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Abstract

The Device-to-Device (D2D) communication model in 5G networks provides a useful infrastructure to enable different applications. D2D communication, with use of cellular or ad-hoc links, improve the spectrum utilization, system throughput, and energy efficiency of the network thereby preparing the ability for the user equipment to start communications with each other in proximity. The purpose of this paper is preparing a survey based on the D2D communication and review the available literature that in a widespread way research about the D2D paradigm, different application scenarios, and use cases. Moreover, new suspicion in this area that leads to identifying open research problems of D2D communications in cellular networks.

A Survey on Device-to-Device Communication in 5G Wireless Networks

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***Abstract*—The Device-to-Device (D2D) communication model in 5G networks provides a useful infrastructure to enable different applications. D2D communication, with use of cellular or ad-hoc links, improve the spectrum utilization, system throughput, and energy efficiency of the network thereby preparing the ability for the user equipment to start communications with each other in proximity. The purpose of this paper is preparing a survey based on the D2D communication and review the available literature that in a widespread way research about the D2D paradigm, different application scenarios, and use cases. Moreover, new suspicion in this area that leads to identifying open research problems of D2D communications in cellular networks.**

Keywords—Device-to-device communication, D2D, 5G networks, Cellular network, Survey

I. INTRODUCTION

Cellular communication will face with the fifth generation (5G) soon. In order to successfully handle all the demands of the subscribers for higher data rates and support several applications, make 4G systems be replaced by 5G. Considering the current 4G technologies cannot fulfill the huge gap between the actual communication performances and the forthcoming user expectations, Third Generation Partnership Project (3GPP) has been developing an enhanced Long-Term Evolution (LTE) radio interface called LTE-Advanced (LTE-A). LTE-A radio interface is designed with advanced communication techniques such as carrier aggregation, massive Multiple-Input Multiple-Output (MIMO), low-power nodes, as well as D2D communication, which are expected to dramatically improve the current cellular technologies (4G) in terms of system capacity, coverage, peak rates, throughput, latency, user experience, etc. [1].

5G is the result of using various technologies like mm-Wave communication, Massive MIMO, and Cognitive Radio Networks (CRNs)[1]. 5G, despite of the first four generations of cellular networks that completely dependent upon the base station (BS), is heading towards device-centric approach, which means that network setup is managed by the devices themselves.

A rigorous growth exists in networks traffic over the years and will continuously increase in the following years, as depicted in Fig. 1. This results in overloading at the base station (BS). Due to this mounting load on the base station (BS), there is an increase in the demand for power.

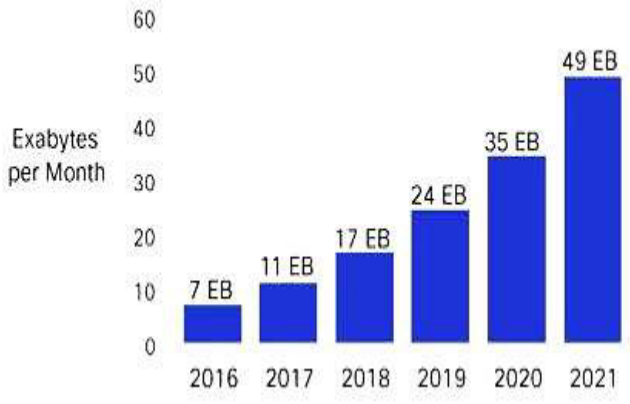

Fig. 1. Cisco forecasts 49 Exabytes per month of mobile data traffic by 2021[2]

offloaded from the base station and here D2D communication plays a crucial role. Since D2D communication allows devices to communicate with each other without traversing the base station, load on the base station is highly reduced.

Some have speculated that Wi-Fi offload will be less relevant after 4G networks are in place because of the faster speeds and more abundant bandwidth. However, 4G networks have attracted high-usage devices such as advanced smartphones and tablets, and now 4G plans are subject to data caps similar to 3G plans. For these reasons, Wi-Fi offload is higher on 4G networks than on lower-speed networks, now and in the future according to Cisco projections. The amount of traffic offloaded from 4G was 63 percent at the end of 2016, and it will be 66 percent by 2021 (Fig. 2)[2].

