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A Comprehensive Review on Device-to-Device Communication Paradigm: Trends, Challenges and Applications

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Abstract
Sensors and smartphones are used in industry and healthcare technology for data gathering. The sensed data can be acquired by devices and processed through multiple gateways to the Internet of things (IoT) enabled cloud framework. Device-to-device (D2D) communication paradigm is a central part of the third generation partnership project standards to facilitate peer-to-peer connectivity that will be an important part of IoT. There is no centralized control in D2D which strengthens the wireless networks more energy-efficient and spectrum. The D2D enhances the data transmission process with advance security schemes and also improves the quality of service. This paper surveyed recent works on D2D, which is mainly focused on resource allocation, power consumption, security, and also highlights the major challenges. The role of D2D communication systems in healthcare has been discussed here.

Keywords Device-to-device communication · 4G · 5G · Resources allocation · Power control · Healthcare · Industry · Security · Internet of medical things

1 Introduction

The demands of digital applications (online video streaming, video conferences), and cloud computing has created a demand for high speed and low delay wireless communication technologies [1]. Hence it is a challenge for upcoming 5G technology with network slicing and aggregation to fulfill these demands. Recently, 3GPP-long term evolution advanced specified D2D that provides the proximity-based services and also it was defined in Release

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12 under 4G. D2D communication satisfies the emergent requirements of fifth-generation (5G) networks [2, 3]. D2D establishes direct communication with enhanced spectrum utilization of licensed band between proximity devices/users in a cellular structure without information relay through Base Station (BS) [4]. The potential of IoT devices is to interconnect each other without the human involvement that is defined as Machine to Machine (M2M) communications. It is part of 5G-M2M communication under IoT as M2M is a form of wireless communication to exchange local information that involves one or more devices without direct interaction. The D2D communication reduces latency as well as increases spectral efficiency, reliability, and system capacity. This emerging technology has been considered a part of the 5G network whereas up to 4G technology neglected this D2D communication [5]. The wireless local area networks, wireless personal area networks, etc. are used for direct communication without a licensed band, which may give the advantage of low energy communication with minimal cost [6–8]. But this type of unlicensed band usage is not a good choice as an interference point of view. The controlled interference, better energy consumption rate, better spectrum utilization in a licensed band, etc. make D2D communication as an excellent option for direct communication in 5G technology [9, 10].

Literature shows that D2D communication lacks data aggregation models. But data traffic aggregation took importance in recent years in order to increase system throughput, full bandwidth utilization and to decrease energy consumption, increase the overall QoS. In the data traffic aggregation model, data collection and scheduling operation did first then transmits to the next hop. Data aggregated until proper bandwidth utilization and buffer usage done properly. D2D is associated with the IoT, Internet of Vehicle Things (IoVT), Internet of Medical Things (IoMT), cloud computing, etc. [11, 12]. and also the cloud radio access network enables IoMT, and IoVT [13]. IoT provides human involvement into a network of interlinked devices. There are different D2D pairs communicated directly between devices as well as it relaying information to BSs. Here a small cell is very significant due to offload traffic and increase the coverage area. D2D communication reduces backhaul network loads without requesting BSs and hence improved QoS [14]. The IoT-devices are used to accumulate all information (i.e. medical data) from objects/things using D2D links that acting as an aggregator. This data is processed through the IoT gateway in the core network domain. D2D consists of 3 categories: (a) device-and-gateway domain—provides the connectivity between D2D pairs and IoT gateway, (b) core network domain—As a large number of devices communicating directly, there are aggregators to collect and aggregate data

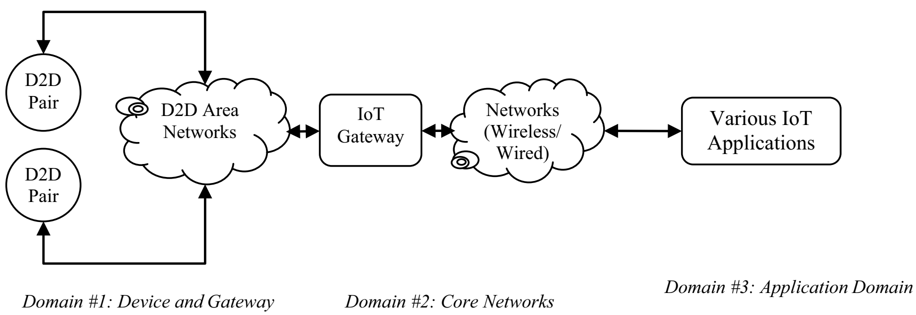

Fig. 1 D2D communication architecture

from D2D pairs, and (c) applications domain—covers the various applications in IoVT, IoMT, public safety, smart homes fields, etc. as shown in Fig. 1.

To transmit over long distances with minimum cost, maintaining quality and less power, radio transmission quickly gained its significance. The generation-wise cellular communication system has been summarized here. 1G—The communication was very insecure and power consumption was large (2.8 Kbps) and there is no direct communication concept. 2G—it failed to transmit video files and data rates increased up to 200 Kbps and few advanced technologies like Enhanced Data rate for GSM, Evolution and General Packet Radio Service introduced. 2.5G was no direct communication. 3G—provides maximum data rate 2 Mbps and enhanced voice quality. Direct communication established between 3.5G with WLAN, and WPAN. 4G—This generation offers data rates, security and many advanced services. 5G—The D2D communication belongs under this generation is expected to come in 2020 with high capacity, better throughput, increased spectral efficiency, lesser delay, improve QoS. The network-centric generations are going to move in device/user-centric communication where the device/user will perform store, relay, compute and deliver content where it was done by BS earlier. D2D communication is specified in 3GPP-LTE–Release 12 proposal and it is mentioned as one of the key elements of 5G networks [15]. D2D paradigm belongs under the IEEE 802.11 family of standards also supports D2D communications, since they support the ad-hoc mode. So D2D is also part of the IEEE 802.11 networks even if most of the deployments follow the Infrastructure approach (Access point-based). The important features of D2D have been discussed in Table 1.

