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REVIEW ARTICLE

Device-to-Device Communication Based IoT System: Benefits and Challenges

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ABSTRACT
Autonomous computing, communication, and collaboration among devices have their importance to transform the digital world. Emerging technology device-to-device (D2D) communication has a great impetus to facilitate peer-to-peer network. Therefore, D2D communication technology is expected to be an essential part of the Internet of Things (IoT). Rapid growth in quality of service demand leads to fundamental changes in the architecture of IoT system. This paper explains the benefits and challenges for intelligent D2D communication that will be required to accomplish the requirements for IoT. Many industries and standardization bodies have shown enormous interest towards the implementation of D2D approach in wireless networks. D2D approach facilitates to work without the essential control of the centralized supervision which makes wireless networks more spectrum and energy efficient with traffic offloading. Inter-networking devices offer various applications towards the development of IoT. Physical constraints of the devices and resource constraints of the networks give rise to several issues which need to be resolved. Here, we review the current status in the advancement of D2D technology subject to resources utilization, routing techniques, and interference management. Moreover, potential future challenges are explored that may be faced by the scientific community.

KEYWORDS
5G technology; Device-to-device communication; Interference management; IoT; Proximity services; Wireless network resources; Wireless security

1. INTRODUCTION

The Internet of Things (IoT) have caught enormous attention of many researchers due to its capability of developments in several areas such as autonomous intelligent networking, smart city, content sharing, advertisements, and multiplayer gaming. Nowadays, more and more people are being connected through the Internet and, therefore, exponential growth is found in the number of connected devices [1]. Mostly, short-range networks such as Bluetooth, Wireless Fidelity (Wi-Fi), Radio Frequency Identification (RFID), ZigBee, etc. are formed among devices for information processing. The process of content creating, sharing, and manipulating requires communication for connecting devices with or without involvements of the human. These devices may be any objects or things (*e.g.*, smartphones, sensors, electronic gadgets, cars, home appliances, or RFID tags) which are configured with intelligently decision-making, computing, and communicating capabilities [2].

Wireless sensor networks have low-power small sensors which are capable of extracting physical information and taking decision intelligently. This leads towards the major issues such as security, authentication, and privacy to facilitate the reliable services in the network. Also, the protocols need to be configured appropriately. Therefore, inter-networking devices with sensing and actuation systems connected to the internet achieve the vision of IoT. In addition, Internet protocols and standards provide infrastructure to connect devices with the physical world.

Information and communications services are recognized worldwide as an important tool for the socio-economic development of a nation. Ubiquitous computing among several devices introduces greater impact in real life environment. In heterogeneous IoT networks, devices are having the ability to collaborate with other devices and use the data collected from the environment to perform tasks actively in the intelligent manner [3]. It has been estimated that there would be more than 25 billion connected devices by 2016–17 (increases by 30%) when the world's population is expected to be about 7.8 billion. Moreover, it has been predicted that more than 50 billion devices will be the part of IoT by 2021 [1,4]. According to Wireless World Research Forum, a large number of devices which include smartphones, tablets, and various new applications will be increasing and will lead to more data traffic on the network [5]. Cisco [1] predicted that overall mobile data traffic is expected to grow sevenfold to 49 exabytes per month (1 exabyte equals 10^{18} bytes) by 2021. Also, it expects that mobile data traffic will increase at a compound annual growth rate of 47% from 2016 to 2021. Kumar [6] clearly mentions the necessities of 5G (Fifth Generation) networks to build smart cities that experience the computation and communication of huge data. Therefore, there is a requirement to provide sufficient bandwidth for applications and services to increase the network capacity. One solution is to deploy the new base stations (BSs) to improve the capacity of cellular networks, but this is very expensive from the operators' point of view. An alternative solution is data offloading to solve this problem.

The 3rd-generation partnership project (3GPP) has standardized the device-to-device (D2D) communication as a key technology for long-term evolution (LTE) release-12 [7], and will be incorporating new technology components that will help to meet the need of the future. The modern wireless network seems to provide enhancements in user experience and a new paradigm will offer advancements in e-health, e-learning, national security, business management, and intelligent transportation.