The amount of traffic offloaded from 3G will be 55 percent by 2021, and the amount of traffic offloaded from 2G will be 69 percent. As 5G is being introduced, plans will be generous with data caps and speeds will be high enough to encourage traffic to stay on the mobile network instead of being offloaded, so the offload percentage will be less than 50 percent. As the 5G network matures, we may see higher offload rates thereby D2D communication as one more mechanism for network offloading will become more applicable.

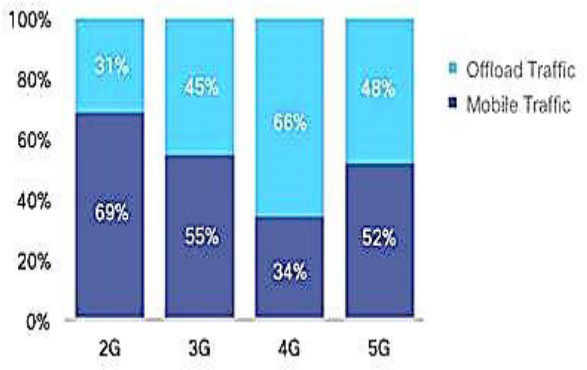

Fig. 2. Mobile data traffic and offload traffic[2]

II. OVERVIEW OF DEVICE-TO-DEVICE (D2D) COMMUNICATION

D2D communication is being considered as an essential component of the 5G networks. Communication features such as system capacity, throughput, spectral efficiency, and latency are expected to improve with the help of applying D2D communication technique [3-4]. In [5], the evolutionary development of cellular communication generations has been given. An overview of the services supported by the generations of cellular communications is shown in Fig. 3.

While working on the D2D technology, some challenging issues like interference management, radio resource allocation, procedures management, and communication session setup appear in the cellular network and are reported in the recent literature [6-9]. A. Asadi et. al. [3], have been proposed several taxonomies of possible D2D architectures. In particular, D2D communications separate into two main categories, in-band, and out-band. The first category uses radio spectrum that occurs on the cellular spectrum while the other use unlicensed spectrum.

When the communication is in the unlicensed spectrum, the coordination between radio interfaces is either controlled autonomously by mobile terminations (MTs) or by BS (i.e., controlled). Interference mitigation between cellular and D2D communications is the main challenging issues on in-band D2D communications and several research proposals focus on the study of this problem [10-11]. Concerning out-band D2D communications, the research focuses on inter-technology architectural design and power consumption [12]. All these proposals point out the potentialities of the different approaches in terms of energy consumption and of bandwidth resources.

Fig. 3. Generation of cellular communication

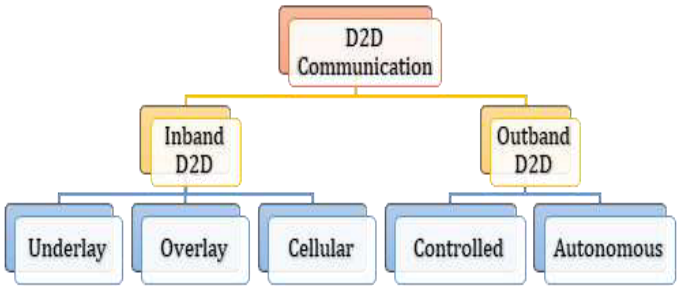

Fig. 4. D2D Communication Category

One of the most significant challenges in in-band D2D communication is how to allocate spectrum for such type of communication. The classification of D2D communication as resource allocation is depicted in Fig. 4. Up to now, there are three resource allocation modes for reusing licensed spectrum resources[13]:

- **Underlay Mode:** D2D pairs and cellular user equipment (UEs) share the same spectrum resources, which has the advantage of achieving the best spectrum efficiency. It is noticed that in underlay mode, one of the key issues is to effectively control the D2D-to-cellular and cellular-to-D2D interference.
- **Overlay Mode:** Dedicated frequency resources are allocated for D2D communications, and the remaining part is allocated for cellular communications. In such mode, there is no interference issue between D2D and cellular communications. One research focus is how to optimize the resource allocation ratio.
- **Cellular Mode:** Instead of communicating directly with each other, D2D UEs communicate with the eNB acting as an intermediate relay, which is the same as the traditional cellular system.