The key benefits of D2D communication are as follows: (a) users can experience high data rates, low latency and reduced energy consumption due to direct communication in a short-range and its potentially favorable propagation conditions, (b) coverage range can be extended and capacity improved without additional infrastructure cost, (c) users at cell edge experience poor performance in uplink/downlink transmission but here can communicate directly to nearby terminals or to the BS where mobile users acting on relays., (d) spectrum reuse between traditional cellular communication and direct D2D enhanced the spectral efficiency and allow a larger number of concurrent transmission, and (e) offers the local management of short-distance communication, it allows for data offloading from the BS which alleviates network congestion, traffic management effort at central nodes.

D2D communication is going to be an important part of the upcoming 5G network and different IoT applications. Hence there is an increase in network traffic, low spectral efficiency, reduction in energy efficiency and throughput, an increase in delay, etc. [16]. D2D communication can treat this situation very intelligently without traversing the core network. Actually, D2D is like Mobile Ad-hoc Networks and Cognitive Radio

Table 1 Useful features of D2D communication paradigm

Features	D2D
QoS	Hard QoS
Pairing	Base station/device assisted
Spectrum	Licensed and unlicensed
Pricing	Operator dependent
Maximum covered distance	400–500 m
Maximum data rate	10 Gbps
Standardization	OFDMA, SCFDMA

Networks, having control from the operator to enhance spectral efficiency and overall performance through the IoT [17]. The M2M doesn't have the capability to increase spectral efficiency unlike D2D [18]. The D2D system can be classified as Inband and Outband (Fig. 2). The underlying method leads to opportunistic (more profitable for operators and more spectrum use) but overlay scheme having easy implementation.

There is an anticipation of high gain from D2D underlying communication if there is proper reuse of radio resources (frequency/time) allocated to the D2D users. There are 2 possibilities: it may help to decrease and offload the high traffic of base stations if radio resources utilize properly; otherwise, there is a high chance of interference to the cellular user communication, which is the key challenge in D2D communication [19]. The outbound D2D operates an unlicensed spectrum (38 GHz mm-Wave or 2.4 GHz ISM band). It eliminates interference between cellular users and D2D but interference is present in devices like Bluetooth and Wi-Fi. Outbound D2D communication uses the same wireless channel for Zigbee/Bluetooth/Wi-fi Direct but not use for D2D. D2D should address that how the allocation of the resources (frequency/time) shared by the BS is possible in such a way which should meet the following aims like increasing throughput, enhancing spectral efficiency, maximizes the offload base station traffic, maintaining fairness, minimizing latency, higher mobility, maximizing data rate, increasing user capacity, lower power consumption, maximizes the offload base station traffic, maximizing SINR, etc. with a lower mutual interference environment [20–22]. The power consumption issue should be taken care of and the security in data communication is very important [23]. The D2D communications have been thoroughly studied in literature and they are being standardized inside the 3GPP as a key 5G component. It surveys the most significant research work and presents a major investigation of the IoT-D2D communication services and applications available in the healthcare industry and smartphone market.

Some of the important parameters have been discussed here that are going to provide better D2D system performances. These are *Throughput:* It is the average rate of successful information transformation among D2D users over a channel (bits/sec). A higher value of throughput in D2D communication is desirable. *Signal to interference noise ratio (dB):*—A high value is desirable. *Power consumption:* It is the average power consumed by the D2D user. A lower value is desirable. *Energy efficiency*: It is defined as the ratio of throughput to power over energy consumption per unit area is known as energy efficiency. *User capacity:* If the maximum data rate is the constraint, then the maximum number of D2D users that can accommodate in the network for a given set of cellular users is known as user capacity. The higher value of user capacity is desirable. *Fairness:* It is mainly applicable for resource allocation for D2D communication where the allocation of resources is done in a reasonable way to D2D users. Any unfairness leads to resource starvation/wastage. It aims to quantify the quality of equality in the treatment of similar individuals of a system. It is measured by the fairness index. *Latency:* Delay

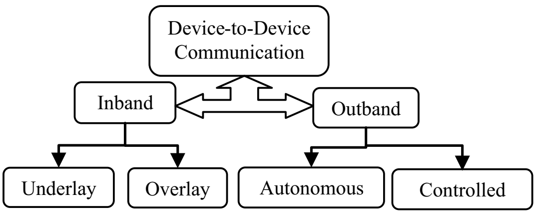

Fig. 2 Types of D2D communication

is measured between the transmission and reception of information. The lower value is desirable. *Data rate:* It the speed at which the bits are transferred between two D2D users. It is measured in Mbps in D2D communication and a high value is desirable. *Spectral efficiency (bits/Hz):* It is the number of bits transmitted per unit bandwidth.

