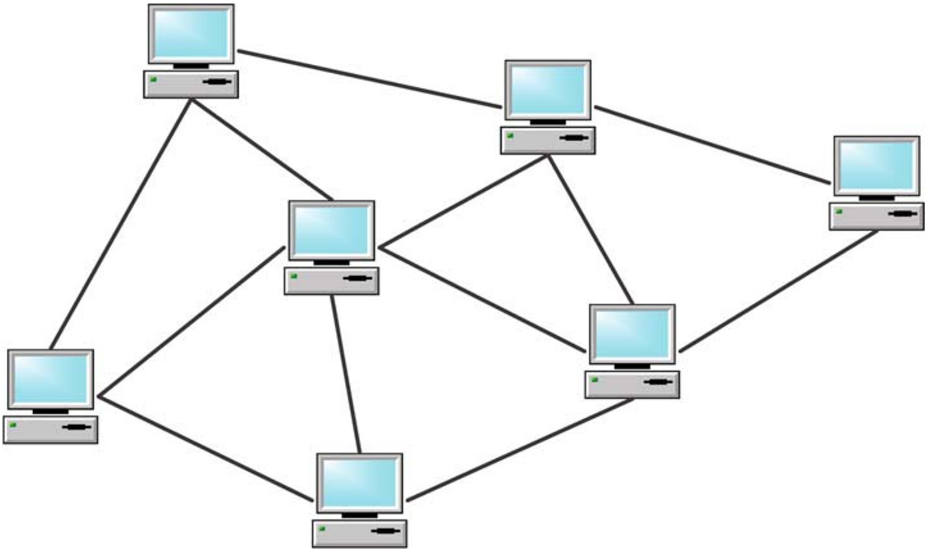

Figure 3 Helper selection in P2P networks

The researches of helper selection in NDNs and ICNs mainly focus on three aspects: cache location, intelligent algorithm and hybrid cache. In terms of cache location, Wang et al. [84] discussed four caching methods. There are no cache; Evolved Packet Core (EPC) cache; EPC + Radio Access Network (RAN) cache and EPC + RAN + D2D. Katsaros et al. [43] designed a content caching model based on MultiCache. Sourlas et al. [71] proposed distributed autonomic management architecture. These articles are mainly discussing the problem about what to cache and where to cache. The performance of these systems will vary depending on the selected cache location and the size of the cache.

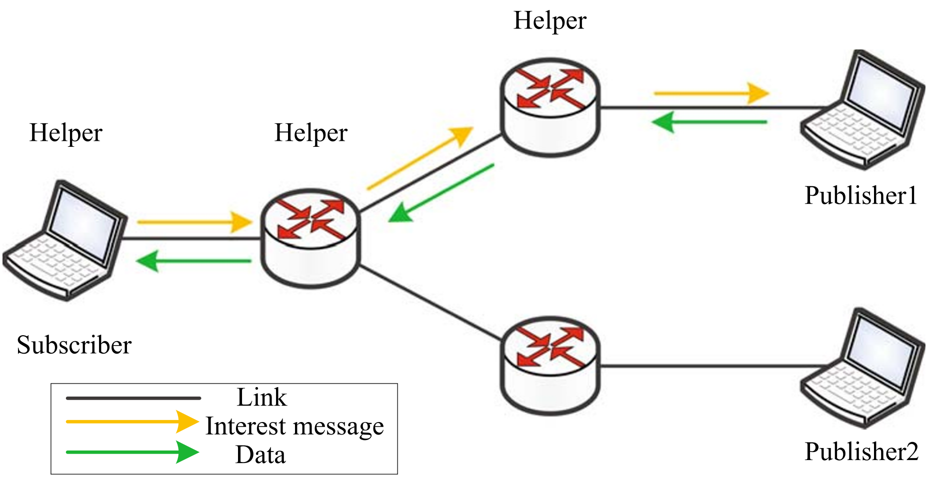

Figure 4 Helper selection in NDNs

In terms of intelligent algorithms, Banerjee et al. [8] proposed a greedy cache, and Huang et al. [34] proposed pre-caching. They all have high requirements for content popularity, and have better improvement of the network performance of the designed scenarios, but the generality is not strong.