III. APPLICATION SCENARIOS AND ADVANTAGES OF D2D COMMUNICATIONS

In this section, first, different D2D communications application scenario is explored then discuss more the advantages of D2D communications while comparing with similar networks.

A. Use cases and usage scenarios

Various use cases and application scenarios of D2D communications have been proposed. As shown in Fig. 5 and according to the participation of cellular base stations or core networks, D2D communications scenarios categorize into three representative types.

In-Coverage D2D communications between two user devices are fully controlled by the network infrastructure of operators, such as BS or core networks. In this scenario, all user devices are located in the coverage of cellular networks. The operator manages the shared cellular licensed spectrum between the D2D links and normal cellular connections. Typical use cases of this scenario not limited to local traffic offloading from the core networks and operator controlled local

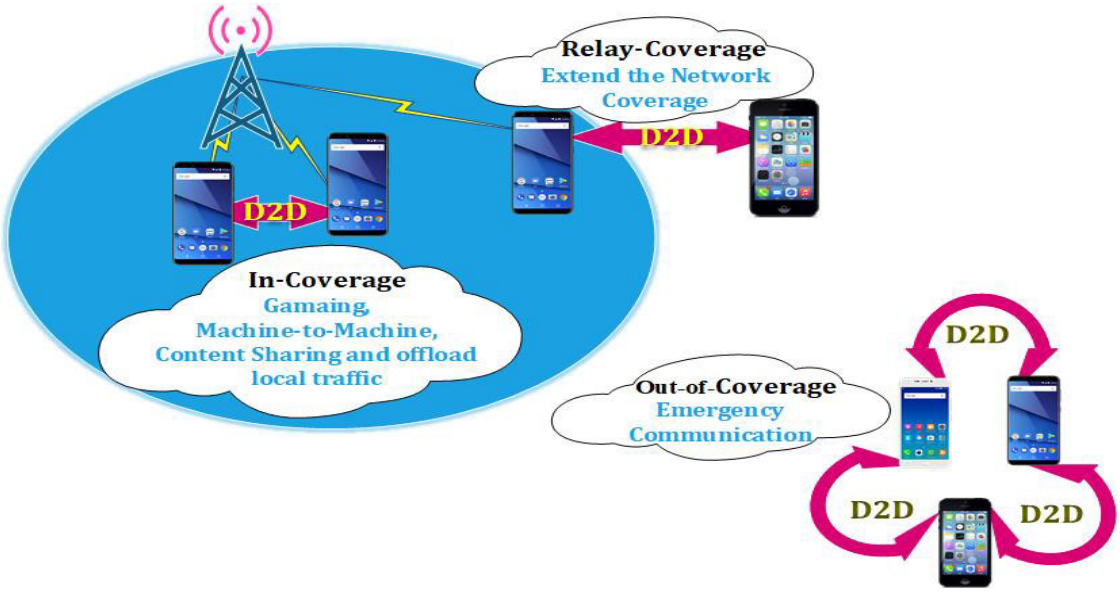

Fig. 5. D2D communication application scenario

data services, such as local content sharing, gaming, and Machine-to-Machine (M2M) communications.

Relay-Coverage In this scenario, D2D communications can improve network service quality at the edge of network coverage by extending the coverage of cellular networks. User devices that are out of Base Station (BS) coverage can use other covered devices as a data communication relay and by means of them communicate with the core network (BS). Like the previous scenario, the operator fully controls the connection establishment, resource allocation for both User-to-BS connections and D2D (User-to-User) connections and D2D link used the shared cellular licensed spectrum.