The new applications demand higher data rate, low latency, enhanced capacity, and better quality of service (QoS) from the wireless networks [4,7]. The performance of the wireless network can be improved with an emerging technology: D2D communication, in which users' equipment communicate directly with each other without the essential control of a BS. D2D approach offers new paradigms which facilitate in throughput enhancement with reduced delay [8]. Moreover, BS can be relieved from heavy traffic load. In IoT system, D2D communication provides autonomous intelligent mechanism or services that lead to energy- and spectrum-efficient systems. However, several technical and physical issues are encountered in D2D communication, such as cooperation among objects, interference, energy, and power consumption [9].

D2D communication concept was inspired from [10] as a multihop cellular network that suggests a new architecture in wireless networks. Fitzek and Katz [11] discussed the key aspects of cognitive and cooperative principles in wireless networks. They state that mobile devices need to enhance their capabilities in order to improve efficiency in the use of radio resources as well as to improve both link and network performance. Later, spectral efficiency of cellular networks on the perspective of D2D communications was investigated in [12,13]. With all this, other potential D2D use-cases such as multicasting [14,15] and peer-to-peer communication [16] were introduced in the literature. Moreover, machine-to-machine communication [17] and cellular offloading [18] in the context of D2D were also areas of interest by researchers.

Qualcomm's FlashLinQ [19] was an initiative to implement D2D communication in underlaying cellular network by designing a network architecture. In addition, device discovery has been widely studied in various wireless networks, such as ad-hoc networks, mobile sensor networks, and delay-tolerant networks. Qualcomm [20] is also investigating LTE-direct technology by providing always-on proximal discovery (*e.g.*, inside a retail store) with privacy, battery efficiency, range, and capacity which scaled up the user experience.

A brief overview of 3GPP D2D proximity services (ProSe) can be found in [21]. Proximity services are an emerging concept to enhance the user experience in IoT environment. 3GPP Service and System Aspects working group 1 (SA1) has documented the specification features, services, capabilities, and requirements on proximity services. LTE-direct technology started in the third quarter of 2014 supports the proximity service applications. To enable proximity services at a new level in LTE depends on the infrastructure and available devices. A wide range of proximity use-cases is available such as broadcast commercial expressions, public transport, tourism, and local programs.

In Figure 1, different application scenarios for D2D-based IoT system are shown. It includes e-medicine for health care; proximity services for context sharing, gaming, advertisement, and ubiquitous computing among surrounding devices; intelligent vehicle-to-vehicle communication for avoiding accidents; and quick disaster relief action that can be taken by instantly exchanging information. Figure 1 is briefly described in the following sections:

1.1. Healthcare IoT

Healthcare solutions aim to integrate the remotely monitored smart sensors with the medical devices to enable on-time healthcare services for everyone. Portable or wearable smart devices can be monitored remotely. In smart hospital, patients may track their treatment process and communicate with the physicians. With all this, the environmental characteristics can be regulated and also it allows the monitoring of medical assets. However, there is a challenge for hospital IT to manage and secure the exchange of data among the number of connected devices.