The main contributions of the paper are mentioned below:

1. Survey on D2D communication paradigm highlights different characteristics, and findings the research gaps
2. Limitations of generation-wise networks have been discussed
3. The key parameters of D2D communication have been summarized
4. Study of various open challenges, potential benefits
5. The system model with different applications of D2D communication is discussed
6. Evaluation and comparison with existing D2D works in an IoT
7. Discussed resource allocation, power control, and security briefly

The organization of the paper is as follows. We present the latest review of the relevant work Sect. 2. The proposed system model with an application is presented in Sect. 3. The major research challenges are discussed Sect. 4. Finally, we describe the conclusions with future scope in Sect. 5.

2 Background and Related Work

There is a big chance of interference while D2D/cellular users are sharing the same resources at the same time, which to be controlled to achieve QoS. Therefore there are numbers of interference resistive resource allocation algorithms including peer discovery and mode selection in the literature. At the same time, power control and security are the major issues too and literature is dense by those algorithms. The comparative analysis of the most promising solutions has been discussed here. Therefore the entire literature can be classified into the following sections: resource allocation algorithms, power control, and security mechanisms.

2.1 Resource Allocation Schemes

The available resources are one of the major parts after device discovery over the direct paths. This scheme is used to allocate frequency resources over cellular networks and also enhance spectrum utilization. The features of D2D resource allocations are low latency, ubiquitous availability, low cost, and flexibility. The effective resource allocation scheme is needed to promise the fulfillment of QoS demands, maximize the network throughput, achieved fairness for user data rates, and minimizes the load in the BS. The four modes can be considered for enhancing the D2D communication i.e. (a) dedicated mode—some resources are available for direct transmission, (b) silent mode—devices are in silent due to lack of resources, (c) Reuse mode—uplink/downlink resources are reused, spectrum efficiency can be achieved and (d) Cellular mode—data is transmitted. The resource allocation can be achieved by different performance objectives.

Ahmed et al. [24] used overlapping Coalition Formation algorithm for representing secure resource allocation possessing the benefits of investigated physical layer security and resource allocation problem for socially aware D2D communications. This algorithm leads to a drawback that is physical realization difficulties and not enough secured. Esmat et al. [25] considered proper resource allocation to remove interference using D2D underlying multicell mobile networks algorithm. In this regard, there is an advantage of having good QoS, good throughput along with a drawback that it did not consider other system parameters. Hossen et al. [26] proposed on online resource allocation by using relax online resource allocation (RORA) and conservatively relax online resource allocation which leads to the positive side of providing good algorithm in terms of system sum-rate with less number of changes in successive allocation and hand in hand there has its negative side also that is cellular UEs and the D2D pairs are not adversary sets. Xu et al. [27] proposed the optimal allocation of resources using K-means algorithm which leads to eliminate interference and improve the system's overall performance. Gabor et al. [28] proposed on practical resource allocation method using the MinInterf algorithm which leads to low complexity and used in tandem with the optimal binary power control scheme. Islam et al. [29] considered minimum knapsack based interference aware resource allocation and graph-based resource allocation (GRA) on resource allocation with good SNR that leads to the advantage in low complexity and good SNR and along with a drawback of GRA is there that is GRA is complex and SNR is not satisfactory. Liu et al. [30] proposed to achieve a stable matching between important nodes and files during resource allocation using a user file caching method which leads to the reduction in transmission delay. Sun et al. [31] conveyed on the effective solution for resource allocation and optimization of D2D communications using a genetic algorithm that leads to the reduction of complexity. By using the auction algorithm Zaki et al. [32] represented on the purpose to solve allocation problem in a distributed manner that proceeds to have an advantage of low complexity, increased spectral efficiency and increased system data rate and simultaneously there has a problem to be noted that energy efficiency is neglected. Hussain et al. [33] used the optimal resource allocation algorithm to maximize the total system sum-rate but the QoS is a constraint. Liu et al. [34] proposed Quality of Experience aware resource allocation to get good service completion time that leads to better performance in terms of service completion time, the average Quality of Experience, and better throughput. Wu et al. [35] proposed to alleviate the performance deterioration by using the maximum throughput gain resource allocation that leads to the increased throughput reduced rate loss but only applicable for perfect channel state information. Yang et al. [36] conveyed tons enable maximum spatial reuse by resource allocation using the largest aggregated interference first to save resource block usage, improved throughput, and reduced computation time. Liang et al. [37] conveyed the purpose of proper spectrum sharing and power allocation for D2D vehicular communication that leads to the advantage of maximized the argotic capacity of the vehicle to infrastructure but it limited to allowing spectrum sharing within a single cellular user equipment D2D user equipment pair. Asheralieva et al. [38] conveyed using joint utility and strategy estimation based reinforcement learning with regret for the purpose to maximize the network utility which has the advantage of good energy efficiency and throughput but the signal to interference and noise ratio constraints. Hoang et al. [39] proposed to maximize the weighted system sum-rate by using iterative rounding for significant spectrum allocation but there is a drawback of constraints that each D2D link is assigned a link and should maintain a minimum rate. Ren et al. [40] used the graph-based two-step resource allocation scheme to allocate resources and achieve maximum total system capacity which leads to low complexity and good QoS. Dai et al. [41] investigated the sub-channel allocation problem using a cloud-assisted learning algorithm that results in good efficiency. Li et al. [42] using pseudo-code of the overall algorithm for resource allocation to allocate multi-object resources that lead to guaranteed QoS, maintained better fairness for different