Out-of-Coverage This D2D communication scenario looks similar to MANETs. "Out-of-Coverage" scenario serves as the important component for emergency communication services, (e.g., national security, disaster relief, and public safety communications)[14][15]. In an urgent situation where the cellular infrastructure has been severely damaged, caused by a flood, storm, fire etc., D2D user devices, without the assistance of any operators, can establish connections and start D2D communications with each other in proximity.

D2D communications are expected to be an underlying network of LTE-Advanced (LTE-A). In order to introduce the D2D communications into existing LTE Networks and make them compatible with LTE-A, the 3rd Generation Partnership Project (3GPP) proposed ProSe (i.e., D2D communications) system architecture under the framework of LTE Networks[16]. Vehicle-to-Vehicle (V2V) applications for safety and infotainment are based on IEEE 802.11p [17].

Internet-of-Things (IoT) is defined as the interconnection via the internet of computing devices embedded in everyday objects, enabling them to send and receive data. M2M communication is a form of data communication that involves one or more entities that do not necessarily require human interaction or intervention in the process of communication[18]. M2M communication is also named as Machine Type Communication (MTC) in 3GPP. This type of communication could be carried over mobile networks (e.g., LTE or LTE-A) and regarded as an underlaying technology on IoT. D2D communications can apply for M2M communications in the IoT, which means that under the supervision and control of core networks, like Base Station or M2M server, enable intelligent machines to interchange data, communicate directly with each other, and consequently improve network performance, lower power consumption, and reduce transmission delay due to offload the core network local traffic.

B. D2D Communications Advantages

There are lots of study in D2D communications technology to improve the services quality and facilitation. In summary, these services put in three major categories described below.

Emergency communications[19-22] In the case of natural disasters like hurricanes, earthquakes etc., the traditional communication network may not work due to the damage caused. Ad-hoc network can be established via D2D which could be used for such communication in such situations.

IoT Sweetening [23-24] By combining D2D with IoT, a truly interconnected wireless network will be created. Example of D2D-based IoT enhancement is the improvement in Internet of Vehicles (IoV) when two vehicles running at high speeds, a vehicle can warn nearby vehicles in the D2D mode about speed or other information.

Local Services[25-26] In local service, user data is directly transmitted between the terminals and doesn't involve network side, e.g. social media apps, which are based on proximity service.

Although D2D communications on many aspects similar to MANETs [27] but some differences are easy to perceive. First, D2D communications can work on licensed or unlicensed spectrums in different scenarios while MANETs work independently on unlicensed spectrums. Interference is the

main problem in MANETs due to difficult spectrum control on unlicensed spectrums whereas in D2D control of core networks on efficient spectrum resources consumption, minimize the interference between links occurred. However, in the Out-of-Coverage scenario, the D2D communications occur either on unlicensed spectrums like MANETs or in case such as Public Safety Network occur on licensed spectrums [28].

Second, in D2D communications, operations such as resource allocation, node discovery, route search and security management can be performed through the core networks and D2D nodes cooperation or controlled by core networks. While in MANETs each node performs the above-mentioned operations autonomously.

Finally, the distinct difference between MANETs and D2D communications is the routing patterns. D2D communications mainly put single hop communications into services while the leading and troublesome challenges in MANETs that need to consider are the issues of multi-hop routing. It should be considered that in Out-of-Coverage scenario, D2D communications like MANETs faces the same issues in multi-hop routing.