In terms of hybrid caching, Shi et al. [68] combined ICNs with mobile social networks (MSNs). It used the node friendship metric in MSNs and the working methods of the ICNs to select the cache nodes in the network.

2.4 D2D helper selection in cellular networks

Since the D2D communication technology [7, 74, 94] enables direct communication between mobile devices, without the expensive data transmission by cellular link. In other words, content can be carried by mobile devices and propagate directly to nearby interested consumers without involving the cellular infrastructure. It is apparent that expensive cellular spectrum resources can be effectively saved by offloading partial traffic to D2D communication to support content delivery. Therefore, how to choose the appropriate helper to achieve D2D caching [10, 35, 37] has become a research hotspot in this field. The D2D helper selection network architecture is shown in Figure 5. Since the D2D cache needs to take advantage of the mobile device's own capacity, this capacity is often limited. Mobile users also do not want to spend their own cache and traffic to transmit information to

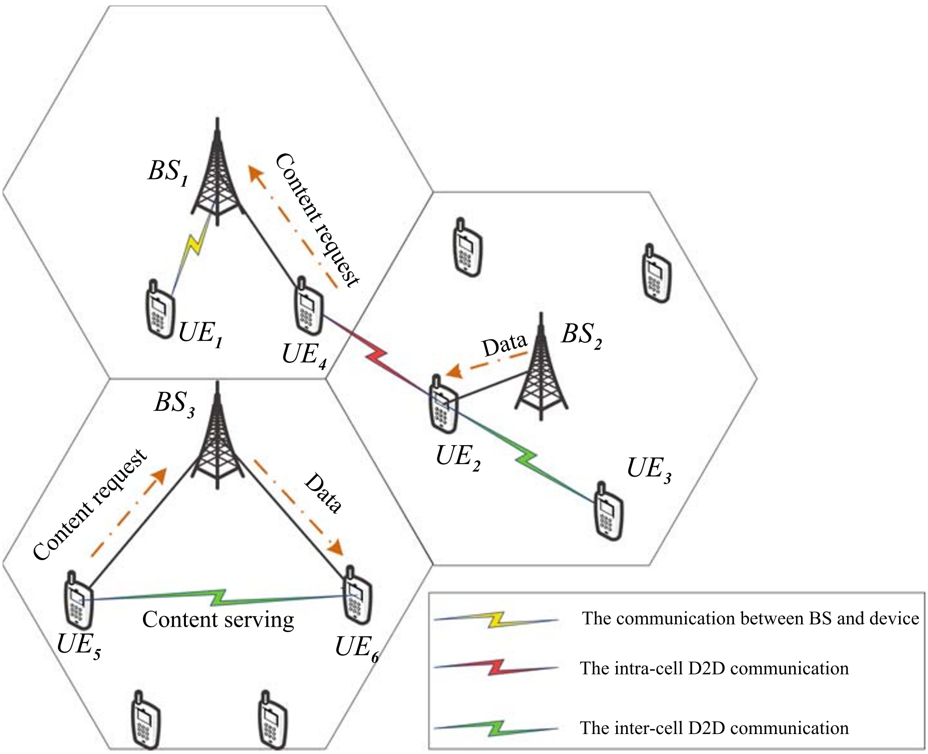

Figure 5 D2D helper selection in cellular networks

strangers. This requires the development of appropriate incentives to make mobile users more interested in becoming helper nodes for other nodes.

We use the Figure 5 as an example to describe how the helper selected in cellular network. In the information request phase, UE_5 transmits the request information to BS_3. In the helper selection phase, BS_3 sends relevant information to the selected helper UE_6. In the D2D communication phase, BS_3 establishes a D2D communication channel between UE_5 and UE_6. UE_6 sends the cached data to UE_5. Then, BS_3 closes the D2D communication channel. In the process, UE_6 plays the role of helper. It is determined by many factors such as its location and cache size. Due to the mobility of mobile users, the helper and the target UE may not be in the same cellular coverage. For instance, there is only one user UE_1 in the coverage of BS_1. At this point, UE_1 generates a communication request. Since there is no other UE in the coverage of BS_1 to service as helper, the information will be transmitted directly from BS_1 to the UE_1. The communication between UE_2 and UE_4 is through the intra-cell D2D link. The Data exchange between UE_2 and UE_3 is through the inter-cell D2D link. In the D2D helper selection, a node can be information requester and helper.