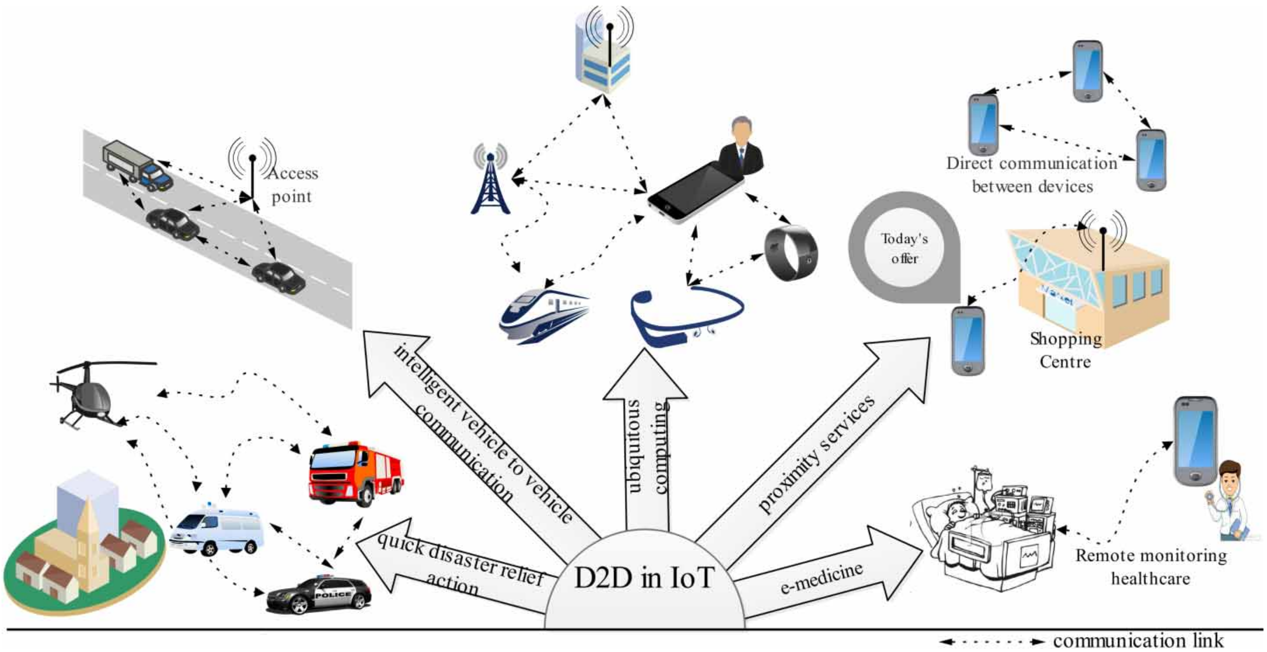

Figure 1: Different application scenarios for D2D-based IoT system

1.2. Proximity Services

Proximity services enable the real-time data exchange in the context of the advertisement, multiplayer gaming, broadcasting, service discovery, etc. Heterogeneous RFID readers connected with cloud radio access networks (RANs) allow IoT ecosystem to provide real-time services based on personal interest and activities. To guarantee the services among nearby devices, application developers need to be focused on the device connectivity with the flexibility to adopt new communication technology.

1.3. Ubiquitous Computing

Ubiquitous computing among several devices is a key feature of the IoT ecosystem. Connected user equipment would be benefited from network services with real-time information. Due to device power constraint and security, cooperation is important in D2D communication especially for multihop communication with optimal routing. Therefore, connectivity and privacy threats are the major challenges in ubiquitous computing.

1.4. Vehicle-to-Vehicle Communication

Intelligent transportation systems must collect, evaluate, and act upon huge data traffic from multiple nodes in a highly efficient and reliable manner. Smart vehicle applications enable real-time services through nearby access points with improved public safety and mobility. Technical framework and security management are yet to be determined which expedite with the crash-avoidance technologies.

1.5. Quick Disaster Relief Solution

In emergency situation, active nodes can form an ad-hoc network on the cloud IoT platform. The IoT system integrates heterogeneous wireless devices and various communicating technologies to enable end-to-end network connectivity. D2D communication facilitates extended network with essential services to out-of-coverage users in a critical situation when the existing infrastructure is damaged. However, there are still some factors such as interference and noise that may affect the performance.

In the age of Internet technology, D2D communication integrated with on-board cloud network will be an essential tool in the industrial applications. For example, IoT in Industry becomes Industrial IoT which plays a significant role to enhance the capacity of production and boost the manufacturing system [22–24]. IoT forms the key foundation for the Cyber Physical Systems (CPS) applications [25]. With the application of IoT in various sectors such as smart cities, healthcare, smart homes, and smart factories, it also opens several issues for CPS such as security, privacy, service monitoring and controlling, and resource management. IoT enables embedded devices to communicate with other devices through D2D communication, Internet, Wi-Fi, Bluetooth, etc. Applications based on this technology will play an important role to transform industry as well as social life dramatically in the near future [26,27].

In this paper, we summarize the functionality of D2D in IoT ecosystem. In addition, open research issues for further research are also addressed. The rest of the paper is outlined as follows. In Section 2, the vision of IoT in the context of D2D is explored and main communication technology (*i.e.*, 5G) subject to achieve promises of IoT vision and their important role is introduced. Section 3 comprises the D2D approach and its benefits. Potential future challenges are given in Section 4 which highlighted the open issues for researchers. Finally, concluding remarks are given in Section 5.

2. VISION OF IOT

The IoT is progressively trying to achieve a worldwide network of interconnected objects which is based on standard communication protocols. This network is operated by the large number of objects that controls the process. The multifold vision of IoT is depicted in Figure 2. IoT vision is not limited to integrate the devices with the current framework but also it is networking oriented. Therefore, this can be categorized as Things-oriented, Internet-oriented, and Semantic-oriented [28]. These three branches converge to the complete vision of IoT with the collaboration of things, networks, and semantics.

