Edris, Ed Kamya Kiyemba, Aiash, Mahdi ORCID: https://orcid.org/0000-0002-3984-6244 and Loo, Jonathan (2019) Investigating network services abstraction in 5G enabled device-to-device (D2D) communications. 2019 IEEE SmartWorld, Ubiquitous Intelligence & Computing, Advanced & Trusted Computing, Scalable Computing & Communications, Cloud & Big Data Computing, Internet of People and Smart City Innovation (SmartWorld/SCALCOM/UIC/ATC/CBDCom/IOP/SCI). In: 2019 IEEE SmartWorld, Ubiquitous Intelligence & Computing, Advanced & Trusted Computing, Scalable Computing & Communications, Cloud & Big Data Computing, Internet of People and Smart City Innovation (SmartWorld/SCALCOM/UIC/ATC/CBDCom/IOP/SCI), 19-23 Aug 2019, Leicester, United Kingdom. e-ISBN 9781728140346. (doi:10.1109/SmartWorld-UIC-ATC-SCALCOM-IOP-SCI.2019.00296)

Final accepted version (with author's formatting)

This version is available at: http://eprints.mdx.ac.uk/30249/

Investigating Network Services Abstraction in 5G enabled Device-to-Device (D2D) Communications

Ed Kamya Kiyemba Edris
School of Science and Technology
Middlesex University
London, United Kingdom
EE351@live.mdx.ac.uk

Mahdi Aiash
School of Science of Technology
Middlesex University
London, United Kingdom
M.Aiash@mdx.ac.uk

Jonathan Kok-Keng Loo
School of Computer Engineering
University of West London
London, United Kingdom
Jonathan.Loo@uwl.ac.uk

***Abstract*—The increased demand of data rate by mobile users has led to the evolution of mobile network technologies from the fourth generation to fifth generation (5G). 5G mobile network will support various technologies that will be able to provide low latency, offload traffic and connect vertical industries. Device-to-device (D2D) communications will be used as the underlay technology for 5G network in the offloading of traffic from the cellular network and pushing content closer to the user. With D2D communication, various network services can be implemented to improve spectral efficiency and reduce energy consumption of mobile devices. This paper gives a brief overview of D2D communication and discusses different D2D applications. It proposes a network services abstraction and suggests the mapping of existing studies with the network service abstraction which can be used in the harnessing the development and implementation of D2D communication applications in 5G network. The paper also highlights possible future research for D2D communication in 5G network.**

***Index Terms*—network services; applications; network connectivity; device-to-device (D2D) communication; abstraction, cellular network; 5G;**

I. Introduction

Mobile network technologies have evolved over the past few years; there has been an immense growth of mobile usage and multimedia applications. As a result, there has been a need for a new mobile network architecture that supports all these changes and demands, hence the evolution to the next generation of mobile network and wireless systems which is fifth generation (5G). 5G will enable new network and service functions such as enhanced Mobile Broadband network (eMBB) and critical machine communications. In addition, it will create new user cases and connect vertical industries such as tactile industry, Internet of things (IoT) that are used to connect large number of devices and sensors. Furthermore, it will improve quality of experience (QoE) for end users such as mobility and coverage in dense area as well as providing very high reliability, ultra-low latency to support service, such as mission critical services, public safety and eHealth. 5G is predicted to support eMBB, massive machine type communication (MTC), ultra reliable low communication (URLLC) [1].

With that potential, the development of 5G is intended to solve future constraints for services using high data rate such as peer to peer links (P2P) [2], as well as offloading the network traffic to P2P network by using user equipment (UE) to ease the traffic burden on the base station (BS). D2D communication is a P2P network, it is one of the main technologies supporting 5G to enable new applications and service delivery. With D2D, 5G will improve systems performance, network capacity, user experience and magnify mobile application extensively. Initially D2D communication was developed to allow multi hop relays in mobile communications then later enhanced to improve spectrum efficiency and cellular coverage network delay. This increase in wireless traffic has led to the surpassing of mobile cellular spectrum capacity [3], the capacity is no longer adequate for future mobile network traffic. The use of direct communication of mobile UE is one of the advantages of D2D communication, making it the impetus in the evolution of 5G. D2D communication has been applied in Long Term Evolution (LTE) and now in 5G as service, with UEs communicating to each other, allowing users to easily access proximity services (ProSe) such as content sharing, live gaming, video streaming, as well as offloading traffic from the edge network. As standardization of D2D communication in 5G is still being reviewed, current literature proposes that D2D communication will support multi hop relay network and other applications such as priority control of mission critical push to talk (MCPTT), emergency services, vehicle to vehicle (V2V), location-based services.