The D2D helper selection will result in a difference in network overhead. How to choose the optimal helper to reduce network overhead becomes the core issue of this research field. D2D helper selection has chosen a wide variety of research directions, which can be roughly divided into two parts, namely the method other networks for architecture for cellular network and the performance optimization in the cellular network.

The articles [19, 31, 53, 75] are other network architectures for D2D cache for performance optimization. Wang et al. [75] proposed the social Internet of Things (IoT) for D2D caching to allocate wireless resources using the physical and social characteristics of users. Thus, D2D cache performance is improved. Ma et al. [53] also used the social distance model based on physical distance. Unlike [75], this is mainly to improve the performance of specific scenarios. Then, it considers the social relationships between D2D users and the physical proximity between devices. He et al. [31] used MSN and MEC for D2D cache. Network resources are allocated by designing deep reinforcement learning methods. The VANET is an emerging communication network structure, which we will discuss in the next subsection. Cheng et al. [19] utilized VANETs for D2D caching, namely Vehicle Device-to-Device (V-D2D). It is a pity that this paper has only conducted a comparative analysis under the Manhattan model without further discussion of the technology.

The articles [16, 21, 27, 36, 38, 44, 56, 101] are performance optimization in the cellular network. Chandrasekaran et al. [16] designed on-line content caching and off-line assisted selection algorithm. Zhang et al. [101] tried to use unlicensed bands to improve system performance.

2.5 D2D helper selection in vehicular ad-hoc networks

Taking into account the life scenes of mobile users, vehicles become an integral part of everyday life. Using a vehicle to assist helper work can be used as a large D2D helper selection supplement. Some scholars have proposed the vehicle Ad-hoc networks (VANETs) [4, 14, 30, 45, 82, 95] architecture based on this. At the same time, the helper selection in VANETs also provides a new improvement for D2D helper selection. The VANETs architecture is shown in Figure 6. In VANETs, the Road Side Unit (RSU) can act as an Internet gateway for vehicles that provide low-cost Internet. Information can be transmitted to the user via vehicle-to-vehicle (V2V) communication, vehicle-to-person (V2P) communication and vehicle-to-infrastructure (V2I) communication. In VANETs, the helper can be selected as moving vehicle, other UE or the RSU.