D2D multicast groups. Abbas et al. [43] introduced LTE Heterogeneous Network and Service resource blocks Distribution on resource allocation and reuse scenarios for mitigating the interference with high complexity. Chen et al. [44] improved system throughput and D2D user satisfaction ratio using a Time-division schedule. Ciou et al. [45] maximized the system throughput and the number of permitted D2D pairs using the GTM + Algorithm for resource allocation has achieved fast, better throughput and increased number of permitted D2D pairs. Botsov et al. [46] considered Location dependent resource allocation scheme on resource allocation for automotive safety application and also achieved the advantage of good QoS, reliability but it was not applicable for multiple cells. Xu et al. [47] improved the performance of mobile peer-to-peer (D2D) communication using a Non-monotonic descending price auction scheme. It reduced interference, increased system sum rate. Wang et al. [48] proposed a joint scheduling and resource allocation algorithm for improving the D2D performance with increased throughput, increased fairness, and managed interference. Su et al. [49] considered particle swarm optimization mode selection and resource allocation (PSO-MSRA) for maximizing the system throughput with a minimum required rate guarantee. Wen et al. [50] applied the D2D and Users Mode Selection and Resource Allocation (DMSRA/UMSRA) scheme that achieved the QoS and suppress interference with increased system capacity, better interference level. Yin et al. [51] optimized the throughput using asynchronous iterative water filling like algorithm and also reduced D2D communication overhead but it is very complex and performance compromised. Wang et al. [52] applied a resource allocation algorithm on the purpose to extend user equipment battery lifetime. Zhang et al. [53] proposed an interference aware graph-based resource sharing algorithm to investigate resource sharing problems with low computational complexity. Cheng et al. [54] used resource allocation for secondary user algorithm on cognitive D2D communication. It leads to robust and efficient security. Yu et al. [55] considered a resource allocation algorithm on resource management, which leads to controlled interference and better throughput but has got the disadvantage of complexity. Zulhasninee et al. [56] used uplink and downlink resource block schemes efficiently for resource allocation hence avoided interference significantly with high complexities. Janis et al. [57] concluded the practical and efficient interference control by interference aware resource allocation algorithm. The resource allocation algorithms (Table 2) have been discussed with their purpose and limitations.

2.2 Power Control Issues

One of the major issues of D2D is power control that discussed here briefly. The throughput can be enhanced by an optimal power control scheme. This method is used to provide distributed solutions with low computational complexity, minimizes the overall interference, reduces energy consumption, lower transmission power and delay, and increased the system capacity for big-networks.

Saleem et al. [58] applied Energy Harvesting and Gain based Resource allocation algorithm to determine resource partners and allocate power optimally with an advantage higher sum rate and low complexity. Sun et al. [59] minimized interference with increase sum rate, good SINR but the only single-cell environment is considered. Khazali et al. [60] proposed an energy efficiency maximization algorithm for the purpose to control interference and improve performance having the advantage of increased throughput, low computational complexity. Jiang et al. [61] used a dynamic power control scheme for improving QoS performance and limitations being too many constraints. Xu et al. [62] considered join

Table 2 Resource allocation schemes

Authors/Year	Algorithm proposed	Purpose	Advantages/limitations
Ahmed et al. [24]	Overlapping coalition formation	Secure resource allocation	Investigate physical layer security
			Physical realization difficult and not enough secure
Esmat et al. [25]	Underlaying multi-cell mobile networks	To remove interference	Good QoS and throughput
			Not consider other system parameters
Hossen et al. [26]	Relax online resource allocation and conservatively relax online resource allocation	Online resource allocation	Give system sum-rate with less number of changes in successive allocation
			Cellular UEs and D2D pairs are not adversary sets
Xu et al. [27]	K-means	Optimal resource allocation	Remove interference and improve the overall performance
Gábor et al. [28]	MinInterf	Practical resource allocation	Low complexity and used in tandem with the optimal binary power control
Islam et al. [29]	Minimum knapsack-based interference aware resource allocation and Graph-based resource allocation (GRA)	Resource allocation	Low complexity and good SNR
			GRA is complex and SNR is not satisfactory
Liu et al. [30]	User-file caching	To achieve a stable matching between important nodes and files during resource allocation	Reduce transmission delay
Sun et al. [31]	Genetic	effective solution and optimization	Reduce complexity
Zaki et al. [32]	Auction	To solve the allocation problem in a distributed manner	Low complexity, increased spectral efficiency and increased system data rate
			Energy efficiency neglected
Hussain et al. [33]	Optimal resource allocation	To maximize the total system sum rate	Optimal sum rate, minimal interference, removed nonviable D2D pairs
			QoS is constraint
Liu et al. [34]	QoE-aware resource allocation	To get better service completion time	Better service completion time, average QoE, better throughput
Wu et al. [35]	Maximize throughput gain	To alleviate the performance deterioration	Increased throughput rate, reduced rate loss

Table 2 (continued)