5G will enable various technologies and support many industries, the development of supporting applications is not an easy task due its heterogeneous nature and its complex characteristics. With this evolution, new spectrum access, hyper-convergence connectivity and new application specific requirements are emerging as the future of wireless communications. This is brought by the high data rate with low latency interested end user that contribute to the distribution and delivery of content, which requires a lot of network resources and the support of networks services. The main contributions of this paper are the classification and mapping of the network services in three abstraction levels and description of how D2D communication applications can be applied in 5G, for example the offloading of traffic from mobile network backhaul and fronthaul. It also presents different services that can be delivered through D2D communication in relation with existing survey, the paper introduces an abstract

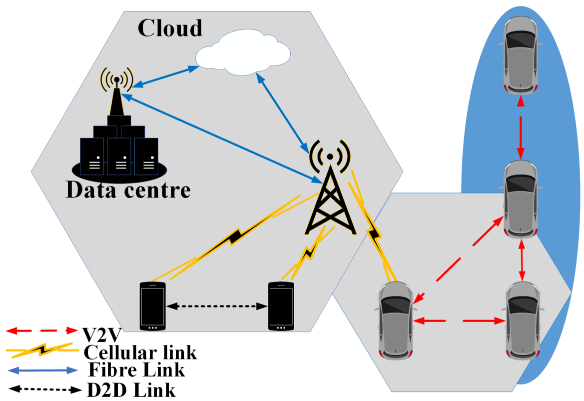

Fig. 1. 5G enabled D2D and V2V communication

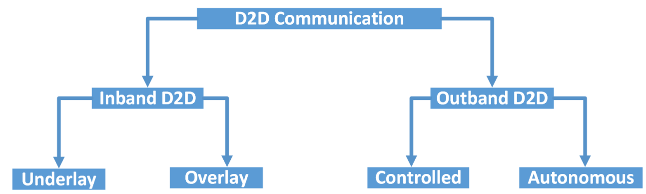

Fig. 2. D2D Communication Modes

model for network services that could be delivered with D2D communication in support of multi connectivity and integrated security frameworks. The three abstraction levels are applications, infrastructure services and network connectivity, they can ease the development and implementation of the network service applications such as service distribution and delivery in 5G enabled D2D communication.

The rest of the paper is organized as follows. Section II presents an overview of D2D communication and its features. In section III related work for D2D communication applications in LTE and 5G including the application, infrastructure services and network connectivity are discussed. An abstraction of D2D communication applications in 5G network is proposed as well as classifying and mapping of the application in different abstract levels in section IV. This is followed by a conclusion and future work direction in section V.

II. D2D Communication Overview

D2D communication was defined in [4] as direct communication between two UEs, without routing assistance from the BS or core network (CN). It was intended to improve spectrum and energy efficiency of the wireless mobile network at the same time increasing the throughput and end-to-end delay performance for D2D links, some of D2D applications are direct, relay, cellular links and V2V as shown in fig 1. D2D communication enables devices in proximity to communicate directly with each other under the control of access points (AP), BS and CN. The D2D communication architecture is similar to that of Mobile Ad-hoc Networks (MANET) and Cognitive Radio Networks (CRN), however D2D communication is controlled through control plane by the BS for connection and synchronization. D2D can supports and improve various technology such as vehicle Ad Hoc network (VANET) were vehicle are able to exchange data while moving at different speeds and D2D can use Wi-Fi for communication.

ProSe are enabled to provide D2D users with exceptional connectivity, which is also a business opportunity for service providers (SP) as they can provide new services to users such as context aware services, where by devices connect through local network and share contents, they are interested in. Which in return could be used to offload traffic from BS, hence improving the spectrum efficiency which can lead to more users and services. The offloading can help to overcome delay and timing issues in V2V which is enable VANET.