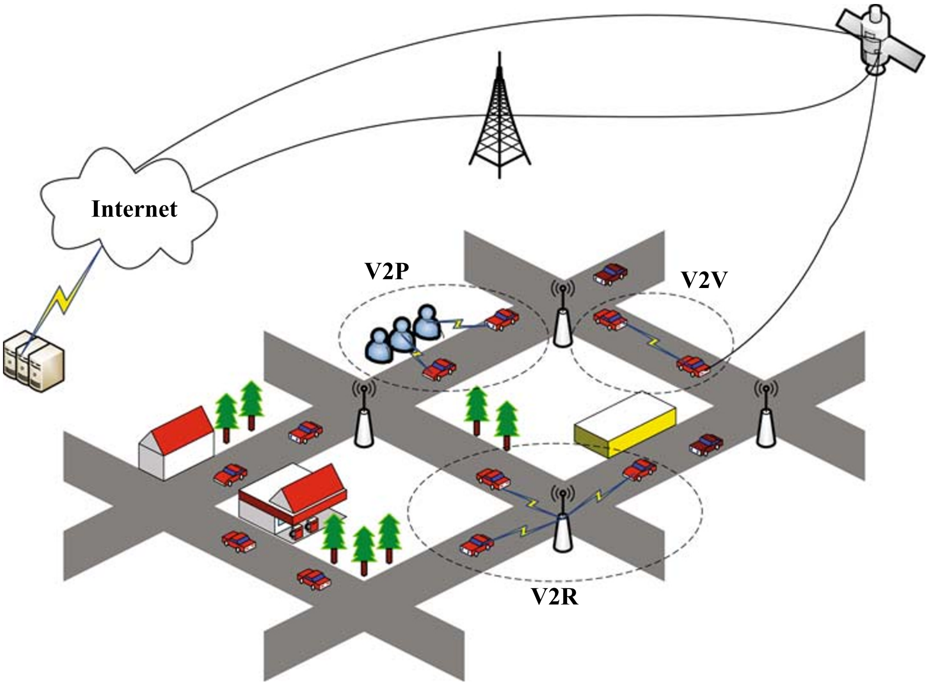

Figure 6 D2D helper selection in VANETs

The studies of D2D helper selection in VANETs focus on three areas: actual scenarios, cache coverage and popularity. In actual scenarios, systems are often divided into Manhattan models, urban environments and highway scenarios. The streets in the Manhattan model are neatly divided for analysis and discussion, but they are not the same as the actual situation; the urban environment is more complicated, and the existence of multiple forks is inconvenient for network analysis; the highway model is equally simple and involves only a road analysis. Raheem et al. [65] based on urban environment discussed three different scenarios: the Macrocell (eNB)-vehicular UEs scenario, the fixed Femtos-vehicular UEs scenario, and the mobile-Femtos-vehicular UEs scenario.

In cache coverage, Bian et al. [11, 12] chose the helper by considering parameters such as cache coverage, vehicle density, transmission radius, and cache rate.

In popularity, Zhou et al. [106] achieve maximizing the total user-satisfaction and achieving a certain amount of fairness. Quan et al. [63] designed a novel popularity-aware content caching and retrieval strategy.

3 D2D helper selection based on computing method

How to select the optimal helper to cache appropriate information is determined by the cost, QoS and other factors. In Section 2, we discussed 5 kinds of network architecture based helper selection. In this section, we will focus on the helper selection based on computing method. A comparison of different mobile computing architectures is shown in Table 3.

Table 3 Comparison of different mobile computing architectures

Item	Cloudlet	MCC	Fog computing	MEC
Originally proposed by	Prof.Satyanarayanan	Not specific	Cisco	ETSI
Hierarchy	3 tiers	2 tiers	3 or more tiers	3 tiers
Latency	Low	High	Low	Low
Ownership	Local business	Centralized by cloud providers: Amazon, Microsoft, etc.	Decentralized Fog node Owners	Mobile operators
Sharing Population	Small	Large	Small	Medium
Location	Between devices and DC, or directly in a device	Large data center	Between devices and DC	RAN
Context awareness	Could be	No	Yes	Yes
Cooperation between nodes	No	No	Yes	No

In particular, we provide Table 4 to compare the existing work. From the table, most computing method based helper selection strategies take advantage of the compute method to select the optimal helper.

3.1 D2D Helper Selection In Mobile Cloud Computing

With the widespread use of smart phones, the demand for computing capacity of the network continues to be strong. Some researchers introduced traditional cloud computing into the Internet of Vehicles environment and proposed the concept of Vehicular Cloud Computing (VCC) [87]. The D2D helper selection in VCC is shown in Figure 7. At the same time, the researchers also proposed the concept of mobile cloud computing (MCC) [22, 25], using the rich computing resources contained in the cloud to perform computing tasks and achieve computing offload through the wireless cellular network. The assistant selection in the MCC is shown in the Figure 8. This makes the D2D helper selection a better solution. Through the distribution of resources in the cloud, information can be cached in more reasonable helper, which can greatly reduce network overhead.

The researches on D2D helper selection in MCC mainly focus on two aspects: cloudlet and cache. In terms of Cloudlet, Magurawalage et al. [55] introduced a data caching mechanism on the cloudlet. Hou et al. [33] also taking advantage of cloudlet technology. Different from [55] focusing on energy consumption, [33] discussed data access efficiency.

In terms of cache, Jiang et al. [40] focuses on how to reduce the amount of data needed to migrate to a server, which will increase energy/time efficiency. Zeydan et al. [96] and Li et al. [47] discussed how to use machine learning for big data analysis and cache visualization, separately.