Authors/Year	Algorithm proposed	Purpose	Advantages/limitations
			Applicable for perfect channel state information
Yang et al. [36]	Largest aggregated interference first	To enable maximum spatial reuse by resource allocation	Saved resource block usage, improved throughput, reduced computation time
Liang et al. [37]	Optimal Resource allocation and robust channel variations	Proper to provide uniform capacity	Supports effective and Reliable vehicular communication
		Using spectrum sharing and power allocation	Limited to allowing spectrum sharing within a single cellular user equipment-D2D user equipment pair
Asheralieva et al. [38]	Joint utility and strategy estimation based reinforcement learning with regret	To maximize the network utility	Good energy efficiency and throughput
			SINR constraints
Hoang et al. [39]	Iterative Rounding	To maximize the weighted system sum-rate	Significant spectrum allocation
			To maintain a minimum rate
Ren et al. [40]	Graph-based Two-step Resource Allocation	Te allocate resource &achieve maximum total system capacity	Low complexity, good QoS
Dai et al. [41]	Cloud-assisted learning	To investigate the sub-channel allocation problem	Good efficiency
Li et al. [42]	Pseudocode of overall algorithm for resource allocation	To allocate multi-object resources	Guaranteed QoS, maintained better fairness for different D2D multicast groups
Abbas et al. [43]	LTE Heterogeneous Networks (HetNets) Service resource blocks distribution	Resource allocation and reuse	Mitigate interference
			High complexity
Chen et al. [44]	Time Division Scheduling	To efficiently use downlink spectrum resources	Improved throughput and user satisfaction ratio
		To support more D2D communication	Reduce interference
Ciou et al. [45]	GTM +	To maximize system throughput, and number of permitted D2D pairs	Fast, better throughput and increased number of permitted D2D pairs
Botsov et al. [46]	Location dependent resource allocation scheme	Resource allocation for automotive safety application	Good QoS and reliability

Table 2 (continued)

Authors/Year	Algorithm proposed	Purpose	Advantages/limitations
			Not applicable for multiple cells
Xu et al. [47]	Non-monotonic descending price auction	To improve the performance of mobile peer to peer communication	Reduced interference, increased system sum rate
Wang et al. [48]	Joint scheduling and resource allocation	To improve D2D performance	Increased throughput and fairness, Managed interference
Su et al. [49]	Particle swarm optimization mode selection and resource allocation	To maximize throughput	Better throughput and minimum required rate guarantee
Wen et al. [50]	D2D and users mode selection and resource allocation (DMSRA/UMSRA)	To achieve QoS and suppress interference	Increased system capacity, the better the interference level
			Many constraints are there for hybrid network and complex analysis
Yin et al. [51]	Asynchronous iterative water-filling like an algorithm (AIWA)	to optimize the throughput	Overhead in D2D communication reduced
			Very complex and performance compromised
Wang et al. [52]	Resource Auction	To extend user equipment (UE)	UE battery lifetime increased
Zhang et al. [53]	Interference-Aware Graph-Based Resource Sharing	To investigate the resource sharing problem	low computational complexity
Cheng et al. [54]	Resource allocation for secondary user	To allocate resource for cognitive D2D	Robust and efficient
Yu et al. [55]	Resource allocation	Resource management	Controlled interference and better throughput
			Complex
Zulhasnine et al. [56]	Uplink and downlink resource blocks allocation scheme	To allocate resource efficiently	Interference avoided significantly
Janis et al. [57]	Interference aware resource allocation	Practical and efficient interference control	Controlled interference

channel allocation and power control methods for the purpose of the efficient management interface and improving network throughput with the advantage of input throughput with limitation of different constraints. Memmi et al. [63] proposed a power control algorithm for mitigating the interference resulting in performance increase and gain increased with limitation lack of reliability. Xu et al. [64] applied a power control algorithm for the maximizing D2D links data transmit power with the advantage of good convergence. Azam et al. [65] applied to join the admission control mode selection and power allocation algorithm to increase system throughput with reasonable computational complexity, QoS and interference as constrain. Nie et al. [66] used a reinforcement learning-based power control algorithm for achieving maximum system capacity and maintain QoS with the advantage of improved system performance. Yang et al. [67] considered iterative resource allocation and power control algorithms to increase the sum rate and control power consumption. Yang et al. [67] proposed an optimal power control algorithm for investigating energy-efficient power control for D2D communication having advantage total throughput increase, guaranteed QoS increase energy efficiency. Wu et al. [68] implemented the optimal power control scheme having the advantage of improved energy efficiency with limitation of throughput constraint. Lee et al. [69] applied the centralized power control algorithm to improve the cellular network throughput with the advantage of improved throughput but it is not reliable. Oduola et al. [70] proposed a joint power control algorithm for optimizing energy efficiency with good QoS. Riu et al. [71] highlighted the distributed power control scheme for energy conservation and enhancement of radio resource utilization with energy-saving and good spectral utilization. Wen et al. [72] proposed a joint resource allocation and power control scheme to allocate proper power for each D2D user on each channel having guaranteed QoS, good energy efficiency and lower scheduling complexity. Rego et al. [73] considered iterative channel inversion power control algorithm for controlling interference and system performance with improved SINR, good power control. Fodor et al. [74] used a distributed power control scheme to achieve better system performance where the overall power consumption is minimized. Gu et al. [75] proposed the dynamic power control mechanism for reducing interference and improved performance with controlled power consumption. The power control methods have been discussed in Table 3. There is no suitable power control scheme in D2D found from 2009 to 2010.