D2D communication was proposed to allow multi-hops relays in cellular networks [5], the authors in [6] studied how D2D communication could increase spectral efficiency of cellular networks. Several D2D use cases have been suggested such as multicasting, P2P communication, video dissemination [7] machine to machine (M2M) communication and cellular offloading [8]. D2D communication was introduced as underlay technology for cellular network with PHY/MAC architecture using FlashLinQ to develop timing synchronization, peer discovery and link management [9]. Furthermore, 3GPP and its partners explored ProSe in LTE based D2D communication and its architecture. They introduced D2D communication to support the public safety network in case of communication emergency.

The authors in [10] explored how D2D communication can offload traffic from the core network (CN) and supporting new use cases and services like local advertisement and content sharing. The evolution in LTE-Advanced (LTE-A) was standardized under LTE direct, it included ProSe and V2V communication released under Rel.11 – 13. While under IEEE 802.11 protocol Wi-Fi direct technology that enabled devices to automatically act as both AP and client in D2D communication network was proposed. 5G promises to support proximity-based data sharing services through using D2D communication. Moreover, it will improve proximity and diversity during D2D direct link communication. Because D2D communication is non-transparent to the cellular network, it transpires on cellular licensed spectrum or unlicensed spectrum and this is achieved under two types of modes:

- Inband mode: The D2D users use the same licenced spectrum as the cellular users. They can both share the resource blocks (underlay inband) or part of the cellular resources can be dedicated to D2D users (overlay inband).
- Outband mode: The D2D communication uses the unlicensed spectrum, when the radio interface direction is controlled by the cellular network is referred to as controlled mode and when the D2D communication control is under the D2D users is referred to as autonomous mode as shown in fig 2.

The following techniques are used when establishing D2D communication:

A. Peer and Network Discovery

Devices in D2D communication can discover other devices in proximity by using open and restricted discovery methods. With open discovery a device is discovered if they are within the proximity of other devices and whereas restricted discovery a device cannot be discovered without permission from the BS. Network discovery is a fundamental fragment of D2D communication, that enables the D2D users to identify devices in proximity. The devices share beacon signals to send information to different devices, such as IDs for interested parts. Moreover, they share their channel state information (CSI) for possibility of pair grouping. The network discovery structure is grouped into network centric (NC) and device centric (DC).

B. Synchronization

Periodic broadcasts are sent by BS to get time and frequency synchronization, the same broadcasts can be used by D2D device that are from the same BS to synchronize. In D2D communication for a device to discover and communicate to its peer it uses the right time slot and frequency for energy efficiency, however in most cases due to proximity, local synchronization is used instead of global.

C. Mode Selection

After devices in D2D communication have discovered each other the next step would be to communicate but if they find the direct communication noisy, they could choose cellular communication with less noise or interference. Two devices can select a communication mode whether D2D or cellular to achieve performance objective such as low latency and spectral efficiency.

D. Devices Connectivity

For connectivity, the device checks if the D2D devices are in range and if the throughput provided is high than the cellular communication, and if request is from the BS. In addition, the transport conditions are checked, if they are satisfactory then the BS arranges a D2D radio bearer between the devices to communicate directly using available resources. A connection is initiated by one of the devices, the gateway tunnels transmit the traffic between two devices without the BS involvement. The BS sustains the radio resource control for the cellular and D2D communication, as well as the bearer for cellular communication.

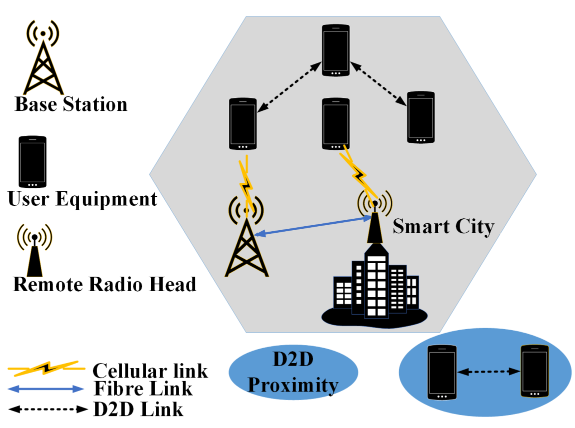

Fig. 3. 5G enabled D2D communication network architecture

E. Resource Allocation

In D2D communication, creating and maintaining the direct links between two D2D devices in cellular network depends on the radio resources allocation phase. The resource blocks that are not in use by the cellular devices are used. For instance, in outband communication the resource allocation avoids using the industrial, scientific and medical (ISM) bands resources which might be allocated for other D2D users in the proximity.