3.2 D2D helper selection in fog computing

With the development of communication technology, relying solely on the MCC has been unable to meet the demands of mobile users for real-time. Thus, some scholars have proposed fog computing [1, 20, 72] to improve the insufficient of cloud computing in solving

Table 4 The comparison of D2D helper selection in network architecture

Integration	Papers	Algorithm	Communication	Simulation	Networking	Caching
MCC	[55]	MCC offloading	Wi-Fi	CloudSim 2.0	Wireless network	Multi-level Caching
	[40]	LRU	Wi-Fi	VirtualBox	High-bandwidth network	Cooperative Caching
	[33]	GDA	Wi-Fi	OMNET++	Mobile network	Cooperative Caching
FC	[70]	SCC	Wi-Fi	–	IoT network	IoT-based Caching
	[41]	STC	Wi-Fi	MATLAB	Wireless network	Steiner tree caching
	[77]	Cachinmobile	LTE	–	D2D network	Social-aware Caching
MEC	[98]	VCE	Wi-Fi	–	Urban-VANETs	Cooperative Caching
	[29]	–	Wi-Fi	MATLAB	Wireless network	Task Caching
	[32]	LECC	LTE	–	5G network	Cooperative Caching

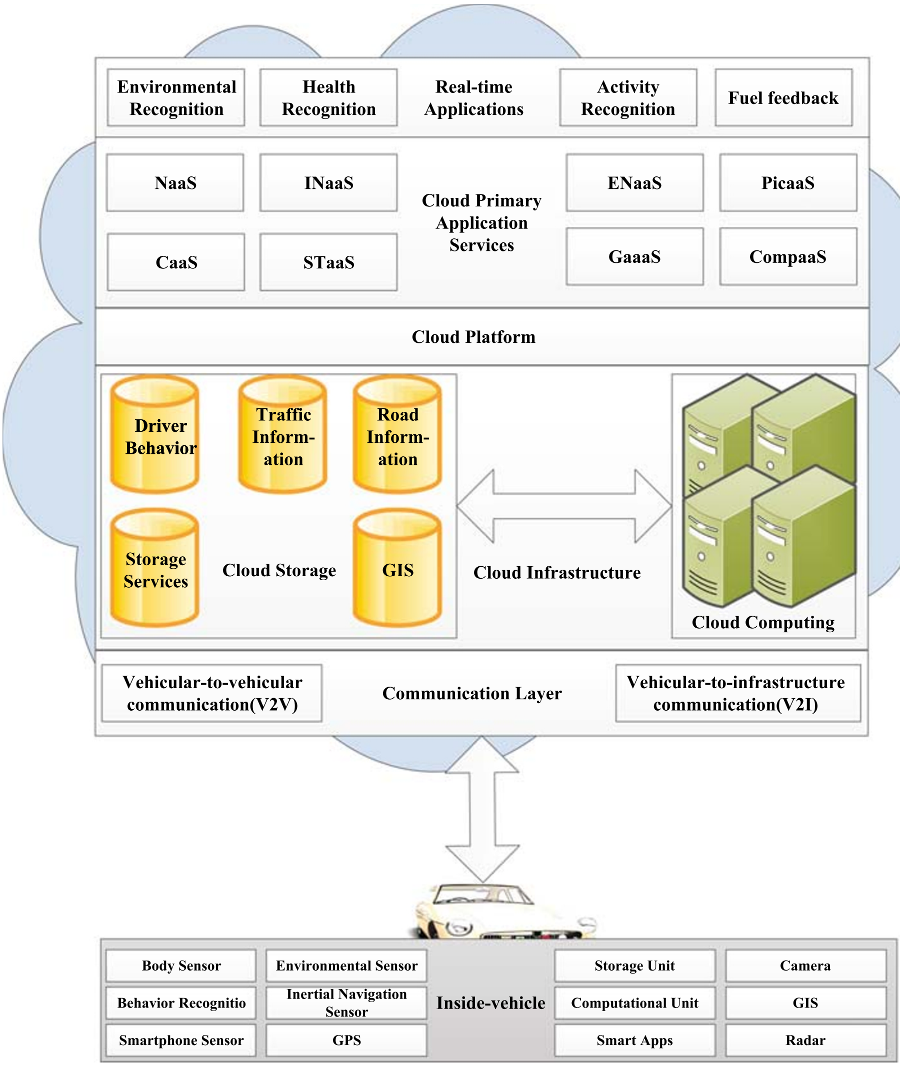

Figure 7 D2D helper selection in VCC

real-time performance. The D2D helper selection in the fog computing is shown in Figure 9. In the fog computing, D2D helper selection can be computed on the fog node, which will greatly improve the speed of D2D helper selection.

The researches on D2D helper selection in fog computing mainly focus on two aspects: intelligent optimization algorithm and hybrid with network architecture. In terms of intelligent optimization algorithms, su et al. [41] proposed a caching scheme based on Steiner tree. Then, the cached path scheme is obtained.