Things-oriented vision of IoT includes smart things for example RFIDs, smartphones, sensors, and actuators which intelligently create or capture information and process. Primarily, RFIDs are the interest of industries in trading networks to identify or trace the objects but now the worldwide applications have been developed. However, IoT vision is not limited to but is beyond the object identification. Internet-oriented vision includes web services, protocols, standardization, and IP for smart objects. All communicating things ensure

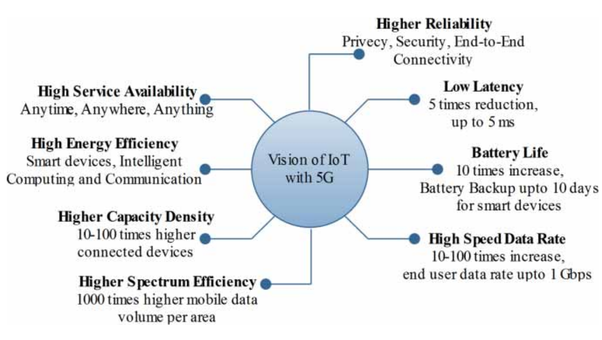

Figure 2: Vision of IoT with 5G

the connectivity of each in the network infrastructure. With all this, the semantic-oriented vision of IoT is mainly focused on to interconnect, search, and organize the information which is in large amount [29]. Semantic technologies in the context of IoT are supposed to develop reasoning techniques for huge data. Extension of semantic execution architecture is required for intelligent processing and storing data to accomplish IoT challenges with reduced level of complexity.

In IoT networks, devices are the main objects that capture the physical data and capability to manipulate and take decision autonomously. These devices may be small in size, low-cost sensors, or actuators. It may be any mobile device such as smartphones, wearable devices, etc. Different communication technologies can be used by devices for data exchange. These devices have physical constraints such as processing speed, transmission power, data storage, and battery backup.

Communication among objects can be classified in various categories which involve devices, machines, and/or humans. Single-hop communication is like direct communication between source and destination without intervention of any other object while multi-hop communication includes intermediate object as relay or access point between end to end devices. Also, communication can be intra-domain (within the same network) or inter-domain (with two or more networks involved) [4]. Intelligent devices should have decision-making capabilities that take action without the involvement of the human.

Generally, moving towards dense networks high data rate and low latency are the main requirements. Traffic efficiency and data security is the matter for consideration under network deployment cost. Particularly, to meet the requirements in urban dense areas, it is expected that the network should support 300 Mbps for downlink and 60 Mbps for uplink data speed [30]. Therefore, future network will be designed in order to provide up to 500 Gbytes per device per month traffic volume which is 1000 times more as compare to present traffic volume per subscriber.

The next-generation wireless technology, *i.e.*, 5G is likely to address the challenges such as massive device connectivity, higher data rate, higher capacity, and lower end to end latency. The fundamental design of 5G architecture with an overview of challenges is given in [31]. According to the Ericsson survey [32], 5G will support the surge of data being transmitted among IoT devices and that 5G technology will decrease the maintenance

Table 1: Summary of some international projects related to 5G technology

International Research Projects	Contributions
5G PPP (5G infrastructure Public Private Partnership) [38]	To create the next-generation communication networks and services, ubiquitous super-fast connectivity with energy efficient and secure networks.
5G NOW (5G Non-Orthogonal Waveforms) [40]	Non-Orthogonal waveforms for asynchronous signalling, investigating applications and prototypes to support 5G technology in terms of data rates, signalling and spectrum.
METIS (Mobile and wireless communications Enablers for 2020 Information Society) [41]	Provide a holistic framework 5G system concept that fit the needs beyond 2020 in order to gain scalability, versatility and efficiency.
NSF (National Science Foundation) future internet architecture project [42]	Design and development of future internet, Five projects (Named Data Networking, MobilityFirst, NEB ULA, eXpressive Internet Architecture, and ChoiceNet) are funded by this program.
IMT-2020 (5G) Promotion Group [43]	To promote 5G technology research in order to develop 5G enabling wireless technologies and 5G system framework.