Even though the D2D communication schemes such as WIFI direct, MANET, VANET, V2V differ in how they deliver various applications to the users and the network, they are similar in way that they use architecture similar to ad hoc network to enable other applications such as autonomous cars, intelligent transportation system, autonomous vehicles, public safety, live streaming as shown in fig 3. Different studies have been carried out on 5G and D2D communication for instance, in [11] the authors carry out a comprehensive survey on 5G, it included architectural changes, MIMO, Physical layer protocols and D2D can support 5G. In [12] the authors discussed the challenges in a macro cell tier and device tier such security and pricing models. Multihopping provides guaranteed quality of services (QoS), flexibility and adaptability. A comprehensive survey on routing in multi-hop D2D networks is provided in [13]. While [14] explores propagation features of millimeter wave (mmwave) communications and resources schemes that can enable non interfering D2D links. However, the abstraction of the applications in most studies lack concise abstract for networks service-related applications. Therefore, in the next section more applications are discussed and mapped according to our proposed abstraction level.

III. Network Service Abstraction of D2D Applications

A. Mapping of Existing Related Work

In this paper, the existing literature on D2D communication applications are classified and mapped with the proposed network service abstraction. Some of these applications are for legacy systems which are used to support the recent studies on the next generation mobile network, include surveys and solutions on network and security of D2D communication in 5G network. Even though most of the authors of existing studies presented various solutions D2D communication related issue, there is no clear classification and mapping of these D2D communication related applications in terms of which part of the network architecture they were specifically linked to. By abstracting the network service on different levels of the network it enables full utilization of security and network applications in synch with the network levels. As defined in network function virtualization (NFV) architectural framework by ETSI, "a network service is a composition of network functions that defines an end-to-end functional and behavioural specification, supporting network infrastructure [15] . Network services provide functionality to the network infrastructure to deliver services to the intended users. D2D communication is also classified as network service as it used to enable specific network connectivity service to the UE without relying on cellular network. Moreover, D2D communication will be used as an underlay function to facilitate the offloading of traffic from CN to edge and pushing content closer to the user.

We now classify and map the existing literature on D2D network services in legacy systems and 5G network into three abstraction levels: Application, network services and network connectivity.

1) Application Level: This level consists of over the top (OTT) applications such as phone applications, gaming, user request activities, multimedia service, social networking, local advertising, security that are intended for the UE [16] [17] [18].

Application related studies have been carried out on legacy and next generation networks, investigating the delivery of content to the user and security issues affecting the application layer such as violation on identity and data privacy. In [16] the authors discussed video streaming performance, high quality of experience (QoE) at high resource efficiency, resource management, co-channel interference of D2D pairs for D2D communication in 5G network. An optimal rate allocation and description distribution for high performance video streaming between D2D helpers, requesters and BS is proposed. The authors in [13] discuss UE, media content sharing, security issues in D2D communications. A secure content sharing protocol (SCSP) with credibility between users is proposed. It combines user's interest, interaction and geographical location, by applying authentication, encryption and digital signature to ensure mutual authentication, data confidentiality and non-repudiation. With content delivery between proximal users, caching at user equipment in D2D communication network.

A caching scheme is proposed based on the impact QoS requirements, UE's limited caching capacity is analyzed. The authors in [18], suggested a cooperative content retrieval, content centric service in D2D communications for offloading traffic and enabling connectivity in mobile networks. With a social-aware NDN (sNDN) framework to accomplish efficient cooperative content retrieval is proposed. sNDN is constructed on named data networking value. It involves putting users of high physical proximity and content similarity together creating friendship circles.

2) Infrastructure Service Level: This level consists of network services for D2D communication such as ProSe, service sharing, service discovery, resource allocation, content discovery and delivery to the user, locating and delivering services to UEs [19] [20] [21].

Different studies have explored content sharing, data caching and distribution, resource utilization, network capacity and information centric networking (ICN) frameworks in D2D communication network. Content sharing and caching in D2D networks where proximity content distribution increased resource allocation and network capacity have been investigated. For instance, an incentive method to persuade other device to cache content for others is proposed, it is a hierarchical caching scheme divided into self, friends and strangers. Moreover, user's relationship is used to create cost function as well social ties and physical distance. The authors in [19] discussed content distribution in D2D communication network. A novel information centric networking framework using mobile content caching and distribution for direct D2D communication was proposed. With content caching at the network edge using D2D communications involving the BS and the user terminal, users tend to request the same popular contents at different time instants, using transmission and caching policies in joint design method while user demands are known beforehand.