In terms of intelligent hybrid with network architecture, [5, 70, 77] used different network architectures to improve the helper selection in Fog computing, separately. Song et al. [70] Proposed to build intelligent collaborative cache, combining ICNs with Fog computing.

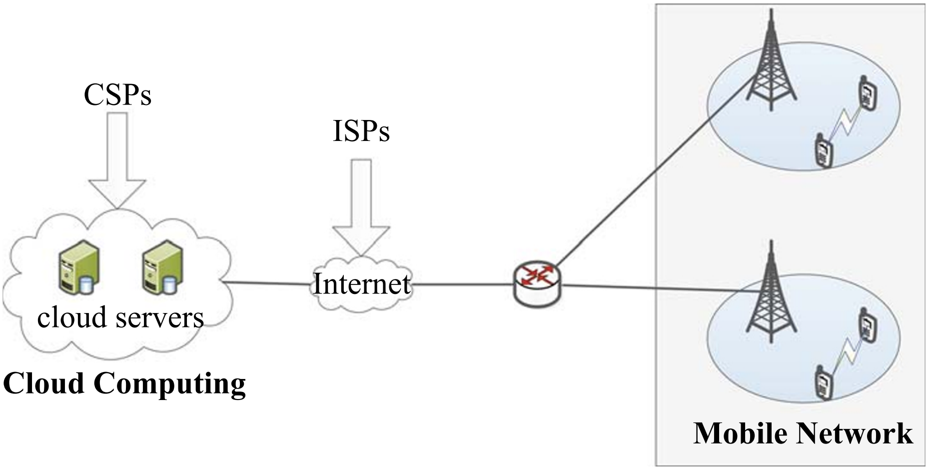

Figure 8 D2D helper selection in MCC

Al et al. [5], similarly. The difference is that [5] focused on the value of exchanging data and chose the optimal helper by estimating the value. Wang et al. [77] utilized Fog computing for social network and D2D communication technology, which used the edge nodes in the network to cache information and offloading.

3.3 D2D helper selection in mobile edge computing

Similar to the fog computing, Mobile Edge Computing (MEC) [18, 54, 57] is also proposed to serve as a complement of mobile cloud computing. The difference from the fog computing is listed in the Table 3. The D2D helper selection in MEC is shown in Figure 10. MEC is envisioned as a promising technology to provide agile and ubiquitous computing enhancement services for mobile devices, by endowing considerable computational capability to mobile communication networks. Thus, D2D helper selection in MEC can benefit D2D communication content caching.

The researches on D2D helper selection in MEC mainly focus on two aspects: efficient caching strategy and hybrid with network architecture. In terms of efficient caching strategies, We list two typical papers for discussion. Hao et al. [29] proposed the concept of task caching to achieve joint optimization of edge cloud task caching and offloading under computational and storage resource constraints. Similarly, Hou et al. [32] proposed a proactive caching mechanism named Learning based Cooperative Caching (LECC) strategy based on MEC architecture to reduce transmission cost while improving user QoE for future mobile networks. Both of them introduced intelligent optimization algorithms to improve network performance and reduce network throughput.

In terms of hybrid with network architecture, [93, 98–100] optimized cache performance by combining with VANET or 5G networks. Zhang et al. [98] used MEC resources to enhance the storage capacity of nodes. Zhang et al. [99] designed an offloading framework, combining MEC with VANETs. Yang et al. [93] and Zhang et al. [100] discussed energy-efficient offloading problem, combining MEC with 5G and VANETs. Different from the others, Ge et al. [26] mainly studied the network edge assisted video adaptation problem.