costs associated with these next-generation solutions. A detailed survey on socio-5G network technologies can be found in [33]. Several projects aim to deploy the new IoT paradigm. According to the International Telecommunication Union (ITU) vision of the IoT, "from anytime, anyplace connectivity for anyone, we will now have connectivity for anything" [34]. FlashLinQ [35], a project under Qualcomm, attempts to provide a wireless "neighborhood area network" that will support the proximal communication. The European union METIS project [36] has given the objective of laying the foundation for 5G systems, which has ended successfully and afterward METIS-II [37] has been started in the collaboration with 5G PPP [38] with the aim to develop overall 5G RAN design. Research project 5GNOW [39] is a European collaboration working on the services and heterogeneous transmission set-ups. Their aim is to ensure the contributions to upcoming 5G standardization. Moreover, several international projects are working towards enhancement in 5G technology that aims to serve smart and intelligent IoT system. Some international projects are summarized in Table 1 with their contributions.

3. D2D COMMUNICATION APPROACH

D2D in wireless network is the area of interest due to its several advantages. This approach is best suited to reduce the traffic load at the network infrastructure [44]. According to D2D approach, two devices will communicate to each other without the essential control of BS. It also transforms two-hop communications (via BS) to single-hop communication. Figure 3 illustrates the direct D2D communication with conventional cellular communication in the wireless network. With rapid growth in the number of devices, deployment of D2D technology is important to provide better services. For example, in emergency or disaster situation such as when network is out of service or damaged, then D2D communication can relieve the dependency on existing central infrastructure.

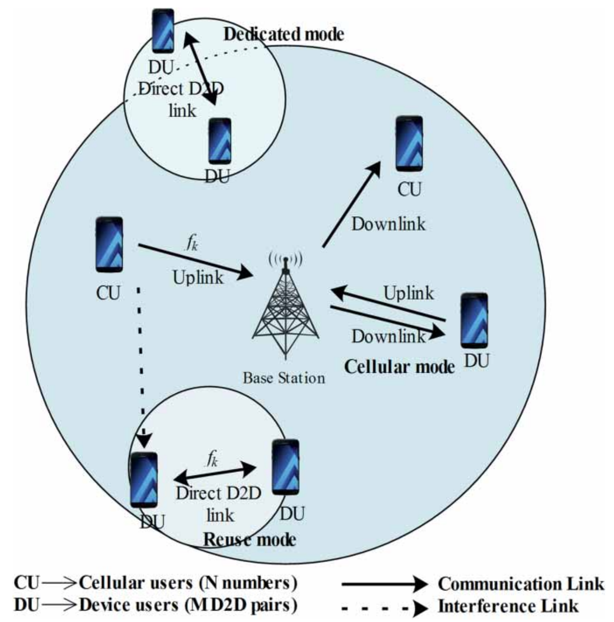

Figure 3: D2D underlaid with the cellular network and all three modes of the D2D communication

Basically, D2D communication can be classified on the basis of operating in licensed band or unlicensed band [45]. In unlicensed band, Bluetooth and Wi-Fi are the mostly used technology to establish small network for data sharing. It provides a crucial platform for innovators due to its freely availability. Using unlicensed spectrum for industrial, scientific, or medical (ISM) applications, a secure network can be established for short-range communication anytime and anywhere [46]. Because of the limited range of signals, the network is restricted to its boundaries. For large network, it requires several intermediate nodes which leads to more bandwidth consumption and creates latency issues. These technologies are also vulnerable to interference. On the other hand, in licensed band, a wireless network can transmit 10–100 times more power and up to 100 times farther than unlicensed spectrum. It increases the range, throughput, and performance of the communications. Security issues can be reduced and it is also less prone to interference. Further, efficient resources utilization and interference

Table 2: Summary of some research articles with their contributions in terms of objective, technique used, and brief summary