IV. CONCLUSION

This survey showed that Device-to-Device (D2D) communication in cellular networks is an emerging wireless technology for direct communications among devices furthermore provides one more mechanism for network offloading and is a new useful tool for social networking. D2D is expected to be a key technology to improve system capacity and user experience in various service scenarios as LTE-D2D is being positioned for emergency services. Although D2D is now on the way towards standardization through 3GPP but still under development and in spite of the numerous benefits offered by D2D communication, there are many technical issues including how to coexist with cellular network users and how to deal with interferences are still being unresolved and thus a fertile ground for research. When sharing the same resources, interference between the cellular users and D2D users' needs to be controlled. A number of concerns are involved with its implementation whereas we need to develop D2D applications which are attractive to both operators and users. Peer discovery and mode selection, power control for the devices, radio resource allocation and security of the communication are the other concerns that should be mentioned. These are open issues which proposed potential future research directions.

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V. REFERENCES

[1] J. Liu, N. Kato, J. Ma, and N. Kadowaki, "Device-to-Device Communication in LTE-Advanced Networks: A Survey," *IEEE Commun. Surv. Tutorials*, vol. 17, no. 4, pp. 1923–1940, 2015.

[2] "Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2016–2021 White Paper - Cisco." [Online]. Available: https://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/mobile-white-paper-c11-520862.html. [Accessed: 06-Jan-2019].

[3] A. Asadi, Q. Wang, and V. Mancuso, "A survey on device-to-device communication in cellular networks," *IEEE Commun. Surv. Tutorials*, vol. 16, no. 4, pp. 1801–1819, 2014.

[4] B. Jedari, F. Xia, and Z. Ning, "A Survey on Human-Centric Communications in Non-Cooperative Wireless Relay Networks," *IEEE Commun. Surv. Tutorials*, vol. 20, no. 2, pp. 914–944, 2018.

[5] A. Gupta and R. K. Jha, "A Survey of 5G Network: Architecture and Emerging Technologies," *IEEE Access*, vol. 3. pp. 1206–1232, 2015.

[6] G. Fodor *et al.*, "Design aspects of network assisted device-to-device communications," *IEEE Commun. Mag.*, vol. 50, no. 3, pp. 170–177, Mar. 2012.

[7] Lei Lei, Zhangdui Zhong, Chuang Lin, and Xuemin Shen, "Operator controlled device-to-device communications in LTE-advanced networks," *IEEE Wirel. Commun.*, vol. 19, no. 3, pp. 96–104, Jun. 2012.

[8] D. Feng, L. Lu, Y. Yuan-Wu, G. Y. Li, G. Feng, and S. Li, "Device-to-Device Communications Underlaying Cellular Networks," *IEEE Trans. Commun.*, vol. 61, no. 8, pp. 3541–3551, Aug. 2013.

[9] K. Doppler, M. Rinne, C. Wijting, C. Ribeiro, and K. Hugl, "Device-to-device communication as an underlay to LTE-advanced networks," *IEEE Commun. Mag.*, vol. 47, no. 12, pp. 42–49, Dec. 2009.

[10] Wei Xu, Le Liang, Hua Zhang, Shi Jin, J. C. F. Li, and Ming Lei, "Performance enhanced transmission in device-to-device communications: Beamforming or interference cancellation?," in *2012 IEEE Global Communications Conference (GLOBECOM)*, 2012, pp. 4296–4301.

[11] Rongqing Zhang, Xiang Cheng, Liuqing Yang, and Bingli Jiao, "Interference-aware graph based resource sharing for device-to-device communications underlaying cellular networks," in *2013 IEEE Wireless Communications and Networking Conference (WCNC)*, 2013, pp. 140–145.

[12] Qing Wang and B. Rengarajan, "Recouping opportunistic gain in dense base station layouts through energy-aware user cooperation," in *2013 IEEE 14th International Symposium on "A World of Wireless, Mobile and Multimedia Networks" (WoWMoM)*, 2013, pp. 1–9.

[13] Chia-Hao Yu, K. Doppler, C. B. Ribeiro, and O. Tirkkonen, "Resource Sharing Optimization for Device-to-Device Communication Underlaying Cellular Networks," *IEEE Trans. Wirel. Commun.*, vol. 10, no. 8, pp. 2752–2763, Aug. 2011.