2.3 Security Issues

Security issues are a more challenging area in D2D where end-devices need to exchange data securely in ad-hoc mode. Researchers are mainly focusing the security for the end devices/users. Security is required for transmitting the data over broadcast wireless channels to avoid the number of attacks. Security is still lacking on the outside coverage area, so designing the security method is essential. The traditional security scheme might be good but not for D2D. IoT security mainly needs in ad-hoc distributed systems. D2D communications have been facing different security threats like denial-of-service, trust forging attack, impersonate and eavesdropping attack, man-in-the-middle, location spoofing, malware attack, IP and bandwidth snoofing, privacy violation, replay attack, and free-riding attack. To overcome these threats D2D considered the following requirements: data confidentiality, authentication, integrity, traceability, privacy, non-repudiation, availability, revocability, and fine-grained access control. The trust management is essential for different IoT applications to protect the data.

Table 3 Power control schemes

Authors/Year	Algorithm proposed	Purpose	Advantages/limitations
Saleem et al. [58]	Energy Harvesting and Gain based Resource Allocation	To determine resource partners and allocates power optimally	Higher sum rate, low complexity
Sun et al. [59]	Interference limited area scheme considering power control	To mitigate interference	Increased sum rate, good SINR
			Only the single-cell environment considered
Khazali et al. [60]	Energy efficiency maximization	To control interference and improve performance	Increased throughput, low computational complexity
Jiang et al. [61]	Dynamic power control	To improve QoS	Improved performance
			Too many constraints
Xu et al. [62]	Joint channel allocation and power control algorithm	To efficiently manage interference and improve the network throughput	Improved throughput
			Different constraints
Memmi et al. [63]	Power control	To mitigate interference	Performance increased, gain increased
			Lack of reliability
Xu et al. [64]	Power control	To minimize D2D links data transmit power	Good convergence
Azam et al. [65]	Joint admission control, mode selection and power allocation	To increase system throughput	Increased number of users
			Reasonable computational complexity, QoS and interference as constraints
Nie et al. [66]	reinforcement learning-based power control	To achieve high capacity and maintain QoS	Improved system performance
Yang et al. [67]	Iterative Resource Allocation and Power Control	To increase the sum rate	Increased controlled average power
Yang et al. [67]	Optimal power control algorithm	To investigate energy-efficient power control for D2D communication	Total throughput increased, guaranteed QoS, increased energy efficiency
Wu et al. [68]	Distributed power control	To implement the optimal power control	Improved energy efficiency
			Throughput constraint
Lee et al. [69]	Centralized Power Control	to improve the cellular network throughput	Improved throughput
			Not reliable
Oduola et al. [70]	Joint power control	to optimize the energy efficiency	Better QoS

Table 3 (continued)

Authors/Year	Algorithm proposed	Purpose	Advantages/limitations
Riu et al. [71]	Distributed power control	For energy conservation and enhancement of radio resource utilization	Energy saving
			Good spectral utilization
Wen et al. [72]	Joint Resource Allocation and Power Control	To allocate proper power for each D2D user on each channel	Guaranteed QoS, good energy efficiency and lower scheduling complexity
Rego et al. [73]	Iterative Channel Inversion Power Control algorithm	To control interference and system performance	Improved SINR, good power control
Fodor et al. [74]	Distributed power control algorithm	To get better system performance	Overall power consumption minimized
			Sum rate constraint
Gu et al. [75]	Dynamic power control mechanism	To reduce interference and improve performance	Controlled power consumption
2009—2010	There is no suitable algorithm found		

Chen et al. [76] observed social trust aided D2D communication using a social trust matching algorithm and also increased the secrecy rate by 63%. Cao et al. [77] conveyed to secure the D2D communication using lightweight key distribution and lightweight index matching algorithm with low computing resources and energy consumption. Zhang et al. [78] proposed a lightweight and Robust Security Aware scheme to secure confidentially and unforgeability. D2D assist data transmission protocol has led to enhance security but relay selection strategy did not consider. Liu et al. [79] considered wireless power transfer policies on the topic to investigate secure D2D communication in large scale cognitive cellular networks that leads to the nearest power beacon offered better secrecy with lower complexity. Zhang et al. [80] proposed a secure data sharing protocol algorithm to achieve data security in D2D communication. It has got an efficient and practical solution. This method assumed that the communication between eNB and gateway is secured but the hostile environment the channel is not secured. Ometov et al. [81] proposed a distributed coalition formation algorithm to provide a security framework for additional coverage of users has led to able to deliver security for extra users outside the coverage area. Zhang et al. [82] proposed to merge and split based coalition formation algorithm for improving system secrecy rate and social welfare has led to improved security. Jayasinghe et al. [83] considered a secure beamforming algorithm to prevent eavesdropping on the relay assisted D2D communication leads to higher secrecy. Zhang et al. [84] implemented the Kuhn-munkres algorithm for secure underlaid connection with high system secrecy capacity. Shen et al. [85] considered a key agreement protocol to set up secure connections efficiently and with high usability. Yue et al. [86] proposed the Benchmark algorithm on the purpose to guarantee the information-theoretic secrecy but it has low complexity. The security in D2D has been discussed in detail in Table 4.

3 D2D System Model for Various Applications

D2D is the most promising communication paradigm that uses in different applications (i.e. file sharing, multicasting, video streaming, local advertising, online gaming, etc. over short ranges). D2D also finds its applications at cognitive-communication, IoT, cooperative communication, and M2M, Group and multihop relay communications. D2D provides service providers to increase spectral efficiency. Public safety, traffic safety, disaster management, national security will be flooded by D2D communication. D2D includes social networking, smart city, location-aware services, smart grids, smart homes, smart parking, green communication, ubiquitous computing, multiuser MIMO enhancement, virtual MIMO, etc. Especially D2D with IoT is a very emerging area like intelligent IoVT, quick disaster relief action, e-medicine, proximity services, and IoMT. Most interestingly, D2D plays an important role in emergency scenarios where cellular coverage is completely lost due to natural disasters. Figure 3 depicts the D2D communication overview in general with public safety, traffic safety, IoVT, and IoMT.