ProSe, discovery and communication in D2D communication are explored in [22], the authors discussed security techniques used in short radio communication for public safety ProSe (PS-ProSe) application, new communication and group formation in D2D communication. They proposed a group key management (GKM) for secure exchange of D2D messages during discovery and communication stages. In addition, content centric, content sharing, content delivery, and transmission modes in D2D communication have been analyzed for performance of content delivery, unicast and multicast. This was achieved by quantifying the number of cache users, request users, serving time of a content request. In [20], mobile content, content distribution, mobile as a service, user mobility data analytics, content aware mobile network at the edge in 5G network are discussed. The authors proposed a device level information centric networking architecture for intelligent content distribution operations that utilizes context information based on mobility and content features. Distributed device location, distributed cache, distributed content dissemination in D2D communication facilitate network service delivery. The average, lower of helper and an optimal helper amount are investigated and a location based distributed helper selection scheme is proposed for distributed caching.

The services and technologies that support 5G network the authors include proximity-based services, social applications, D2D discovery, communication, advertisement, radio spectrum in D2D communication. They proposed a centralized architecture to achieve energy efficiency during discovery and communication of devices.

3) Network Connectivity: This level consists of connectivity and communication applications such as routing, radio access, spectrum sharing, network discovery, V2V, mmWave, D2D communication, D2D discovery application for improving, securing connectivity and communication [9] [22] [23].

D2D communication network connectivity involves transmission and routing of services. In [4], the authors explored how 5G can use mmWave to support the increasing demand of data rates. A scheme that combines social IoT and D2D communications to solve the mmWave line of sight (LoS) was proposed. D2D communication can enhance network performance and enable new user cases such as content distribution, location aware advertisement. D2D communication can improve spectral efficiency and decrease communication delay, however, it creates interference control overhead and protocols problems. Furthermore, automobile industry, cellular technologies vehicular connectivity, intelligent transport system is discussed in [24]. The authors investigated how to achieve dependable content distribution in D2D based cooperative vehicular networks and proposed an algorithm based on real world and realistic traffic, using global positioning system and geographic information system data creating a coalition formation game approach. It is also essential to secure communicating data between D2D communication entities from threats through trust methods. Different security solutions have been proposed to address issues such as trust through the CN and assessed by device.

The authors in [23] discussed network assisted D2D communication between two devices in mobile network. A novel key exchange protocol based on Diffie-Hellman (DH) and cryptographic function is proposed for two UEs in the D2D communication for 5G network. In addition, vehicular technologies, social multimedia applications, vehicle social network (VSN), could as well use D2D communication are as underlay technology. Where a novel framework for content delivery in VSNs using D2D communication have been proposed to decrease on traffic load. In such frameworks content centric mode are applied to get naming information while parked vehicles create social communities with moving vehicles. The process includes content delivery, interest sending, content distribution and content replacement. 5G like other any other heterogenous network, spectrum resources, mobile network operator's role play big role in D2D communication. In D2D communication features such as peer discovery, resource allocation, mmWave, ultra-dense networks (UDNs), handover procedure along with various architectures and systems will be used to support 5G network [25]. To complement these features other technologies that have been investigated in support of D2D communication as an underlay technology, include cell system design, Wi-Fi, small cell, visible light communication, full duplex radio. In addition, investigation on 5G performance requirements for D2D communication have been studied. The benefits of D2D communication in 5G mobile network such as device discovery and communication, can be utilised for device discovery and access structure strategies and carry out a performance analysis using discrete time Markov process model.

IV. Network Services Abstraction in Relations with 5G Protocol Stack OSI Model and Mobile Internet Structure

The existing studies that have been discussed in this paper, did not apply any form of abstraction when proposing the D2D applications to distinguish their applicability in the network and how they would fit with the architecture, network layers and protocols. Our proposed network service abstraction can be applied when reviewing and developing various applications in D2D communication in 5G. With different abstraction levels D2D applications can be structured and mapped to one or more abstraction levels. By dividing the network services in three levels, various D2D applications, it allows the meticulously development applications such as network services, connectivity and security solutions with interoperability and integration on multi layers. For instance, it could be applied in conjunction with security frameworks such as X.805 [26] can be integrated with the proposed abstraction level to evaluate security in D2D communication network. The abstraction method is could be used when analyzing modular architectures and systems.