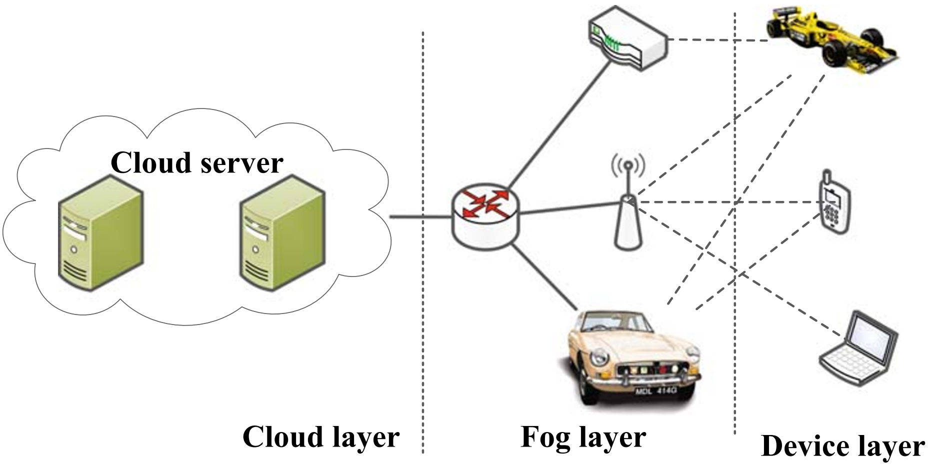

Figure 9 D2D helper selection in fog computing

4 D2D helper selection in social-aware attribute

In Sections 2 and 3, we discussed the D2D helper selection problem of network architecture and computing method. In related research, we also covered the social attribute [39, 48, 83, 97] factors of mobile users. With the development of mobile communication technology, the social attributes of users have become an indispensable consideration. However, due to the user's selfishness, they are not necessarily willing to spend their own traffic and storage space to help strangers cache files. How to make mobile users more actively participate in caching becomes a direction in this research field. However, this article is not intended to describe the user incentives in detail. On the contrary, we are more concerned about how to use the social attribute of mobile users to provide more convenience for the D2D helper selection. The D2D helper selection in social-aware attributes is shown in Figure 11. The social bond can relieve the user selfishness cost.

The researches on D2D helper selection in social-aware attributes mainly focus on two aspects: incentive cache and hybrid with network architecture. In terms of incentive cache, zhu et al. [107, 108] analyzed four caching schemes: random cache, selfish cache, incen-