Healthcare perspective: Reliable communication is requiring among the devices for healthcare data delivery. D2D supports sufficient reliability over short ranges connectivity. IoMT is used to collect the data from the medical devices and applications are linked up with IoT enabled cloud systems (Amazon web services). The Wi-Fi-equipped devices process the data via D2D under IoMT. The near field communication and RFID tags help to share data under IoMT. The IoMT platform is used to monitor remote patient data via telemedicine [87]. The sensors acquired medical data received by the devices,

Table 4 Different security schemes

Authors/year	Algorithm proposed	Purpose	Advantages/limitations
Chen et al. [76]	Social Trust Matching	To observe social trust to implement efficient resource allocation	Increased secrecy rate (63%)
			Smaller uplink spectrum usage in 5G
Cao et al. [77]	Lightweight key distribution and lightweight index matching	To secure the D2D communication	Minimal computing resources and energy consumption
Zhang et al. [78]	Light-weight and Robust Security-Aware D2D-assist data transmission protocol	To secure confidentiality and unforgeability	Enhanced security
			Relay selection strategy not considered
Liu et al. [79]	Wireless power transfer	To investigate secure D2D communication in large-scale cognitive cellular networks	Nearest power beacon offered better secrecy with lower complexity
Zhang et al. [80]	Secure data sharing protocol	To achieve data security in D2D communication	Efficient and practical solution
			Hostile environment the channel is not secured
Ometov et al. [81]	Distributed coalition formation	Provide security for additional coverage of users	To deliver security for extra users outside the coverage area
Zhang et al. [82]	Merge-and-split-based coalition formation algorithm	To improve system secrecy rate and social welfare	Improved security
Jayasinghe et al. [83]	Secure Beamforming	to prevent eavesdropping	Higher secrecy
Zhang et al. [84]	Kuhn-Munkres	To secure the underlaid connection	Higher secrecy
Shen et al. [85]	key agreement protocol	To set up a secure connection	Efficient and high usability
Yue et al. [86]	Benchmark	To guarantee the information-theoretic secrecy	Low complexity
2009—2012	There is no suitable algorithm found		