TABLE I
RELATIONSHIP BETWEEN PROPOSED NETWORK SERVICE ABSTRACTION AND OTHER MODULAR FRAMEWORKS

OSI Model	**Services**	**Abstraction Level**	**5G Protocol Stack**
Application Presentation Session Layers	OTT -	Applications	APP
Transport Layer	CCN	Infrastructure Services	TCP UDP
Network Layer	Internet - CCN	Infrastructure Services	IP NAS RRC SDAP
Data Link Layer	Connectivity - D2D	Network Connectivity	PDCP RLC MAC
Physical Layer	Connectivity - Radio Access	Network Connectivity	PHY

The proposed network service abstraction is mapped with the OSI reference model, 5G protocol stack, network layers and network services provided in each layer as shown in table I. It illustrates how the NS abstraction is analogous with OSI model and the 5G protocol stack. This enables future work to develop abstracted solutions at the lower and high level of the network in support of multi connectivity, service delivery and integrated security frameworks.

V. Conclusion

In this paper, the benefits and role of D2D communication as the underlay technology for 5G network have been discussed. In addition, a brief overview on D2D communication and its standardization was presented, pointing out the evolution of D2D communication from public safety to proximity-based services and content sharing. In addition, the delivery and sharing of network services in D2D communication, the relationship between network services abstraction, network architecture high level and protocol stacks were discussed. An abstraction for network service in D2D communication for its applications is suggested, as well as mapping of the existing studies on D2D communication applications with the proposed network service abstraction that could enable full utilization of security and network applications in synch with the network levels. Furthermore, we discussed how the abstracting of network services can be applied with different frameworks to address service and security issue in 5G enabled D2D communication network.

We finally highlighted various studies on network architecture, services and security have been carried out for D2D communication network in legacy systems. However, 5G network standardization is still yet be finalized, due to its requirement and the introduction of new use-cases and their applicability, the security of 5G enabled D2D communication still needs to be investigated extensively to propose new security mechanism. This paves way for future work on 5G enabled D2D communication applications using the proposed network services abstraction.

References

[1] L. Liu and W. Yu, "A d2d-based protocol for ultra-reliable wireless communications for industrial automation," *Wireless Communications, IEEE Transactions on*, vol. PP, no. 99, p. 1, 2018, iD: ieee10.1109/TWC.2018.2836937.

[2] S. Mumtaz and J. Rodriguez, "Introduction to d2d communication in smart device to smart device communication," 2014, includes bibliographical references.; ID: alma991002748459704781.

[3] T. Peng, Q. Lu, H. Wang, S. Xu, and W. Wang, "Interference avoidance mechanisms in the hybrid cellular and device-to-device systems," pp. 617–621, 2009, iD: ieee10.1109/PIMRC.2009.5449856.

[4] O. Bello and S. Zeadally, "Intelligent device-to-device communication in the internet of things," *Systems Journal, IEEE*, vol. 10, no. 3, pp. 1172–1182, 2016, iD: ieee10.1109/JSYST.2014.2298837.

[5] Y.-D. Lin and Y.-C. Hsu, "Multihop cellular: a new architecture for wireless communications," pp. 1273–1282, 2000, iD: ieee10.1109/INFCOM.2000.832516.

[6] K. Doppler, M. Rinne, C. Wijting, C. Ribeiro, and K. Hugl, "Device-to-device communication as an underlay to lte-advanced networks," *Communications Magazine, IEEE*, vol. 47, no. 12, 2009, iD: ieee10.1109/MCOM.2009.5350367.

[7] X. Lin, J. Andrews, A. Ghosh, and R. Ratasuk, "An overview of 3gpp device-to-device proximity services," *IEEE Communications Magazine*, vol. 52, no. 4, pp. 40–48, 2014.

[8] N. Pratas and P. Popovski, "Low-rate machine-type communication via wireless device-to-device (d2d) links," *arXiv.org*, 2013, iD: proquest2085242805.

[9] X. Wu, S. Tavildar, S. Shakkottai, T. Richardson, J. Li, R. Laroia, and A. Jovicic, "Flashlinq: a synchronous distributed scheduler for peer-to-peer ad hoc networks," *IEEE/ACM Transactions on Networking (TON)*, vol. 21, no. 4, pp. 1215–1228, 2013, iD: acm2525583.