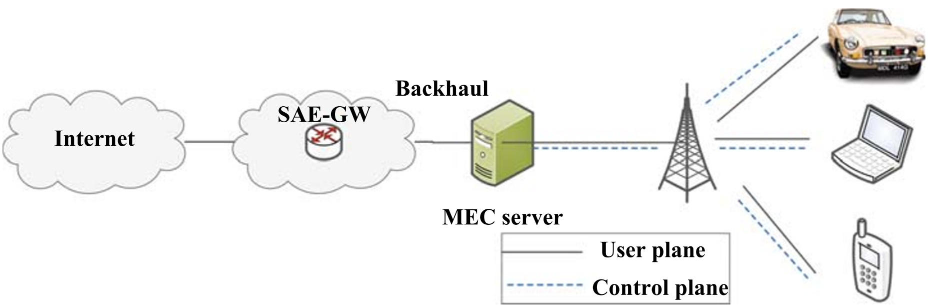

Figure 10 D2D helper selection in MEC

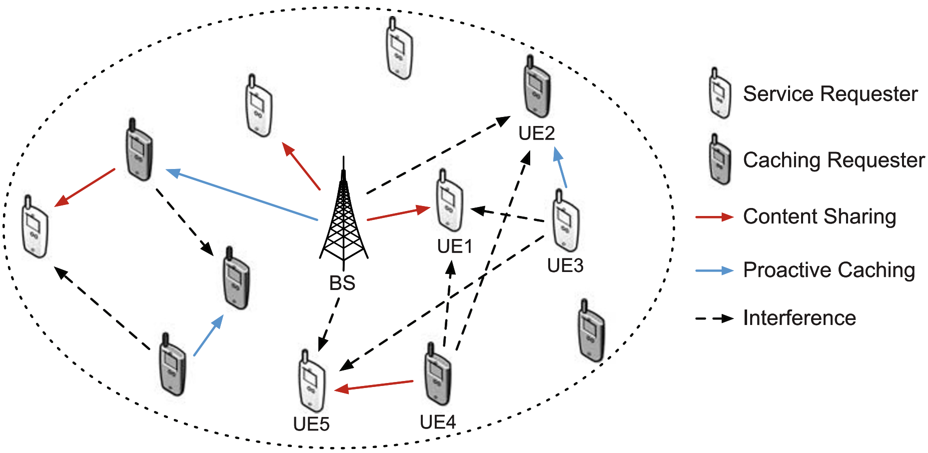

Figure 11 D2D helper selection in social-aware attributes

tive cache, and social-aware incentive cache. Then, he discussed some of the effects of the impact helper selected parameters, such as social relationships and physical distance. These two parameters are the basic parameters that most papers will cover in discussing social attributes. Another incentive caching scheme is implemented by dividing mobile individuals in the network. Zhi et al. [105] divided the mobile individuals in the network into three actual categories, namely individual node, friend nodes and stranger nodes. Then according to the user's social attributes, the optimal helper is selected. These literatures in this area are mainly aimed at how to reduce network overhead and how to balance the users, to achieve helper selection in D2D caching.

In terms of hybrid with network architecture, many network architectures for social-aware attributes can be utilized to improve system performance, as described in the previous section. We will introduce some other interesting articles to reflect the advantages of social-aware attributes. The application scenarios of social-aware attributes are mainly concentrated on the node-intensive scenarios, and the performance in the sparse scenarios is degraded. However, in the ultra-dense networks (UDN), the communication cost of the network will increase greatly. Yi et al. [49] divided the BSs in the network according to performance, and uses high-performance BS as very important base station to serve other BSs and users.

In the environment of the VANETs, social-aware attributes have an important impact on the information transmission between vehicles. Quan et al. [64] utilized social-aware attributes for VANETs and ICNs to improve the quality of highway vehicles media services.

5 Discussion and future work

Despite the promising future of D2D helper selection, there are still many significant research challenges that need to be addressed before the widespread implementation of D2D caching systems [73, 78, 88]. In this section, we will introduce some of these research challenges and then discuss a broader perspective.

5.1 Heterogeneity

In the future network, with the rapid development of communication technology, the heterogeneity of D2D cache becomes a key issue [17, 28, 92]. How to use different network architectures makes communications seamlessly connected. How to make users in different network systems become helpers in D2D caching technology. Although some existing studies have designed this discussion, they are often limited to theoretical analysis and experiments, instead of real data simulation and research. Thus, the system performance needs to be further strengthened. This requires a depth study of the heterogeneity of D2D helper selection in future work.

5.2 Realtime analysis

Considering that in the future communication, mobile users have more demand for realtime information, and some existing tolerant delay network technologies need to further reduce the time for information transmission [24, 90, 103]. In the content of communication, the video stream has a higher demand for information transmission. How to transmit information in real time becomes a big challenge for D2D helper selection.

5.3 User Mobility

The random mobility of users becomes one of the challenges of D2D helper selection. The user's movement will result in changes in the network topology, especially in VANETs environment [30]. In VANETs, due to the influence of the speed of vehicle, the network topology changes frequently. Although this problem can be compensated by a status-based approach, the performance of the network is greatly affected. In edge calculations, frequent user movements can also cause dramatic changes in edge nodes, which in turn can degrade network performance. How to solve the problem of mobile network research caused by the random movement of users caused by the problem of mobile network research has also become an urgent problem to be solved in this research field [17, 44, 76].

5.4 Extensibility

Compared with traditional systems, extensibility is an important feature of D2D helper selection. With the popularity of 5G mobile devices, more and more mobile devices require service scalability [73]. This has a further need for the performance of UDNs systems. How to effectively use D2D helper selection technology to save network resources has become a challenge in this field.

5.5 Security

The information security of mobile devices is a top priority for every UE [3, 31]. However, with the widespread use of smart devices, users' personal information and privacy are threatened in many ways. Especially in the use of social-aware technology, the social circle of mobile users is almost in a transparent state. How to effectively protect users' personal privacy and information security has become a major challenge for D2D helper selection technology. While trusted friends can reduce the risk of this security, they also need better reward mechanisms to collaborate because of their selfishness [52].

6 Conclusion

With the popularity of smart phones, device-to-device communication technology has become the key to 5G communication technology. This is because D2D communication can communicate between mobile devices directly, without the expensive data transmission by cellular link. In this work, we studied the D2D helper selection problem. Then, D2D helper selection technology is classified as the following: D2D helper selection in network architecture, D2D helper selection on computer method and D2D helper selection in social-aware attribute. Finally, we analyzed the existing challenges and future developments of D2D helper election.

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