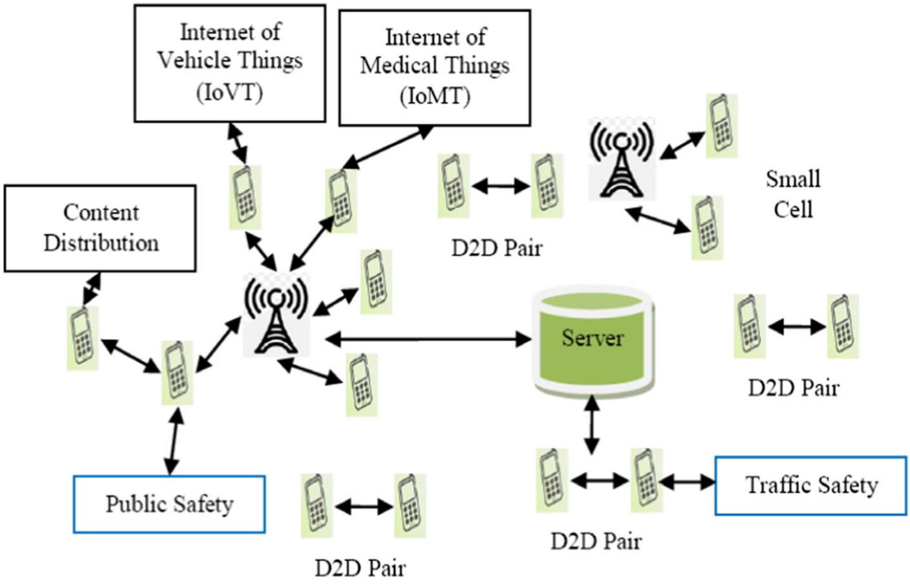

Fig. 3 D2D communication overview

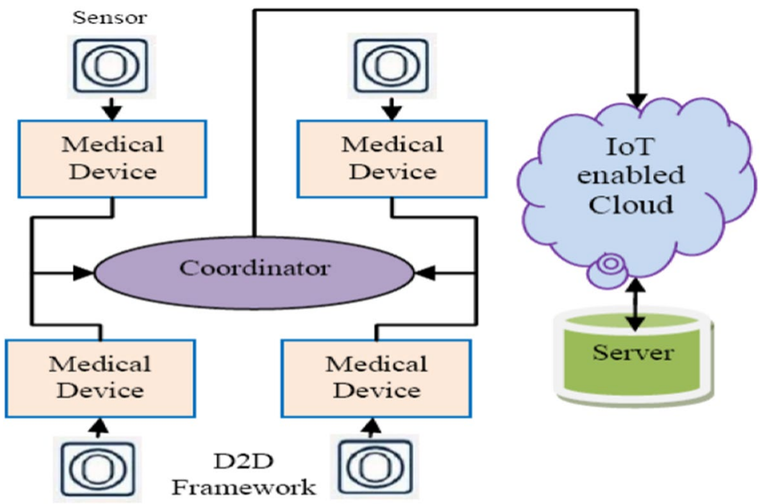

Fig. 4 D2D communication for IoMT

and send to the coordinator using the 5G-D2D tool. This data transfer to IoT enabled cloud framework for storage and manipulation that are shown in Fig. 4. The processed data is secured by protected health information regulated by the Health Insurance Portability and Accountability Act. The medical or industry data directly processed to the server without access point using near field communication, UWB, Bluetooth, Zigbee, Wi-Fi Direct/Wi-Fi ad-hoc/LTE Direct. The coordinator transfers the large volume of medical data to the server. So the proper scheduling algorithm is required before data processing. The D2D communication method provides larger throughput in a network with many links and gives optimal and efficient resource partition. It improves the data rates, reduces latency, coverage expansion, and enhances system capacity. It is used to provide reliable healthcare monitoring services. The role of D2D in IoT-healthcare has been discussed here.

4 Major Research Challenges

The major challenges of D2D communication in wireless networks have been discussed. Some issues exist in the literature which is recovered to get the QoS of D2D communication. (a) *Neighbor discovery:* searching for the nearest D2D user by search/scan mechanism. (b) *Synchronization:* D2D users should get the broadcast message with good synchronization so that it can identify the proximity user quickly. Until there is a discovery of D2D proximity user to make the connection, there is always a continuous monitoring process which leads to more energy consumption. The synchronization with the underlying cellular network is necessary. (c) *Mode selection*: Taking the decision of this mode selection is very important. This mode selection depends on different factors: the distance between D2D transmitter and receiver, the status of channel state information, the frequency at which there should be update operation, how often the communication mode of the D2D users to be updated, the timescale for mode selection, etc. it consists of 2 modes, (a) direct—two users establish a direct link, and (b) cellular—two users make a link through the BS. A transceiver pair may use any one of the 2 modes. (d) *Spectrum access:* how D2D users access the spectrum. There are 2 choices: overlay and underlay. The overlay is the orthogonal spectrum access between a D2D user and cellular UEs and underlay is the non-orthogonal case. (e) *Spectrum use:* As the licensed bandwidth is very costly, the available spectrum must be used efficiently with proper techniques. (f) *Interference management:* If D2D reuses the frequency of cellular spectrum (shared channel) then there is a chance of interference. D2D link may be formed at any distance which may cause interference and affect system performance. There should be proper interference cancellation/avoidance/coordination techniques. (g) *Channel modeling*: It is a difficult confront as it has different propagation properties. Firstly, the D2D transmitter and receiver both have a small-sized antenna. It may be the transmitter and receivers are in moving state whereas the BS is at a fixed location. There may any obstacle in communication links which creates a shadow problem. D2D communication may have the frequency range in the mm-wave scale which requires additional propagation requirements. (h) *State acquisition:* in conventional cellular communication, channel state information (CSI) between the device and BS is recommended. Unlike the conventional cellular networks, here CSI between D2D users is also required along with the CSI between D2D devices and the BS. It creates unavoidable overhead to the system. (i) *Resource allocation:* D2D communication is popular to increase the spectrum utilization of the cellular network. Within the cellular network, the proper allocation of frequency resources is a key challenge. After the neighbor discovery with synchronization and mode selection, the frequency resource allocation must be optimal to meet the aim of D2D communication. During resource allocation, interference and power control should be considered. (j) *Power control:* It may decrease the system performance if applied blindly in a cellular network. Power control of user equipment is an utmost priority to utilize resources efficiently. For a better SINR requirement and increase the overall system performance, D2D users should limit their transmit power. (k) *Energy* *efficiency:* To achieve good energy efficiency in D2D communication is an issue due to its low battery capacity. (l) *Security:* The state of the art cellular network is associated with a core network which is a trusted party. But transmissions take place in D2D communication without the assistance of the core network and with the help of wireless broadcasting channels, hence the information becomes insecure. D2D users should use the facility of security scheme when it comes under any cellular network but outside of cellular network range the security is a burden. In that case, the security signal may be passed through relays which again a very vulnerable for malicious attack. (m) *Joint resource allocation:* resource allocation should be joint with mode selection and power control to take in the full potential of D2D communication. (n) *Optimal resource allocation:* With low complexity efficient power optimization and taking care of energy efficiency is a major challenge in the D2D resource allocation scheme. (o) *User satisfaction ratio:* the ratio of the number of D2D pairs whose data transmission rates are satisfied with the total number of D2D pairs. Other challenges are *blockchain* and *non-orthogonal multiple access*.

5 Conclusion

D2D communication paradigm is the most challenging about once implemented it can improve spectral efficiency and system capacity hence can enhance the performance of next-generation IoT based solution with reasonable costs. This paper discusses a systematic review of the state-of-the-art on D2D services and applications for the healthcare industry. This paper focused on all the three key challenges of D2D communication and surveyed existing methods with advantages and disadvantages. The system model with different applications has been discussed. The impact of D2D communication in healthcare has been discussed. Through the direct D2D communication between the users, offload of BSs and other performance metrics like network coverage at the edge, end-to-end latency, and energy consumption can increase. But interference is a major constraint for D2D communication. Efficient resource allocation schemes are required to implement to avoid interference. At the same time, one should care about power consumption for communication which is another important design parameter for any technology. While communication is going on, there should be enough security, which is another challenge. In future work, better algorithms are required to diminish any one of a challenge like interference, power control, and security, etc. One can focus on the aggregation process as literature is still lacks this side.

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