[10] G. Fodor, E. Dahlman, G. Mildh, S. Parkvall, N. Reider, G. MikloS, and Z. TuraNyi, "Design aspects of network assisted device-to-device communications," *Communications Magazine, IEEE*, vol. 50, no. 3, 2012, iD: ieee10.1109/MCOM.2012.6163598.

[11] M. Agiwal, A. Roy, and N. Saxena, "Next generation 5g wireless networks: A comprehensive survey," *IEEE Communications Surveys & Tutorials*, vol. 18, no. 3, pp. 1617–1655, 2016, iD: ieee_s7414384.

[12] M. N. Tehrani, M. Uysal, and H. Yanikomeroglu, "Device-to-device communication in 5g cellular networks: challenges, solutions, and future directions," *IEEE Communications Magazine*, vol. 52, no. 5, pp. 86–92, 2014.

[13] F. S. Shaikh and R. Wismuller, "Routing in multi-hop cellular device-to-device (d2d) networks: A survey," *IEEE Communications Surveys & Tutorials*, vol. 20, no. 4, pp. 2622–2657, 2018, iD: ieee_s8386758.

[14] J. Qiao, X. Shen, J. Mark, Q. Shen, Y. He, and L. Lei, "Enabling device-to-device communications in millimeter-wave 5g cellular networks," *IEEE Communications Magazine*, vol. 53, no. 1, pp. 209–215, 2015, iD: ieee_s7010536.

[15] ETSI. (ISG), "Network functions virtualisation (nfv); architectural framework," Unpublished, Tech. Rep. ETSI GS NFV 002 V1.2.1 (2014-12), 2014.

[16] T. Q. N.-S. Vo, A. Duong, D. T. Hoang, and A. Kortun, "Optimal video streaming in dense 5g networks with d2d communications," *Access, IEEE*, vol. 6, pp. 209–223, 2018, iD: ieee10.1109/ACCESS.2017.2761978.

[17] L. Wang, Z. Li, M. Chen, A. Zhang, J. Cui, and B. Zheng, "Secure content sharing protocol for d2d users based on profile matching in social networks." IEEE, 2017, pp. 1–5.

[18] L. Pu, X. Chen, J. Xu, and X. Fu, "sndn: A social-aware named data framework for cooperative content retrieval via d2d communications." ACM, 2015, pp. 14–19.

[19] G. Chandrasekaran, N. Wang, and R. Tafazolli, "Caching on the move: Towards d2d-based information centric networking for mobile content distribution." IEEE, 2015, pp. 312–320.

[20] G. Chandrasekaran, N. Wang, M. Hassanpour, M. Xu, and R. Tafazolli, "Mobility as a service (maas): A d2d-based information centric network architecture for edge-controlled content distribution," *IEEE Access*, vol. 6, pp. 2110–2129, 2018.

[21] E. Abd-Elrahman, H. Ibn-khedher, and H. Afifi, "D2d group communications security." IEEE, 2015, pp. 1–6.

[22] N. Golrezaei, A. F. Molisch, A. G. Dimakis, and G. Caire, "Femtocaching and device-to-device collaboration: A new architecture for wireless video distribution," *Communications Magazine, IEEE*, vol. 51, no. 4, pp. 142–149, 2013, iD: ieee10.1109/MCOM.2013.6495773.

[23] R. Sedidi and A. Kumar, "Key exchange protocols for secure device-to-device (d2d) communication in 5g." IEEE, 2016, pp. 1–6.

[24] Z. Zhou, H. Yu, C. Xu, Y. Zhang, S. Mumtaz, and J. Rodriguez, "Dependable content distribution in d2d-based cooperative vehicular networks: A big data-integrated coalition game approach," *IEEE Transactions on Intelligent Transportation Systems*, vol. 19, no. 3, pp. 953–964, 2018.

[25] I. ul Haq, I. ul Haq, Z. U. Rahman, M. I. I. Abid, S. Ullah, and K. A. Shah, "Architecture and emerging technologies for d2d communication," *IJRCCT*, vol. 6, no. 01, p. 23, -02-12 2017.

[26] Z. Zeltsan, "Security architecture for systems providing end-to-end communications," 2005.