Year	Authors	Objective	Technique used	Brief Summary
2010	K. Doppler *et al.* [48]	Mode selection for D2D underlying cellular networks	Binary mode selection technique for D2D communication in cellular network	Proposed mode selection procedure ensures a reliable D2D communication with limited interference
2011	C. H. Yu *et al.* [49]	To optimize the throughput with resource sharing for D2D underlaying cellular networks	Linear optimization techniques are applied to maximize the sum rate	The optimum radio resource allocation between D2D and cellular with controlled interference
2012	P. Cheng *et al.* [50]	Resource allocation for D2D communication in cognitive cellular networks	Evolutionary game theory is used to optimize the mode selection for utility optimization	The optimal power allocation for each mode (D2D mode and cellular mode)
2012	F. Wang *et al.*[51]	Joint radio resource and power allocation scheme to improve the performance of the system in the uplink period	Energy efficiency as an objective with battery life is constraint. Reverse iterative combinatorial auction game is used	An algorithm is proposed to solve the allocation problem as an auction game. Numerical simulation is given for validation
2013	C. Xu *et al.* [52]	To optimize the system sum rate over the resource sharing of both D2D and cellular modes	A reverse iterative combinatorial auction is used	Low-complexity resource allocation scheme is proposed in order to improve the system sum rate
2013	Q. Duong *et al.* [53]	On efficient resource allocation for D2D communication underlaying a cellular network	Distance based resource allocation is applied based on outage probability analysis	Interference aware resource allocation scheme is proposed in order to improve spectrum efficiency
2013	D. Feng *et al.* [47]	To maximize the overall network throughput	Maximizes overall throughput under consideration of SINR of device users and cellular users for uplink control	D2D access rate and the overall network throughput performance is improved by the proposed scheme
2014	G. Yu *et al.* [54]	Joint mode selection and resource allocation for D2D communications	The heuristic low-complexity algorithm is proposed for light and medium load scenario	Low-complexity algorithms according to the network load is developed with maximization of overall system throughput
2014	L. Wang *et al.* [55]	To maximize the overall system performance	For pairing Hungarian algorithm is used. Optimize the power component with maximize the sum data rate	Resource sharing problem is considered with power and QoS constraint with maximizing overall performance metrics
2015	Q. Ye *et al.* [56]	Distributed resource allocation in D2D enhanced cellular networks	Resource block and power allocation with end to end transmission relaying concept are given to improve D2D performance	Significant throughput gain is achieved with low overhead
2015	J. Liu *et al.* [57]	To improve coverage probability and ergodic rate of D2D overlaying multichannel downlink cellular networks	Stochastic geometry approach is applied on D2D based cellular networks in order to improve network coverage performance	Enabling the D2D link based two-hop connection can significantly improve the network coverage performance
2015	Y. Zhang *et al.* [58]	To optimize the traffic offloading process in D2D communications	Indian buffet learning process to model online social network. Chernoff bound is derived to evaluate the proposed algorithm performance.	A novel social-aware approach for optimizing D2D communication for traffic offloading is proposed
2016	K. W. Choi *et al.* [59]	Discovering Mobile Applications in Cellular D2D Communications	A code based protocol is proposed for cellular D2D communications where hash function and bloom filter based approach is used	The proposed protocol deals with high device density and fast discovering with relatively consuming small amount of radio resources
2016	H. Tang *et al.* [60]	Mixed mode transmission and resource allocation for D2D communication	A two-step approach has low-complexity, mixed mode D2D communication with resource allocation technique is proposed	Distributed algorithm requires little signaling overhead with low computational complexity
2016	A. Hourani *et al.* [61]	Stochastic geometry study on D2D communication as a disaster relief solution	Analytically, a disaster relief solution is given using stochastic geometric approach by enabling D2D technology	A novel analytical methodology is given for severely varying network conditions and parameters
2016	Y. Haung *et al.* [62]	Mode selection, resource allocation, and power control for D2D-enabled two-tier cellular network	Geometric vertex search approach issued to solve the power allocation problem and to achieve performance gains with mode selection	Proposed analytical methodology shows that frequency sharing approach improves system sum rate
2017	A. Sultana *et al.* [63]	To optimize D2D user transmission rate with constraints power, interference, data rate.	Subcarrier allocation scheme is proposed with cognitive radio network and further power allocation scheme is developed	Optimal solution is found with low computational complexity algorithm for nonlinear problem
2017	M. L. Ku *et al.* [64]	To maximize the sum rate of the DUs by jointly designing beamforming and time allocation, maintaining QoS	Semi-definite relaxation (SDR) approach is proposed for uplink and downlink beamforming	Jointly studied beamforming andresource allocation for wireless-powered D2D communications underlaying a cellular network
2017	Ji Lianghai *et al.* [65]	Applying Device-to-Device Communication to Enhance IoT Services	Network control sidelink communication scheme is given with context aware algorithm to ensure the efficiency	Signaling scheme is used to configure sidelink and cellular link in order to facilitate D2D communication in massive machine type communication

management are major subjects to realize the network performance. To establish a bridge between unlicensed and licensed band is important for D2D communication in IoT environment.