[14] 3rd Generation Partnership Project; Technical Specification Group Services and System Aspects;, "Proximity-based services (ProSe); Stage 2," no. Release 12, 2014.

[15] G. Fodor, S. Parkvall, S. Sorrentino, P. Wallentin, Q. Lu, and N. Brahmi, "Device-to-Device Communications for National Security and Public Safety," *IEEE Access*, vol. 2, pp. 1510–1520, 2014.

[16] 3rd Generation Partnership Project; Technical Specification Group Services and System Aspects;, "Study on architecture enhancements to support Proximity-based Services (ProSe)," no. Release 12, pp. 1–17, 2014.

[17] IEEE Computer Society. LAN/MAN Standards Committee., Institute of Electrical and Electronics Engineers., and IEEE-SA Standards Board., *IEEE standard for Information technology--telecommunications and information exchange between systems--local and metropolitan area networks-- specific requirements : Part 11 : Wireless LAN medium access control (MAC) and physical layer (PHY) specificati*. Institute of Electrical and Electronics Engineers, 2010.

[18] F. Ghavimi and H.-H. Chen, "M2M Communications in 3GPP LTE/LTE-A Networks: Architectures, Service Requirements, Challenges, and Applications," *IEEE Commun. Surv. Tutorials*, vol. 17, no. 2, pp. 525–549, 2015.

[19] K. Ali, H. X. Nguyen, P. Shah, Q. T. Vien, and N. Bhuvanasundaram, "Architecture for public safety network using D2D communication," in *2016 IEEE Wireless Communications and Networking Conference Workshops, WCNCW 2016*, 2016, pp. 206–211.

[20] M. Hunukumbure, T. Moulsley, A. Oyawoye, S. Vadgama, and M. Wilson, "D2D for energy efficient communications in disaster and emergency situations," in *2013 21st International Conference on Software, Telecommunications and Computer Networks, SoftCOM 2013*, 2013, pp. 1–5.

[21] K. Ali, H. X. Nguyen, Q. T. Vien, P. Shah, and Z. Chu, "Disaster Management Using D2D Communication with Power Transfer and Clustering Techniques," *IEEE Access*, vol. 6, pp. 14643–14654, 2018.

[22] A. Alnoman and A. Anpalagan, "On D2D communications for public safety applications," in *2017 IEEE Canada International Humanitarian Technology Conference (IHTC)*, 2017, pp. 124–127.

[23] J. Lianghai, B. Han, M. Liu, and H. D. Schotten, "Applying Device-to-Device Communication to Enhance IoT Services," *IEEE Commun. Stand. Mag.*, vol. 1, no. 2, pp. 85–91, 2017.

[24] L. Militano, G. Araniti, M. Condoluci, I. Farris, and A. Iera, "Device-to-Device Communications for 5G Internet of Things," *EAI Endorsed Trans. Internet Things*, vol. 1, no. 1, p. 150598, Oct. 2015.

[25] Y. Zhang, E. Pan, L. Song, W. Saad, Z. Dawy, and Z. Han, "Social network aware device-to-device communication in wireless networks," *IEEE Trans. Wirel. Commun.*, vol. 14, no. 1, pp. 177–190, Jan. 2015.

[26] X. Lin, J. Andrews, A. Ghosh, and R. Ratasuk, "An overview of 3GPP device-to-device proximity services," *IEEE Commun. Mag.*, vol. 52, no. 4, pp. 40–48, Apr. 2014.

[27] M. Natkaniec, "Ad Hoc Mobile Wireless Networks: Principles, Protocols, and Applications (Sarkar, S. K. et al.; 2008) [Book Review]," *IEEE Commun. Mag.*, vol. 47, no. 5, pp. 12–14, May 2009.

[28] K. Ali, H. X. Nguyen, P. Shah, Q.-T. Vien, and N. Bhuvanasundaram, "Architecture for public safety network using D2D communication," in *2016 IEEE Wireless Communications and Networking Conference*, 2016, pp. 1–6.