The operation of D2D communication is explained in three steps: admission control, mode selection, and power allocation [47]. First, admission control is to check whether devices are admissible to communicate with each other or not. Devices may be mobile or static. We can observe the possibility of communication link existence by the observation on their relative velocity.

Next, we check for mode selection. Basically, there are three types of operating modes for D2D communication in cellular networks. They are cellular mode, dedicated mode, and reuse mode. Selection of operating modes may depend on the location and/or transmit power of the communicating devices. Here, we briefly explain each mode.

3.1. Cellular Mode

In this mode, devices communicate as a conventional cellular communication. The data are transferred through the BS which acts as an intermediate node. It requires two links (uplink and downlink) from the transmitter to the receiver.

3.2. Dedicated Mode

In this mode, a single link is established between transmitter and receiver, which offer direct communication between them. There is no interference observed between cellular communication and D2D communication.

3.3. Reuse Mode

In this mode, D2D communication shares the available resources with cellular communication (either uplink or downlink). It gives the flexibility to reuse the channel which is already occupied by cellular communication. This mode provides efficient use of available network resources. In reuse mode of operation, resource management and interference management are the major issues to be resolved.

Power allocation is another open optimization problem which aims to maximize the efficient use of channel capacity. One D2D pair reuses the available channel from the uplink or downlink channel of cellular communication. The problem is more complicated when more D2D pairs exist. Several literatures are available where optimal power allocation algorithms are proposed. In Table 2, a list of some research papers with their contributions in terms of used techniques and their outcomes is given.

Most of the articles are mainly focused on the issues such as resource allocation, interference management, and power allocation. Very few articles are found on the protocols for D2D communication architecture. Raghothaman *et al.* [66] addressed the protocol stack for inband D2D communication. Moreover, they suggest architecturally and protocol modification in the existing cellular network to ensure communicating through D2D links without losing cellular connectivity. D2D server is added with the interface with Mobility Management Entity, Evolved Packet Core network, Policy and Charging Rules Function, and D2D application servers. In [67], a novel beacon-enabled D2D communication protocol is investigated for public safety applications. New protocol stack that connects LTE which integrates Wi-Fi direct protocol is introduced in [68]. Moreover, a feasibility study for Proximity Services by 3GPP working group is introduced in [69] with various use cases. Furthermore, required enhancement in architecture and protocol in the context of D2D proximity applications are given in [70].

4. ISSUES AND FUTURE CHALLENGES

D2D communications in the IoT have taken a lot of attention and interest by researchers in industries and academia. Also, standardization bodies have taken awareness towards designing new paradigms and deployment of D2D technologies in the IoT. For successful implementation of designing communication infrastructure, there are several challenges that are required to be resolved. Some major challenges are explained in subsections that are important to resolve for D2D communication in IoT environment. In addition, a summary of some major issues faced by the researchers and related literatures are provided in Table 3.

4.1. Resource Optimization

To meet the requirements for IoT ecosystem, D2D approach in wireless network is introduced which meets users' demand and optimally utilizes available resources.

Table 3: Summary of some major issues and related literature

Issues	References
Resource Optimization	[12], [13], [48], [58], [60], [62], [71–80]
Interference Management	[13], [53], [72], [75], [81–84],
Route Discovery	[21], [66], [68–70], [85]
Wireless Security	[86–94]

With increasing load on the BS and limited spectrum available in wireless (cellular) network, the user suffers from degraded QoS such as low speed, high latency, and poor network coverage. Power control and resource sharing methods are adapted to optimize sum rate throughput with maximum transmit power or energy constraints. Research should be focused on optimal resource allocation in wireless D2D communications, which is indispensable for achieving spectral and energy efficiency, and providing QoS to different applications. IoT devices are resource constraint, and therefore significant reduction in energy use may lead to reduced operating cost.

4.2. Interference Management

Interference management is another important aspect of achieving reliable and robust communication. Devices may be operated in the licensed or unlicensed spectrum in which communicated data can be affected by nearby devices. Hence, the cellular network is affected by the harmful interference from other communicating devices, resulting degradation in the performance of the system. Particularly, when devices are operated in reuse mode of communication, proper interference control approach is required. While in unlicensed spectrum, devices are affected by the inter-system interference which can be simply controlled by allocating orthogonal channels of ISM band. Several research works are found which investigate the impact of power control mechanism on reducing the interference in cellular networks. Another approach is the efficient resource allocation with controlled interference in order to ensure the reliability of the cellular and D2D communication and improve the overall system performance. Inter-cell interference with dense networks lead to a more complex scenario. Therefore, the interference management strategy needs to be designed for complicated scenarios in IoT systems.

4.3. Route Discovery

Intelligent protocols are required to design route discovery and management for end to end transmission. Devices in mobility create a more complicated scenario. Also, the lack of cooperation among connecting devices degrades the performance in the IoT system. Traditional discovery protocols are insufficient to meet the requirements for future scenarios. For example, devices are communicating in licensed spectrum with multi-hopping, the routing protocol must be capable of switching unlicensed spectrum in case any intermediate node fails. It is important to support routing techniques in both licensed and unlicensed spectrum with cooperation. Network Coded Modulation (NCM) techniques can be used to design routing protocol to manage D2D communications in the IoT system.

4.4. Security

Security is also an important issue in wireless networks. Lots of information is exchanged over the networks, which may be hacked, corrupted, or lost. Privacy, authentication, and integrity are must within the IoT ecosystem to attain the QoS. Confidentiality is important to maintain the privacy of the user and authentication is also an important issue in autonomous D2D communication. Inference and distributed denial-of-service attacks affect the QoS of wireless networks. Therefore, it can be concluded that the field is open for security challenges in D2D communication.

4.5. Other Issues

D2D communications in cellular networks, whether devices communicate directly or via BS, the radio resources used by devices may be same as the conventional cellular users or different from them. This necessitates to design a system for mode selection and sharing spectrum resources between cellular and D2D communication. Very little work is done on architecture in order to support D2D communication. Delay tolerant analysis is also required with maintained performance of the systems.

It is also important to globally synchronize with common external source such as GPS, cellular BS, etc. It enables devices to follow a common OFDMA PHY/MAC protocol which restricts the device discovery to a small fraction of real time. A distributed protocol can be designed which determines connections that avoid the mutual interference. Devices make the decision based on the SIR (Signal to Interference Ratio) and randomized selection of services on their priority basis. This mechanism enables devices to make scheduling decision by intelligently choosing the energy level of the signal.

Most literatures are found which generally utilise the system-level simulation and/or numerical simulation. These evaluation methods are suitable to analyse the potential gains but they are still far away from reality due to assumptions. Various network simulators are available such as NS3 [95], OPNET [96], QUALNET [97], or Omnet++ [98] could be helpful in performance evaluation. However, in [99] an experimental analysis is found, but more experimental study is required that can reveal the new challenges and real performance in the IoT environment.

A stochastic geometric-based approach may be used for heterogeneous network deployment. Mathematical formulation of spectrum sharing and resource optimization models that characterize the D2D communication and evaluating its practical feasibility needs to be carried out. However, most IoT devices have some hardware and software constraints such as battery life, small size, transmission power, and processing speed which also play a vital role in the implementation of the mechanism that will be used by the IoT devices. Future wireless communication systems need to be designed by keeping these goals in mind so that resources can be utilized efficiently. In addition, it should fulfil the network requirements to function satisfactorily over long periods under adverse circumstances.

In a nutshell, potential benefits of D2D communication in IoT system include radio resource management in which by using licensed spectrum, interference could be minimized and system performance can be improved. Communication in proximity reduces the latency that may result in higher throughput. D2D enables reuse of frequency bands which allows the efficient utilization of available spectrum. In D2D communication, devices directly communicate with another device in its vicinity that offloads the network traffic from the central entity like BS. Development of the resource management approaches is still an open issue to provide low-energy consumption and coverage extension which is one of the essential requirements to enable IoT in the near future. D2D communication in cellular networks is expected to open up new business opportunities. Some examples are augmented reality, social networking, mobile commerce, and advertising.

5. CONCLUSION

IoT requirements to connect "anything, anytime, and anywhere", builds a bridge between the real world and the digital world. Smart devices operate autonomously with proper cooperation. The increasing number of devices and new applications demand higher data rate, enhanced capacity, low latency, and better QoS from the wireless networks. Therefore, D2D communication approach accomplishes these requirements but has to face several challenges. This paper is mainly focused on highlighting the potential of D2D approach in the advancements of IoT ecosystem. Particularly, we explore the current status of D2D technology with its benefits and future challenges in the deployment of D2D in IoT.

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

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